Sustainable Options

Economic development lessons from applied environmental resource economics in South Africa

Editors:
James N Blignaut and Martin P de Wit

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Dedicated to:
Our wives, Truida-Marthe and Rianne, and children, Lemuel, Adiël, Mariska and Tiaan, who had to bear the social cost

Sustainable Options:
Economic development lessons from applied enviromental resource economics in South Africa

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Preface and acknowledgements

South Africa's natural and environmental assets provide the platform for its economic activity and social well-being. The reality is that the use and abuse of these assets are not measured properly, at best leading to a situation of *ex post* environmental assessment focused on mitigation, or at worst, complete ignorance. The sustainability of the economy, and that of the people who depend on it, is at stake, let alone that of the biophysical systems. This reality makes environmental management an economic concern.

The field of environmental and resource economics (ERE) provides a coherent framework to place an economic value on the stock of natural capital and the flows of benefits that are derived from it. This provides the required information to include natural capital into accounting frameworks that will support more inclusive economic decision-making.

The last few years have seen an explosion of research and consultancy work in ERE in the country. There are many books on applied ERE produced internationally, but none so far documenting its application in South Africa and within the context of economic development. It has become time to take stock, evaluate and contemplate a future direction, hence *Sustainable Options*.

The idea of producing a book on applied environmental resource economics (ERE) in South Africa presented itself during a discussion on the significant progress made in ERE over the last couple of years in the country. ERE is increasingly being applied across a wide spectrum of issues and an extensive list of case studies is available, showcasing ERE's ability to integrate economic theories and concepts and social and environmental challenges. This integration produces a framework that increases the chance of finding a more sustainable outcome regarding the interaction between the economy and the natural environment. It is, then, the purpose of the book to highlight the ability of ERE methods and tools to promote economic development and policy-making by seeking sustainable options within the social context of a developing country. To accomplish this purpose the book has three parts.

Part A is a description of the context of the economic development in South Africa, and associated problems, and the theory and tools at our disposal to redress these problems. We consider this part important for two reasons, namely to provide an understanding of the concept of ERE and of the developing country context within which it operates.

Part B contains a series of case studies according to the classification of environmental services, sources and sinks. With regard to environmental services, the issue of compensating the provider of these services is considered (Chapter 5), as well as the cost of failing to maintain these services (Chapters 6 and 7). In an arid country such as South Africa, invasive alien vegetation obstructs ecosystems to function properly, which leads, *inter alia*, to a decline in water supply services. This is addressed in Chapter 8. On the issue of environmental sources, Chapter 9 investigates the value of water and Chapter 10 the value of aesthetic and amenity attributes of land. Four chapters considering environmental sinks follow: Chapter 11 develops a framework for evaluating water quality, Chapter 12 considers the social cost of declining air quality, Chapter 13 deals with solid wastes and Chapter 14 with noise pollution. The last two chapters of Part B focus on tools and processes that make use of the results of these valuation studies: Chapter 15 considers natural resource accounts as an improved accounting framework and database to evaluate economic development, while Chapter 16 addresses various aspects of project evaluation by way of a critical discussion of the role of economics in the environmental impact assessment (EIA) process.

In Part C a framework is provided for the integration of economics and the environment from both a public policy-making (Chapter 17) and an ethical (Chapter 18) perspective. Finally, the major shortcomings in the implementation of ERE in South Africa are identified, and remedial measures are recommended (Chapter 19). The collection of Chapters 17 through to 19 is seen as the high-level resolution of some of the tensions and problems regarding economic development and social and environmental concerns as described in Part A, providing a pathway towards thinking in terms of sustainable options.

The combination of and overview on the macro performance of the South African economy, a choice selection of ERE case studies in South Africa done over the last few years and a discussion of the political and ethical context for integration, should appeal to academics and students from the economic, political and biophysical sciences. This book is not only written for academics though. The book's hands-on approach and explicit linkages to the real world of economic development and improvements in the quality of life of people, should appeal to policy makers and environmental practitioners faced with the daunting task of making trade-offs between developmental and environmental concerns.

This book is by no means the result of a duo effort. Firstly, we would like to thank the contributors, who are, in alphabetical order: Max Döckel (UNISA), Linda Godfrey (CSIR), Martin Grosskopf (Urban-Econ), Varsha Harinath (CSIR), Rashid Hassan (University of Pretoria), Stephen Hosking (University of Port Elizabeth), Nicola King (CSIR), Anthony Leiman (University of Cape Town), Anthony Lumby (University of Natal), Guy Midgley (National Botanical Institute), Roland Mirrilees (Nathan Associates and GreenGrowth Strategies), Shomenthree Moodley (Minerals and Energy Policy Centre), Randall Spalding-Fecher (Sustainable Solutions), Jane Turpie (University of Cape Town), Rudi van Aarde (University of Pretoria), Hugo van Zyl (Independent Economic Researchers), Nathan Wilson (GreenGrowth Strategies), Harald Winkler (University of Cape Town) and Mark Zunckel (CSIR).

To ensure quality, all the chapters were subjected to at least two reviews. A word of sincere gratitude should therefore go to the reviewers who laboured under severe time constraints. They are, in alphabetical order: Geoff Antrobus (Rhodes University), Pete Ashton (CSIR), Howard Benkenstein (DEAT), Hannes Britz (Milwaukee University and University of Pretoria), Myrick Freeman (Bowdoin College), Mike Goldblatt (Palmer Development Group), Kirk Hamilton (World Bank), Chris Harmse (University of Pretoria), Steven Koch (University of Pretoria), Tony Leiman (University of Cape Town), Rasigan Maharajh (CSIR), Christo Marais (Working for Water), Roland Mirrilees (Nathan Associates and GreenGrowth Strategies), John Raimondo (African Environmental Solutions) and Randall Spalding-Fecher (Sustainable Solutions).

A word of appreciation must go to Mrs Hermien Söhnge for the initial and Stuart Douglas for the final editing of the manuscript. Finally, we wish to express our sincere gratitude to the publishers, especially to Ute Spath whose commitment to the project has gone beyond the normal call of duty.

James Blignaut and Martin de Wit, Pretoria, February 2004

Foreword

At the time of writing South Africa is ten years into democracy and it is natural to take stock. To use an analogy from one of the previous books that I co-authored: are we sowing the seeds of being an *Oasis in the Desert*, where corporate 'lions' continue to rule, with their kingdoms increasingly restricted by their own destructive behaviour and popular discontent; or are we on the road towards the *Plains of the Serengeti* where companies shapeshift into 'elephants' striving for proper balance between cooperation and competition and a continuing diversity of species, large and small, strong and weak? The achievement of the more virtuous state depends on whether we learn to ask the right type of questions. The fast pace of globalisation and unfair trade practices, the rapidly unfolding HIV/AIDS crisis, the growing numbers of unemployed, and the exploitation of the world's natural capital base create not only a sense of urgency, but also a cry of desperation in the search for reasonable solutions. Measures are needed to unmask the real impacts of the 'lion' before it is too late for the human race, including the vast majority that have no influence whatsoever on the decisions that are made today.

Many progressive observers now question the proposition that economic expansion automatically translates into or implies a better life for all. Certainly they connect the linkage between this expansion and a clean, healthy environment. It is the *type* of economic growth that really counts. This begs two questions: Does economic growth lead to a better quality of life for all or just a minority that are included in the mainstream economy? And, does economic growth need to come at the irreversible expense of the natural environment? The reason why these questions are not routinely and consistently asked (whether we are conducting scenario planning for business, drafting a new governmental policy, or negotiating international trade agreements, to name a few), is that we do not have proper indicators of measurement in place. The GDP indicator, often used to measure progress and welfare, fails to count environmental impacts as a cost and fails to capture increasing income inequalities. Actually, society today warrants a strategy of inclusion – a strategy focused on including everyone in the economic system and a strategy that does account for the environmental side-effects of growth. To support such a strategy proper measurements need to be in place.

One can hear the rapid breathing of vested interests and their burning question: Are these arguments really important, given South Africa's particular development challenges? Should we not rather concentrate on sustained economic growth and let the rest wait for a while? Despite many heartening observations to the contrary, it seems as if this (fatal) argument is winning more and more ground. It is the breather of unchecked globalisation, the unwillingness to accept fair trade rules, the volatile state of affairs in international financial markets, and the still unwavering focus on the single bottom-line. All the factors re-emphasise that we are still living in 'lion country'. And South Africa is not escaping this trend. There is no alternative, some of our economists and politicians say.

This book joins the chorus of voices arguing that there *are* many better alternatives. By presenting a simple list of indicators of economic, social and environmental well-being in South Africa, the book leaves the reader with an urge to start looking for alternatives, or more specifically, start looking for *sustainable options*. The authors expose the growing risk of a socially inequitable, exclusive economy and the economic risks associated with a deteriorating natural environment.

But this book goes further than only presenting problems. It presents an economically sound alternative, conceptually simple, but in essence sufficiently radical that businesses and government will find it difficult to ignore. The inevitable trade-offs between social, economic and environmental issues need to be exposed and brought into a common currency. If environmental impacts are quantified, they will be included in financial and economic decisions. Put another way, the strength of the argument lies in the simplicity of the concept: the valuation of the environmental externalities is a way that 'gets the prices right'. The authors show that this is possible in a language that commercial players and political policy makers can understand.

In a series of carefully selected case studies ranging from climate change to noise pollution, the contributing authors have succeeded in turning the discipline of environmental and resource economics into a lively and relevant discourse. Besides which, the book takes the first steps towards outlining a development ethic which embraces what the authors call, the *JustAfrica* dream: an Africa where justice, self-respect and appropriate development becomes part of a new reality.

I have a feeling that this book will influence how the rules of the game will be formulated in the future. It will act as a forerunner for adopting better measures of environmental and social risk in business and government. And, yes, if this happens, it will be an important steppingstone towards the *Plains of the Serengeti.*

Clem Sunter
February 2004

Acronyms and abbreviations

µg	microgram
µm	micrometer
CBA	cost benefit analysis
CBO	community-based organisation
CDM	clean development mechanism
CFCs	chlorofluorocarbons
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
CV(M)	contingent valuation (method)
DALYs	disability adjusted life years
DEAT	Department of Environmental Affairs and Forestry
DME	Department of Minerals and Energy
DWAF	Department of Water Affairs and Forestry
EIA	environmental impact assessment
EPA	Environmental Protection Agency
ERE	environmental resource economics
FDI	foreign direct investment
GDP	gross domestic product
GGP	gross geographic product
GHG	greenhouse gas
GW	gigawatt
ha	hectare(s)
I&APs	interested and affected parties
IEM	integrated environmental management
ICV	internal combustion vehicle
IPCC	Intergovernmental Panel on Climate Change
kg	kilogram
km^2	square kilometre
kt	kiloton
kWh	kilowatt hour
LFG	landfill gas

m^3	cubic metre
MAP	mean annual precipitation
MAR	mean annual runoff
MJ	megajoule
MSW	municipal solid waste
MWh	megawatt hour
N_2O	nitrogen oxide
NAQMP	National Air Quality Management Programme
NEMA	National Environmental Management Act
NGO	non-governmental organisation
NH_4	ammoniac
NMVOC	non-methane volatile organic compound
NOx	oxides of nitrogen
NRA	natural resource accounts
PM10	particulate matter smaller than 10 µm
PM2.5	particulate matter smaller than 2.5 µm
ppb	parts per billion
ppm	parts per million
ppt	parts per trillion
ROD	record of decision
SACS	South African Country Study for Climate Change
SEA	strategic environmental assessment
SEEA	System of Integrated Environmental and Economic Accounting
SIA	social impact assessment
SNA	System of National Accounts
SO_2	sulphur dioxide
SOx	oxides of sulphur
t	ton
ToR	terms of reference
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
US$	United States of America Dollar
V&A	vulnerability and adaptation
VOC	volatile organic compound

WDCS	Waste Discharge Charge System
WHO	World Health Organisation
WTP	willingness-to-pay

part a

prelude

The multiple faces of poverty

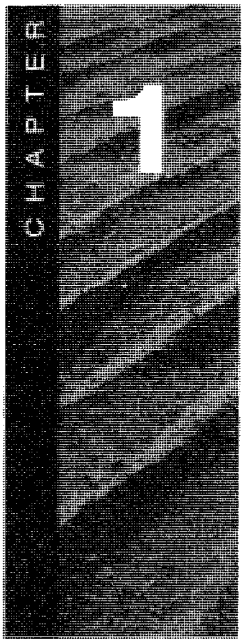
Various interactive forms of poverty bind us all, namely:

Poverty of the body:	Lack of physical capacity
Poverty of adaptation:	Lack of ability to change
Poverty of the imagination:	Lack of ideas
Poverty of will:	Lack of determination
Poverty of the environment:	Lack of resources
Poverty of sensibility:	Lack of wisdom
Poverty of information:	Lack of choice
Poverty of technology:	Lack of solutions
Poverty of direction:	Lack of purpose
Poverty of power:	Lack of influence
Poverty of discipline:	Lack of direction

Solving one appropriately and properly implies impacting on solving all.
Neglecting one implies neglecting all.
The challenge is ours.

All for a prosperous clean and green economy in which everyone participates!

James Blignaut



A perspective on the South African economy

James Blignaut and Martin de Wit

1.1 Introduction

Could economic development and the principles of prudent environmental management be honoured simultaneously in a developing country? In other words, does South Africa have options for sustainable interaction between the economy and the environment? This question summarises the subject matter of this book. Readers are, however, not to be kept in suspense when it comes to answering this question. It is believed that the answer to this question is not only yes; it is, in fact, a must. Prudent environmental management, namely environmental management that takes into consideration ecological and social realities, has become a prerequisite for sustaining economic development, i.e. the creation of economic welfare.

Often one is confronted with strong views from people of all backgrounds, rich or poor, either business, government, labour, academia, or individuals from non-governmental organisations (NGOs) and community-based organisations (CBOs) about the reason why a developing country like South Africa should not be concerned about the environment. People argue that the country's greatest economic challenge, and hence the primary focus of any economic policy and related efforts, should be economic growth. This illustrates the perception that economic growth is by definition beneficial since it creates jobs and general welfare. It furthermore implies that any possible negative side effect that results from economic growth could be justified, at least in the short term. The argument goes further, contending, that the developed nations, having exceeded their ecological space and transgressed beyond a certain environmentally sustainable threshold of economic development and welfare, should be concerned about the environment. Not only are these countries rich enough to be concerned with the *nice to haves*, i.e. a clean and well-managed environment, but they also use the environment as an argument to prevent the developing nations from developing in the same way, to prevent competition. It is argued that Africa, including South Africa, is just too poor to pay any attention to environmental concerns and would like to enjoy the same privilege of using the environment unhindered, as the developed countries did during the nineteenth and twentieth centuries.

A further, and more mainstream, economic view of the environment is that a country will outgrow its environmental problems as long as the economic fundamentals are right. The proponents of this argument maintain that the environment belongs to the conservationists and that they should keep to their bees and butterflies and not upset any kind of investment, whether from local or international sources, through their actions. These arguments are, however, based on the premise that economic development and prudent environmental management are two opposing alternatives. Economic development and environmental protection reflect an either/or situation resulting in inevitable conflict, confirming the dialectic approached. It is argued here that such an approach would only lead to further tension and institutional polarisation, leading to more conflict rather than solutions.

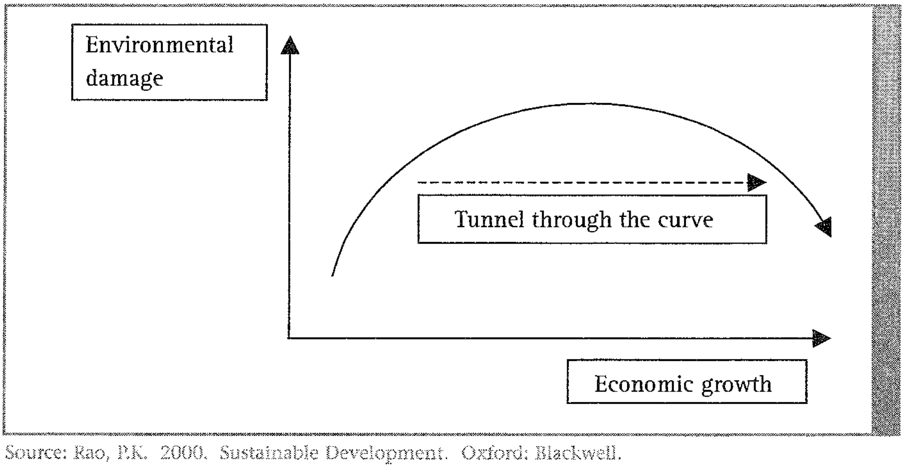
In other cases, the question of prudent environmental management is obscured because of definition differences. In the past, environmental concerns within a developing context were viewed strictly as being equivalent to the protection of wilderness areas, associated with conservation-based tourism. This view is changing, albeit very slowly. This dialectic view leads to the notion that it is possible to support wilderness enclaves and conservation efforts on the one hand, but contribute to environmental degradation and depletion in another area. In the absence of integrated land-use planning, such a view could even lead to conservation areas and areas of potential environmental disaster in close proximity of each other. One example thereof would be the establishment of an industrial area with a heavy ecological footprint adjacent to a national park, as in the case of the Coega Industrial Development Zone and the Addo National Park in Eastern Cape Province of South Africa.

Another, related, example refers to the apartheid regime in South Africa during which black homeland areas were proclaimed adjacent to the Kruger National Park. The entire Park area was South African land (for financial gain), while a large number of people were housed on land with very little infrastructure and means for economic survival on its border. This has led to severe environmental degradation to the extent that the area adjacent to the Kruger National Park is now in serious need of environmental reconstruction.[1]

1.2) Development and the environment: Some theoretical and empirical evidence

The so-called environmental Kuznets curve[2] (see Figure 1.1) depicts economic growth over time on the horizontal axis and environmental damage or degradation on the vertical axis. This curve indicates that at early and advanced stages of economic development the impact on the environment is likely to be limited. This is so because of the minimum use of the environment during the early stage of economic development and the use of sophisticated and environmentally benign technology during the advanced stage, as well as the fact that developed countries base their economy on services rather than industrial production. The concern, however, is the potentially high impact on the environment during the intermediate phase of economic development, in which South Africa currently finds itself, for instance, where the country still has to develop its industrial sector and might not have the money to invest in clean capital.

Is it inevitable that the development path of a country would follow the Kuznets curve, i.e. the development path of the northern hemisphere countries? The answer is no. Ideally, developing countries should tunnel through the Kuznets curve, that is develop, but with reduced impact on the environment. This is possible because clean technologies exist (developed mainly in the northern hemisphere) that can aid the development of these countries. This argument is supported by the capital augmentation and convergence theories. The idea of convergence is based mainly on three aspects. In the first place, the Solow growth model[3] predicts that countries converge to their balanced growth paths. Secondly, the Solow growth model suggests that the rate of return on capital is lower in countries with more capital per worker. This implies the existence of incentives for capital to flow from rich to poor countries. Thirdly, if there is a lag in the diffusion of knowledge, income differences can arise, because some countries are not yet employing the best technologies available. These reasons imply that less-developed countries can catch up because of the diminishing marginal cost of (clean) technology and the fact that the research and development cost of the technology has been borne by northern hemisphere countries. Romer drew attention to the phenomenon that research leads to new knowledge, which is a positive externality to other firms.[4] Such an increasing-returns-to-scale can then be the driving force through the Kuznets curve. However, it does accord a central role to technological progress in explaining long-run, and, in this case, cleaner economic growth.

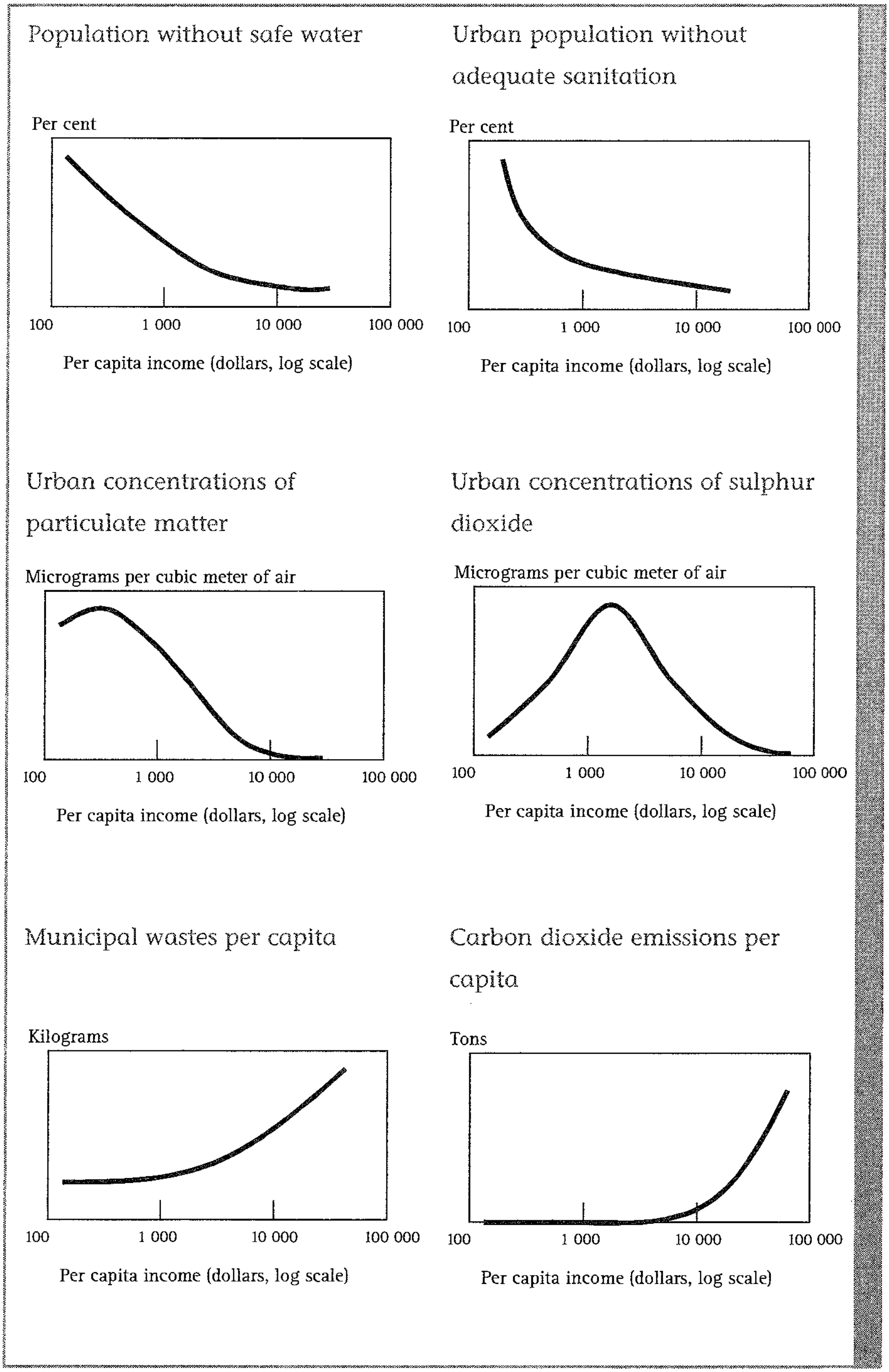


Source: Rao, P.K. 2000. Sustainable Development. Oxford: Blackwell.

Figure 1.1: Environmental Kuznets curve

Theoretically, it seems therefore plausible for developing countries to catch up on their developed counterparts. But, does the empirical evidence support this possibility? The answer lies in the response to two further questions: First, is there empirical evidence in support of the environmental Kuznets curve *per se*? Second, do the convergence theories hold true, i.e. do developing countries in fact catch up? These questions will subsequently be addressed.

There is mixed support for the existence of an environmental Kuznets curve (Figure 1.2).[5] An increase in income due to economic growth has the advantage of a decline in the number of people without access to safe drinking water and proper sanitation. A valuable correlation emerges between income and improved health because of better service provision. With regard to the concentration of urban particulate matter and sulphur, which increases initially but later declines as income levels increase, it seems as if the environmental Kuznets curve does hold for these pollutants. Definite possibilities are therefore at hand to tunnel through this curve, by applying improved technologies at an earlier stage of the development process. All this evidence favours the argument that it is possible to outgrow environmental problems. The concern, however, lies with aspects such as the volume of municipal waste (see Chapter 13) and carbon dioxide emissions (see Chapter 12) generated. These negative environmental externalities[6] increase exponentially as income levels increase, implying that an increase in welfare has a heavier ecological footprint in so far as these pollutants are concerned. The former is intuitively easy to understand, since more income chases more goods and hence more materials are transformed, while, eventually, the materials find their way back to nature, but this time in the form of an input to a landfill, in other words, garbage.



Source: World Bank. 1992. World Development Report. Washington, DC: World Bank.

Figure 1.2: Environmental indicators at different country income levels

The latter of this environmental externality, carbon dioxide, increases because of an increase in the use of fossil fuels (coal, oil and gas) for energy purposes. There is a clear link between income, waste and energy. Energy use is required to transform the increasing number of goods that people demand as their income increases, but this implies a double blow. Not only will an increase in income lead to more waste, larger emission of carbon dioxide and other greenhouse gases and pollutants; it also leads to an increase in the use of resources as inputs, such as land (Chapter 10) and water (Chapters 8, 9 and 11). It has furthermore been documented that current global economic conduct is seriously affecting the material balance within the ecosystem, with wide-ranging consequences.[7] For these aspects the environmental Kuznets curve does not hold.

It would seem as if economic growth could solve some environmental problems, but, in doing so, it creates environmental problems of its own which technology alone apparently would not be sufficient to solve. Viewing these facts, one could conclude that, ideally, a developing country requires a specific type of economic development, one that will lead to improved health, but that is not material and energy intensive. It is therefore disconcerting that the pursuit of unqualified economic growth, as if it is an unrelenting force, is still so deeply entrenched in economic policy-making and general human conduct. In Chapters 3 and 18 this theme is further explored.

Turning to the second of the questions above, namely whether developing countries are in the process of catching up (i.e. moving towards a convergence in income) with their developed counterparts or not, the answer seems to be no. There is evidence[8] that the ratio of per capita income between the richest and the poorest countries increased by roughly a factor of five from 1870 to 1990, indicating significant divergence. This divergence is mainly the result of the different patterns in the long-run economic performance of the two sets of countries. The reason for these long-run economic performances lies, among others, in the level and rate of human capital development as well as the general rule-of-law.[9] Factors other than economic ones are therefore important when considering the uptake of capital. The capital uptake required for convergence does not happen automatically. Tunnelling through the environmental Kuznets curve would, therefore, not occur automatically either.

In brief, what does all this mean in the context of this book? Four issues are of importance. First, it seems as if an increase in income has definite advantages as far as health and health-related issues are concerned. In so far as economic growth generates income and reduces health risk, economic growth should be viewed as beneficial. Second, opportunities exist for developing countries to develop in a way that is more environmentally benign than in the case of developed countries. Third, economic growth, which is based on increased material consumption and fossil fuel induced energy, has severe environmental implications. In the fourth instance, one should not expect that developing countries would automatically tunnel through the environmental Kuznets curve, since there is no evidence to support this notion; the contrary is rather true. This implies that a deliberate economic policy, supported by an appropriate set of incentives, is required to facilitate economic development that is environmentally benign.

Therefore, the issue is not whether a country should grow or not, but how it should grow. This requires asking appropriate questions with regard to economic development, questions that would foster a symbiosis between economic development, an increase in quality of life, and prudent use of the environment. It will be argued in this book that, through the correct application of environmental and resource economic tools and methods, such a symbiosis is possible, even in the context of a developing country. One should rather say that such a symbiosis is essential within a developing context where resources are scarce and the price of failure high. Part B of this book highlights several examples of this symbiosis and Part C attempts a roadmap of how to get to such a symbiosis.

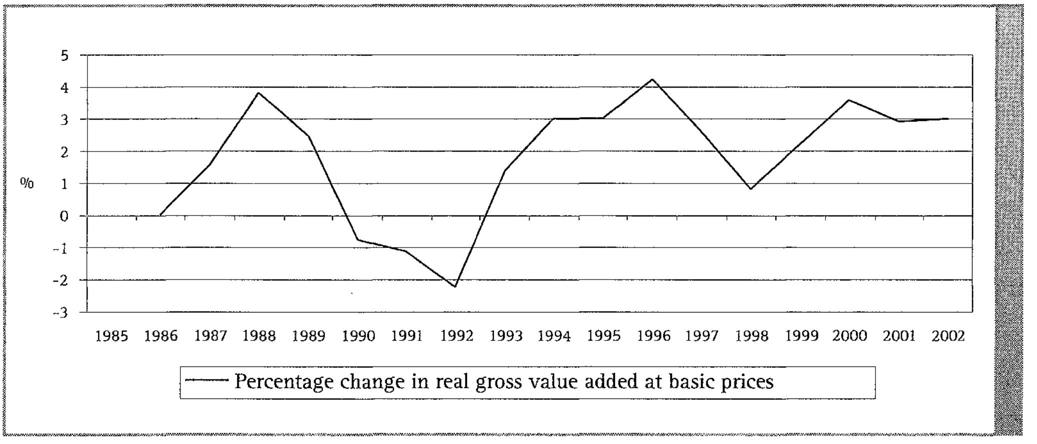
The remainder of this chapter focuses on South Africa's macroeconomic and macro-environmental performance and the need for economic development to provide a profile of the country and to illustrate the development need that exists. This profile provides the backdrop against which the symbiosis discussed above should be fostered.

1.3 The South African economy: Selected key indicators

Generally, macroeconomic policy is aimed at achieving five distinct objectives, namely economic growth, balance of payments stability, price stability, equity and employment. Seen from the perspective of an economic policy, achieving these objectives is the joint responsibility of the governor of the central bank (monetary policy) and the ministers of finance (fiscal policy) and trade and industry. These objectives form the core of their respective job descriptions. How well did the South African office bearers do since the transition to full democracy during the early 1990s? As will be shown below, they did reasonably well with regard to the first three objectives, while no significant progress was made with regard to the latter two.

The rate of economic growth is generally volatile, often linked to international upswings and downswings and natural phenomena such as droughts, floods, or good or bad commodity prices. Immediately after the first democratic elections were held in 1994, the economic growth rate peaked, much of it as a result of the injection of foreign portfolio investment and a steady increase in exports. Portfolio investment, however, subsided as the 'honeymoon' (post-election) period wore off, especially since this form of investment is subject to volatile speculation. Stable and conservative macroeconomic policy has had its positive returns, however, evident from the fact that the economic growth rate stabilised above the 2 per cent mark during the last part of the 1990s. These relatively higher growth rates are, however, most fragile, given the volatility. This volatility (see Figure 1.3) is mainly caused by the large fluctuation of the Rand exchange rate, and other external factors like the East-Asian crisis, the prevailing economic and political crisis in Zimbabwe, and the aftermath of the 11 September 2001 attack on the United States and ensuing world economic recession.

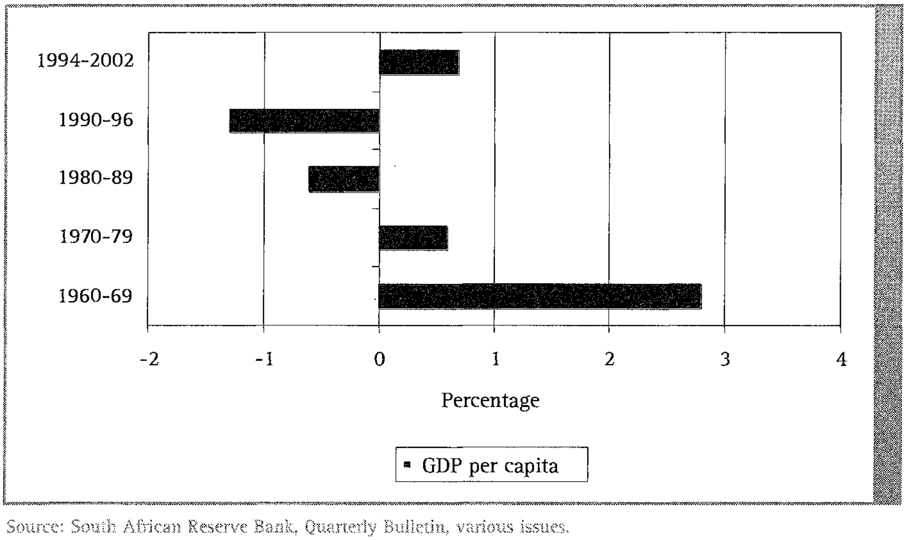
The consequence of the prolonged periods of relatively low economic growth, especially given a sustained population growth in excess of 2.2 per cent per



Source: South African Reserve Bank, Quarterly Bulletin, various issues.

Figure 1.3: Economic growth rate: percentage

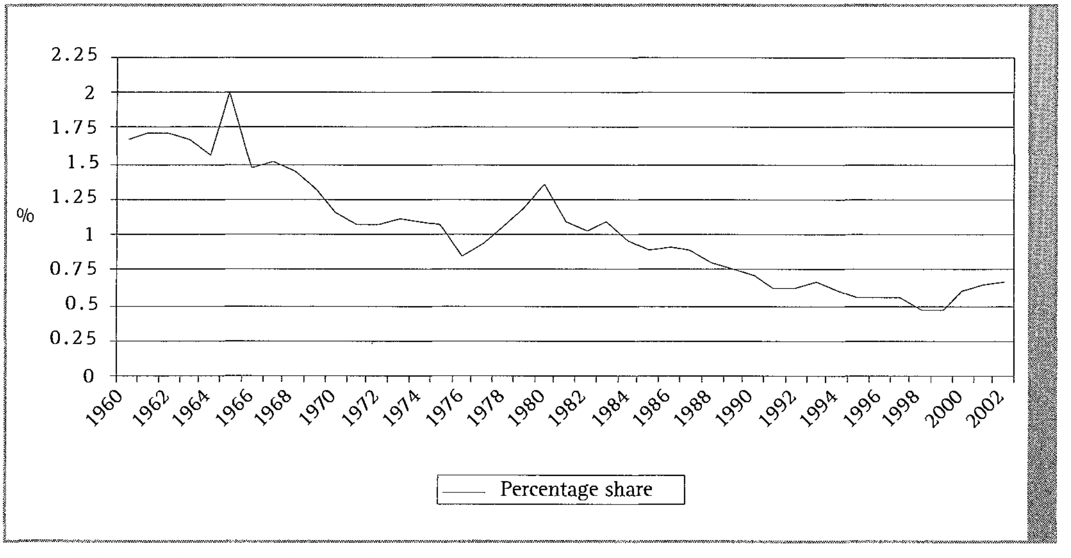
annum, was a per capita income decline over a large number of years, as can be seen from Figure 1.4. The growth in per capita income was negative for the total period of the 1980s and the first half of the 1990s, only improving marginally during the latter half of the 1990s, due to the aforementioned improvements in economic growth. Expressed in US dollar terms, the growth in per capita income for the whole of the 1990s was negative by a half per cent.[10]



Source: South African Reserve Bank, Quarterly Bulletin, various issues.

Figure 1.4: Real GDP per capita: period averages: percentage

This relatively weak performance of economic growth has had a significant impact on South Africa's standing with regard to international trade, which declined consistently from approximately 1.7 per cent during the early 1960s to 0.6 per cent during the middle 1990s. This steady decline was mainly the result of sanctions and disinvestments that occurred during the period because of the political policies followed by the government of the day. Contributing factors had been the steady decline in commodity prices relative to the price of manufactured goods and services, as well as the world economic recession between 1969 and 1976, which inhibited global demand. An exception to the steady decline in South Africa's share of world trade occurred during the early 1980s, mainly because of the high gold price during that period. Since the late 1990s, however, South Africa's share in world trade has improved marginally once again to approximately 0.8 per cent, as can be seen from Figure 1.5. This is mainly because of an active export promotion programme that followed the abolishment of sanctions.



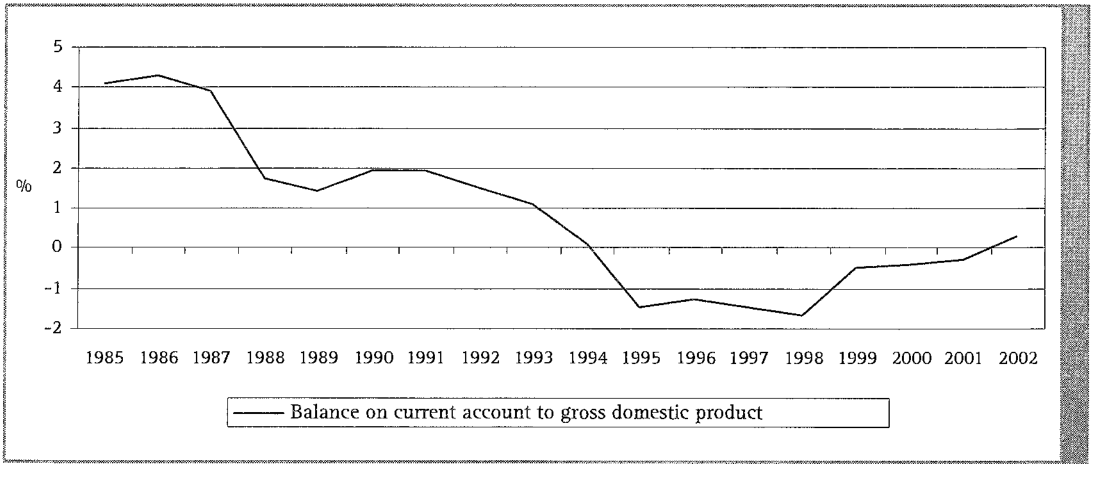
Source: World Bank. International Financial Statistics. Monthly bulletin, various issues.

Figure 1.5: South Africa's share in world trade: 1960 – 2002: percentage

Following the weak economic performance and declining contribution to international trade, the country's current account of the balance of payments came under pressure during the 1980s and 1990s, as is indicated in

Figure 1.6. The current account only improved since 2000, because of the improvement in trade and direct foreign investment that took place during the late 1990s. The increase in direct foreign investment in 2000 happened at the expense of portfolio investment, as is indicated in Figure 1.7. The withdrawal of portfolio investments came about mainly in response to the East-Asian economic crisis, speculation against the Rand and the withdrawal of investments from emerging economies after the attacks of 11 September 2001. Very few of these external effects were related to intrinsic South African factors, which is indicative of South Africa's precarious economic position as a small, open developing country.

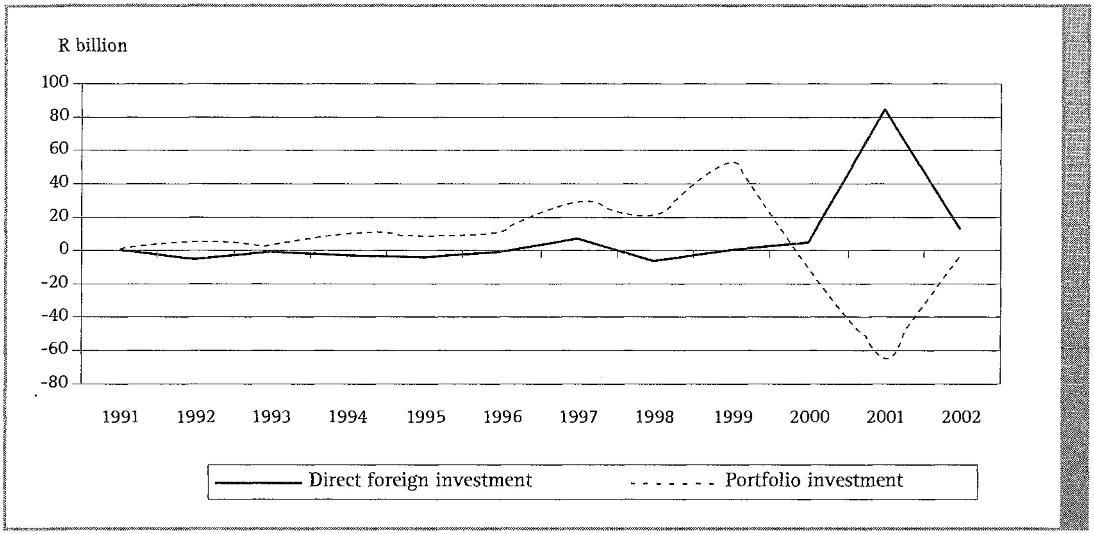
The rapid increase in FDI should actually be considered carefully. The privatisation of some state assets as well as the listing of South African companies on international stock exchanges is considered direct foreign investment. This investment, however, is not new investment that built new infrastructure and new capital, but merely comprises existing financial and fixed assets that underwent a change of ownership.



Source: South African Reserve Bank, Quarterly Bulletin, various issues.

Figure 1.6: Balance on the current account as percentage of GDP

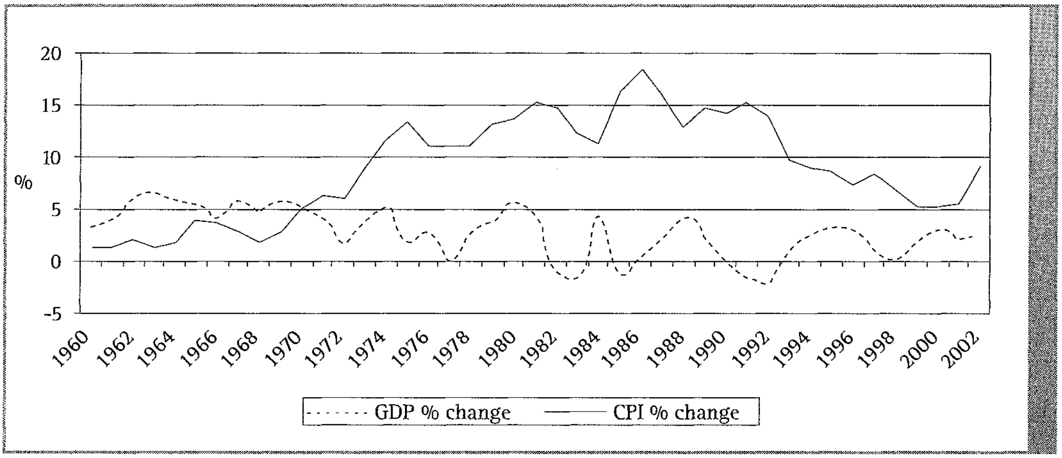
These indicators suggest that the South African economy is performing relatively well, and has been doing so especially since the latter part of the 1990s. This trend



Source: South African Reserve Bank, Quarterly Bulletin, various issues.

Figure 1.7: Direct foreign investment and portfolio investment

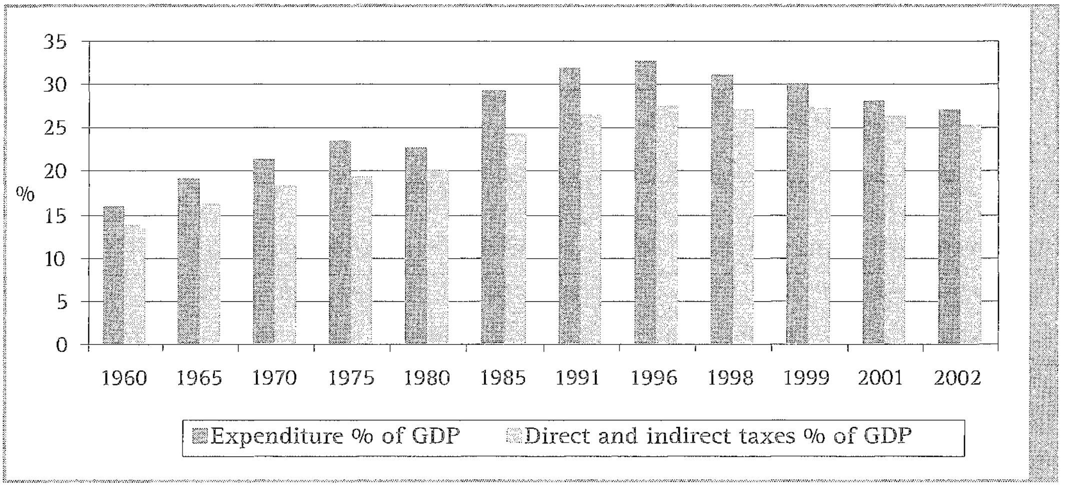
is mirrored when considering price stability, or inflation, as indicated in Figure 1.8, shown here together with the economic growth rate. Inflation, indicated as a percentage change in the consumer price index, shows a steady decline to single digit levels from a high level in the mid-1980s when it approached 20 per cent.



Source: South African Reserve Bank, Quarterly Bulletin, various issues.

Figure 1.8: The relationship between GDP and inflation: 1960 – 2002: percentage

The evidence discussed here would indicate that, seen from a macroeconomic perspective, one could argue that the economic fundamentals of the country have improved significantly during the 1990s. A good, encompassing indicator to further this argument is the decline in the government's share in the economy (some might even argue that the improvement in the macroeconomic condition of the country is because of the decline in the government's share), as is clearly illustrated in Figure 1.9. This decline in the government's share of the economy is quite remarkable, given the economic growth rates discussed above and the pressing social needs of the electorate.



Source: South African Reserve Bank. Quarterly Bulletin, various issues.

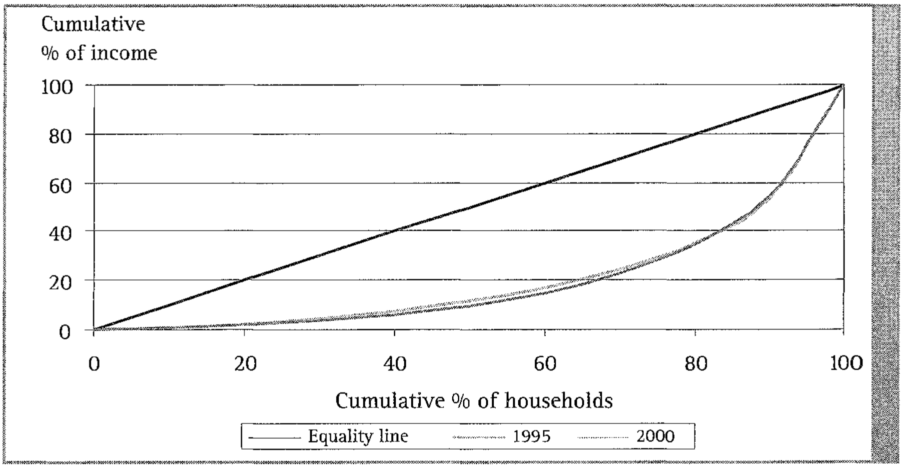
Figure 1.9: Government's share of the economy as percentage of GDP: percentage

Despite these improvements in the macroeconomic conditions in the country, socio-economic conditions remain far from desirable. There is a significant gap between the levels of welfare enjoyed by the rich and those by the poor. Unfortunate, therefore, is the fact that the benefits of these economic fundamentals befall mainly the livelihoods of the rich and not those of the poor.

1.4 The South African economy: The other side

Probably in no other way does the Achilles heel of the SA economy become so clearly visible than when considering income distribution. Income distribution is still very skew in the country, and the situation is deteriorating. In accordance with the economy-wide Gini coefficient, an indicator of income distribution where a value of 0 implies 100 per cent equal distribution and 1 being extremely skew, the value for all households in 1995 was 0.56. The same value for 2000 was 0.57, implying that income distribution had not improved across the country. With regard to African-headed households, the value improved marginally over the period from 0.50 to 0.49, but for white-headed households the income became more skew with the value changing from 0.44 to 0.45.[11]

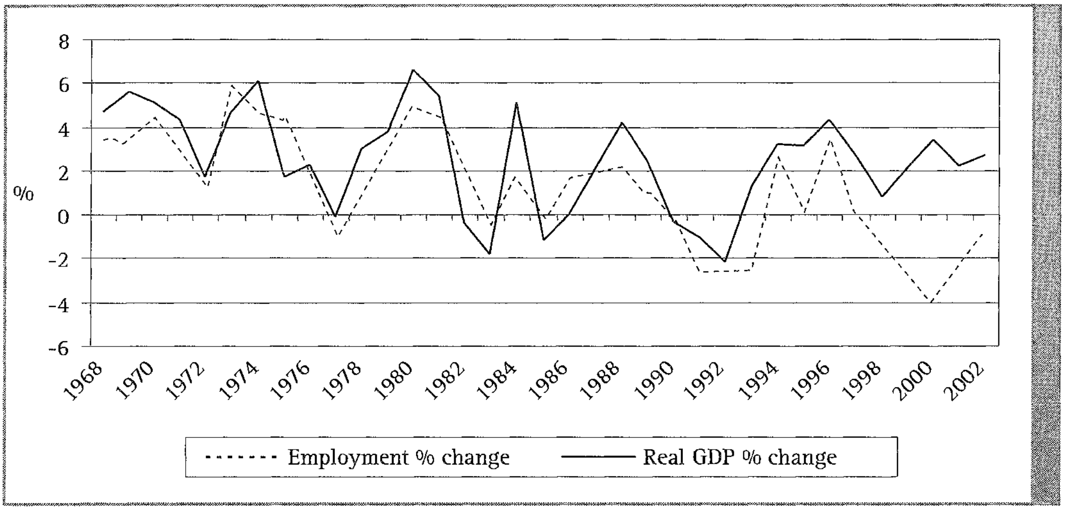
It is interesting to note that the overall economy-wide Gini coefficient is higher, an indication of a skewer distribution of income, than that for the individual population groups, an indication that the distribution among the population groups is still very skew. The marginal improvement in the income distribution among African-headed households gives an indication that the political transition of the early 1990s has not yet benefited the great majority, viz. the African community, implying that by far the larger part of the population has not yet been economically liberated. The fact that the distribution of income is not improving is not race related any more, but it can mainly be ascribed to the high and ever-increasing unemployment. Figure 1.10 presents the Lorenz curve for South Africa, viz. a graph showing the cumulative income distribution for the country. The cumulative percentage households, arranged from the poorest to the most affluent (from 0 per cent to 100 per cent), has been plotted on the horizontal axis, while the cumulative percentage of income, arranged from the least to the most (also from 0 per cent to 100 per cent), is indicated on the vertical axis. The nearer the curve is to a straight line, the more equal the income distribution, or the smaller the Gini coefficient, and vice versa. Figure 1.10 shows that the poorest 10 per cent of households earn only 0.5 per cent of the income while the top 10 per cent earn approximately 46 per cent of all income. There are therefore distinctly different layers of income within South Africa, giving rise to what is now known as a 'double-decker' economy.[12]



Source: Statistics South Africa. 2002. Earning and Spending in South Africa. Selected Findings and Comparisons From the Income and Expenditure Surveys of October 1995 and October 2000.

Figure 1.10: The Lorenz curve for South Africa: 1995 and 2000

The only way in which income can improve is through employment. Should a person not be able to participate actively in an economy, such a person is not economically empowered. This person then is merely a spectator, a witness of an economy functioning without him or her. Although participation in an economy could entail formal employment, it could also imply self-employment. The issue at stake is whether a person can identify with his or her condition and state of mind with dignity or not. Dignity is a key element within the social fibre of an economy and, more often than not, a person's economic position is linked to his or her dignity. Should a person live under trying economic conditions, unable to participate in the economy, it is dignity, and hence the social fibre of the country, that suffers. As is indicated in Figure 1.11, employment in absolute terms has been declining ever since the mid-1960s. Initially this decline was matched by a decline in the rate of growth, but since the mid-1990s, employment declined irrespective of the relatively strong economic growth discussed above. This is indicative of what has now become known as the jobless growth phenomenon, indicated by the increase in the gap between the economic growth and the growth in employment graphs during the latter years, as indicated in Figure 1.11.[13] Three reasons for this phenomenon can be mentioned, namely the fact that economic growth in the majority of countries, including that of South Africa, has lately been based on the expansion of the services and IT-related sectors, excluding a great number of people. A second, and related reason, is the mismatch between the demand for (skilled) labour and the supply of (unskilled) labour that currently exists in the labour market. This is conventionally also called structural unemployment. Lastly, the worldwide trend of big corporations to become more capital and less labour intensive is also mirrored in South Africa.



Source: South African Reserve Bank, Quarterly Bulletin, various issues.

Figure 1.11: Economic growth and employment: percentage

With employment declining since the 1960s, unemployment increased towards 40 per cent, should one use the expanded definition of unemployment,[14] which considers the disillusioned portion of the economically active population as being unemployed. According to the restricted (or official) definition of unemployment, the disillusioned are not considered part of the economically active population; hence the lower unemployment rate, approaching 30 per cent in 2002. Irrespective of the definition used, a significant part of the population is unemployed. This implies that people are dependent on hand-outs for survival, with the ensuing decline in human dignity. These unemployment figures are significantly higher for rural areas (where approximately half of the country's population lives), as is shown in Table 1.1 below, indicating that the unemployment level in rural areas according to the expanded definition is in excess of 50 per cent. Furthermore, Table 1.1 highlights a wide selection of key socio-economic indicators, also differentiating between the economy-wide figure and that for rural areas.

Table 1.1: Selected socio-economic indicators: 2001

	National	Rural
Unemployment rate (%):		
Official (restricted) definition	26.4	33.9
Unofficial (expanded) definition	37.0	52.2
Portion of households (%):		
with piped water in the dwelling or on site	65.7	24.3
using mainly wood for cooking	19.6	53.8
using mainly electricity for cooking	52.5	18.3
using mainly paraffin for cooking	21.1	19.2
with access to hygienic sanitation	62.2	18.0
where refuse / rubbish is removed by a local authority	54.8	15.5
with access to telephone	33.7	22.3
within 14 minutes of nearest clinic	36.3	20.8
within 14 minutes of nearest primary school	54.3	41.7
within 14 minutes of nearest food market	50.9	40.1
depended on remittances	13.8	23.5
depended on pensions and grants	17.8	32.2
with a radio	79.1	72.2
with a TV	56.4	35.0

Source: Statistics South Africa. 2002. South African Statistics 2002. Pretoria: Statistics South Africa.

When considering the portion of households that have access to water in their dwelling or on site, one sees a huge difference between the national figure of approximately 66 per cent and that of rural areas of 24 per cent. Furthermore, approximately 73 per cent of rural households use either wood or paraffin for cooking purposes and only 18 per cent use electricity. The detrimental health impact (mainly respiratory problems) of the indoor use of wood, paraffin and coal has been well documented[15] and should be an issue of great concern. As is furthermore indicated in the table, only 18 per cent of the rural households have access to proper sanitation facilities and only 15 per cent enjoy a regular refuse removal system. Access to all kinds of basic infrastructure, i.e. telephones, clinics, food stores and schools is very restricted. Lastly, 55 per cent of rural households are dependent on remittances, pensions and grants as basic sources of income.

This number is illustrative of the fact that these households do not actively participate in the economy. A contributing factor is that only 14.7 per cent of the country's population have a matric certificate and/or any other qualification above elementary schooling, with only 0.05 per cent of the population having achieved a doctorate. These percentages are contrasted by the 21 per cent that do not have any schooling at all.[16]

These numbers indicate that a significant proportion of the nation does not have easy or proper access to basic services and infrastructure and safe living conditions. They are also unable to participate fully in the economy. There should therefore be no question: South Africa's people are desperate for improved living conditions and development that would support that.

1.5) Is the South African economy environmentally sustainable?

It is clear that South Africa is in a transitionary phase with regard to the management of its natural and environmental resources, and the details explicating the unfolding political economy in the water, energy and land sectors have been described elsewhere.[17] The important question is whether there are any visible signs that these changes in the political-institutional context have brought with them cleaner, that is less material- and energy-intensive and less polluting, economic development. It is important that such indicators are developed within the generally accepted accounting principles of natural resource accounting (see Chapter 15), providing a way to calculate the standing stocks and the flows on such resources comparable to the Systems of National Accounts used for calculating a country's economic performance. Given the fact that full national resource accounts have not been developed for South Africa yet, an alternative method used by the World Bank, the 'genuine savings' method, will be used here to illustrate South Africa's macroeconomic and environmental performance. Genuine savings (see Table 1.2 and Figure 1.12) are perceived to be the true rate of saving of a country after the degradation and depletion of natural resources and the expenditure on education are taken into consideration.[18] Should a negative rate of savings persist, a decline in national well-being is inevitable.[19]

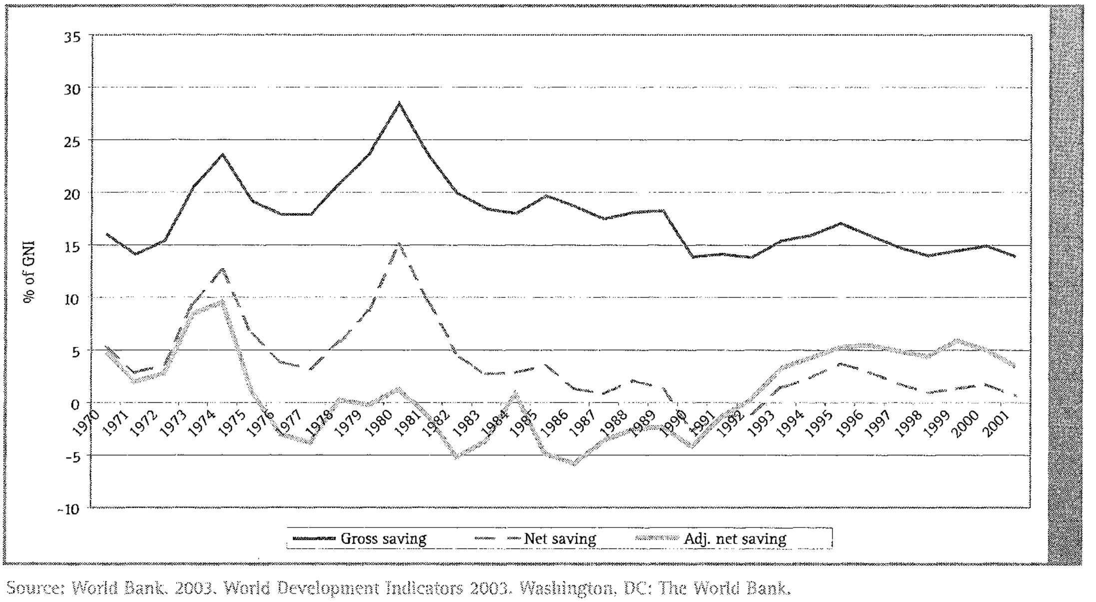
Table 1.2: Genuine savings estimates of the South African economy: 2001

Country	World	Low income	Lower middle income	Uper-Middle income	South Africa
Gross domestic savings (% of GNI)	23.9	22.1	31.2	19.6	13.9
Min: Consumption of fixed capital (% of GNI)	12.6	8.8	9.8	10.6	13.3
Equal: Net domestic savings (% of GNI)	11.3	13.3	21.4	9.0	0.6
Plus: Education expenditure (% of GNI)	4.7	2.8	3.0	4.8	7.5
Min: Energy depletion (% of GNI)	2.1	6.6	8.1	7.5	1.3
Min: Mineral depletion (% of GNI)	0.1	0.4	0.2	0.4	1.0
Min: Net forest depletion (% of GNI)	0.0	0.3	0.1	0.0	0.3
Min: CO_2 damage (% of GNI)	0.5	1.6	1.9	0.6	2.0
Min: Particulate emission damage (%GNI)	0.3	0.6	0.8	0.6	0.2
Equals: Genuine domestic savings (% of GNI) or Adjusted net saving	12.9	6.6	13.3	4.7	3.3

Source: World Bank. 2003. World Development Indicators 2003. Washington, DC: The World Bank.

Notes:
Low-income economies are those with a Gross National Income (GNI) per capita of $745 or less in 2001
Middle-income economies are those with a GNI per capita of more then $745 but less then $9 206
Lower-middle income and upper-middle income countries are separated at a GNI per capita of $2 975
High-income economies are those with a GNI per capita of $9 206 or more

With reference to Table 1.2, it is clear that South Africa has a comparatively low genuine or adjusted savings rate, namely 3.3 per cent, in comparison with all other countries of similar income levels, which range from 4.7 per cent to 13.3 per cent. The genuine savings rate is also significantly lower than the gross savings rate of 13.9 per cent. This indicates that not only the depletion and degradation of the country's natural capital, but also the lack of domestic savings and the high levels of consumption of fixed capital (depreciation allowances), are factors that stand out as a problem with the South African economy.[20] The high levels of investment in education, to be seen as investment is human capital, is comparatively the highest in the world, but not sufficient to counter the country's low savings rates and the above-average use of its fixed capital stock.[21] In this context, the damage caused by carbon dioxide emissions and the depletion of minerals compound the macroeconomic impact of the low levels of net domestic savings. The trend in genuine savings (also called adjusted net savings) from 1970 to 2001 is depicted in Figure 1.12. Here it is evident that the genuine savings were constantly below the net savings rate, and, periodically, even negative, until the early 1990s. Thereafter the genuine savings rate increased, mainly as a result of an increase in investment in human capital. Lately, however, the genuine savings rate is moving sideways at a rate considerably lower than that of the gross savings rate, though the gap is declining. The consequences of these low genuine savings on sustainability and potential future growth and development are significant. Given a population growth of approximately 2 per cent, these growth rates imply virtually zero growth in genuine savings per capita. The engine of wealth generation, savings, is not rising in proportion to the rise in population growth. The only reason for the genuine savings rate being currently positive is the high investment in human capital. Should one reduce that to international levels as indicated in Table 1.2, the genuine savings rate would be zero.



Source: World Bank. 2003. World Development Indicators 2003. Washington, DC: The World Bank.

Figure 1.12: Gross, net and adjusted (or genuine) savings for South Africa: 1970 – 2001

Outside an economic accounting framework, indicators of natural resource use and environmental quality can still be used fruitfully to draw a more specific picture within this macro context. As is illustrated in Table 1.3, South Africa is rapidly becoming a more urbanised country, with associated environmental issues such as air pollution, solid waste and access to water, energy and sanitation supply networks becoming more important in future. On the other side of the coin, population density is decreasing in rural areas, probably relieving some of the stress of subsistence living on natural resources. A high percentage of land is classified as agricultural land, but this has not translated into significantly higher and sustained levels of food production. South Africa's well-managed nationally-protected parks have always been an asset, but it is clear from these statistics that the country does not partake in a worldwide thrust of allocating more land for national protection. However, it must be noted that this is only one part of the picture, as private land is increasingly being allocated for conservation purposes and game farming.

Table 1.3: Selected environmental indicators: 1999 and 2001

Country	World		Low income		Lower middle		Upper middle		South Africa	
	1999	2001	1999	2001	1999	2001	1999	2001	1999	2001
Population (millions)	5 978	6 130,1	2 417	2 506	2 093	2 164	571	503.6	42.1	43.2
Urban population (% of total)	46.4	47.2	31.4	30.8	42.9	45.6	75.4	77.2	50.2	57.6
GDP ($ billions)	30 876	31 121	1 033	1 082	2 609	2 739	2 916	2 422.0	131.1	113.0
GNI per capita, Atlas method ($)	5 020	5 120	420	430	1 200	1 230	4 870	4 550	3 170	2 820
Agriculture										
Land area (1000 sq. km)	130 079	130 178	33 008	33 031	43 918	44 993	22 228	21 135	1 221	1 221
Agricultural land (% of land area)	11.7	38	14.4		10.7	13.0	8.4	43.0	81.6	82.0
Irrigated land (% of crop land)	19.7	20	26.6	25.2	23.0	24.4	11.8	11.4	8.6	9.5
Fertilizer consumption (100 g/ha arable land)	997	1 002	670	663	1 236	1 155	959	1 086	529	514
Food production index (1989-91=100)	128.7	130	130.9	128.0	163.1	152.8	125.5	126.0	103.1	105.0
Population density, rural (people/ sq km of arable land)	520	503	507	510	631	575	193	185	140	125
Forests										
Forest area (1000 sq. km)	38 609	38 561	6 840	9 131	13 966	13 654	2 825	7 742	89	89
Forest area (% of total land area)	29.7	29.7	26.8	27.1	31.7	31.8	35.2	34.5	7.3	7.3
Annual deforestation (% change, 1990-2000)	0.2	0.2	0.6	0.6	-0.1	-0.1	0.5	0.5	0.1	0.1

Table continued on next page >>

Table 1.3 continued

Country	World		Low income		Lower middle		Upper middle		South Africa	
	1999	2001	1999	2001	1999	2001	1999	2001	1999	2001
Biodiversity										
Nationally protected area (% of land area)	6.5	11.7	5.7	9.2	4.8	7.5	6.0	13.0	5.4	5.5
Energy										
GDP per unit of energy use (PPP $ per kg of oil equivalent)	4.2	4.5	3.4	4.0	3.6	3.7	4.3	4.9	3.3	4.4
Commercial energy use per capita (kg of oil equivalent)	1 659	1 694	550	569	1 116	1 206	2 025	1 805	2 681	2 514
Electric power consumption per capita (kWh)	2 084.7	2 176	362.3	352.0	1 063.9	1 193.0	2 481.9	2 252.0	3 831.7	3 745.0
Share of electricity generated by coal (%)	38.4	39.1	43.5	45.0	41.2	47.0	32.2	19.2	92.6	93.1
Emissions and pollution										
CO_2 emissions per unit of GDP (kg per PPP $ of GDP)	0.6	0.5	0.6	0.5	0.9	0.7	0.6	0.5	0.9	0.8
CO_2 emissions per capita (mt)	4.1	3.8	1.1	1.0	3.4	3.0	5.5	4.3	7.9	7.9
Consumption of CFCs (ODP metric tons)		93 099		20 096		44 885		24 507		81.0
Particulate matter (pop-weighted average-ug/m3)		44		64.0		48.0		29.0		24
Passenger cars (per 1000 people)	90	141	5	9	22	23	119	153	94	94
Water & Sanitation										
Freshwater resources per capita (cubic meters)	8 240	8 649	6 203	6 597	7 585	7 066	16 744	23 872	1 187	1 168
Withdrawal for agriculture (% of total freshwater withdrawal)	70	71	87	90	75	75	73	69	72	72
Under-5 mortality rate (per 1000 live births)	78	81	116	123	40	41	34	27	76	71

Sources:
World Bank. 2001. The little green data book. (From the World Bank Development Indicators 2001.) 1999 data.
World Bank. 2003. The little green data book. (From the World Bank Development Indicators 2003.) 2001 data.

Notes:
Low-income economies are those with a GNI per capita of $745 or less in 2001
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South Africa is still a highly energy-intensive country when measured on a per capita basis, both in terms of commercial energy use and electric power consumption, but some improvements can be seen in the GDP produced per unit of energy used, the commercial energy used per capita and electric power consumption per capita. The volume of carbon dioxide produced is under the top 20 in the world if measured per capita and still relatively high when measured per unit of GDP produced. As the reduction of carbon is beginning to increase in economic value it will become an increasingly important commodity characterising the South African economy.

When compared to the rest of the world, South Africa has limited and dwindling amounts of freshwater resources. The share of water used by agriculture is on par with the rest of the world, and better than that achieved in comparable lower-middle income economies. Nowhere is the connection between environmental quality and socio-economic quality of life as evident as in the indicator on the under-five mortality rate, which is much higher than other lower-middle income economies, and close to the world average when all low income countries are included as well.[22]

In summary, on a macro level South Africa is faced with:

- increased urbanisation and decreased population densities in rural areas;
- a low producing agricultural sector;
- below average public protection of natural (conservation) areas;
- high per capita use of energy and electric power;
- high carbon dioxide emissions;
- comparable low absolute levels of water resources; and
- relatively high infant mortality.

The key point is that these issues regarding the country's natural and environmental resources cannot be solved without comprehending the socio-economic drivers of such changes and the impacts these environmental changes will have on the development of the country. To answer the question posed at the beginning of this section, namely whether the South African economy is environmentally sustainable, a few indicators start to paint a picture. South Africa is producing high levels of carbon dioxide and uses lots of energy to sustain its economic development. At the same time, the realities of low agricultural production and water scarcity might, unless managed well, lead to increased costs of financing the required development, and in the worst case might even restrain development. Given the aspirations of many South Africans and their low socio-economic quality of life, it can only be expected that more pressure will be placed on the availability and quality of natural and environmental resources such as energy, land and water.

1.6 Conclusion

It is very significant and appropriate that South Africa is referred to as the rainbow nation. Not only is the country marked with a wide variety of cultures; it is also characterised by varying socio-economic conditions. Some would argue that the South African economy is doing very well and that the fundamentals are sound. Others would ask: How fundamental is it to eat and live in a proper home with access to safe water and sanitation? Or: What if the side effects of such fundamentals lead to high carbon dioxide emissions? Irrespective of one's stand on this issue, there is consensus that South Africa is a developing country in need of economic development. The question is, however: What type of development would be appropriate? Should South Africa follow the development path of the developed countries, or are there alternative options available?

There is no evidence that sustained economic growth alone will guarantee that a country will outgrow its social and environmental problems. Approaches will be needed that are sensitive to South Africa's dualistic or 'double-decker' economy (implying multiple layers of income),[23] but that will, in addition, acknowledge the availability and costs of natural resources and environmental quality in such a development path. By way of example: evidence exists that carbon dioxide emissions increase exponentially as a country becomes more affluent; but then, South Africa already has amongst the highest carbon dioxide emissions intensities in the world; but then many are still excluded from the benefits of electricity, and so on. Given increasing international pressures to reduce carbon emissions, the country can hardly afford to develop in a way similar to that of developed countries. There is neither political nor ecological space, nor the time, for this luxury. South Africa's development path will surely become one of the testing grounds for a realistic, practical focus on the choices between economic efficiency, social development and environmental sustainability in the context of good political leadership and fresh approaches to policy instruments and implementation.

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6 A negative environmental externality is a coincidental or unintended side-effect of an economic activity, which impacts negatively on nature. For example, within a coal-based power plant the intention in not to generate carbon dioxide emissions, but to generate electricity through the burning of coal, the fact that coal-based power stations generate carbon dioxide emissions in the process of generating electricity is unintended and hence an externality.

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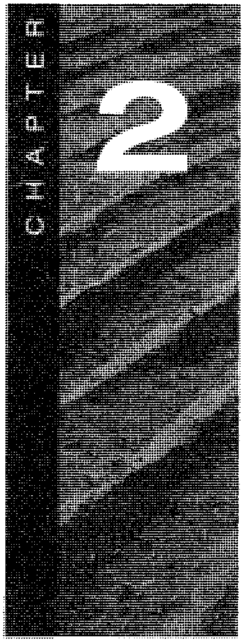
20 These numbers need to interpreted with caution. Much of a country's natural capital stock is often of a communal or public nature. In practice this means that its value is often not reflected in market prices and thus, often ignored in economic decision-making. Although based on best available evidence, many assumptions had to be made on the value of such assets in the construction of genuine savings accounts.

21 The level of the consumption of capital is very much linked to tax policy regimes. Theoretically, consumption of fixed capital should be saved, but it is not necessarily the case.

22 It is obvious that a far more complex picture underlies these statistics. A clear need exists to have indicators on different levels that better track the levels and trends in the use of natural resources and environmental quality over time for more specific sub-sectors of the economy and for more specific environmental themes. As socio-economic and political factors are often the drivers of environmental change, or at least those that can be managed, it becomes important to develop indicators that *measure environmental changes in relation to its socio-economic and political context*. If these indicators are not integrated, the results would become less useful in the holistic management of the economy and the environment. Such integrated indicators on sectoral and thematic levels will be necessary to measure the rate of decoupling in the economy and to inform better updates on macro measurements such as genuine savings measures.

23 Sparks, A. 2003. *Beyond the Miracle. Inside the New South Africa*. Cape Town: Jonathan Ball.



Reflecting on economic growth

James Blignaut

2.1 Introduction

As has been stated in the introduction to Chapter 1, a mainstream economic view pertaining to environmental problems is that a country will almost automatically outgrow these problems. In this chapter, the fundamental errors associated with such a simplistic view are explored. This is not to argue that economic growth is not important, rather that the context and the way in which an economy is growing matter when a wider range of issues are being considered, such as environmental, social and ethical objectives. To cover the topic of this chapter the ideology of growth together with its associated limitations will be discussed, to be followed by an exposition of the measure of economic growth, namely the gross domestic product itself.

2.2) A world possessed by the ideology of growth

Already during the mid-1970s Dopfer emphasised that the subject of economics was in a crisis. He stated:

> Economics has always been in a crisis since it broke away from social philosophy in the late eighteenth century. But from time to time this crisis has been particularly acute ... There is no doubt that contemporary economics is in a crisis, at least if [a] crisis is defined as the inability to meet the challenge of the times.[1]

Not only is this quote self-explanatory, it also highlights at least four important themes. In the first place, economics (and for that matter all the disciplines of modern science as such) formed an integral part of the social philosophy of the late eighteenth century. The fact that economics was part of the social philosophy of the late eighteenth century (the time of the Enlightenment) has very important implications. One implication, which expresses the second theme, is that modern science (economics in this respect) originates in the social philosophy of the Enlightenment.

Thirdly, Dopfer stressed the fact that contemporary economics is in a crisis, pointing out the inability of economic theory to address economic problems. Tinbergen[2] elaborates on this point, mentioning three main problem areas in which economic theory does not provide sustainable answers, namely the problems of income distribution, the division of labour between the poor and the rich countries, and environmental hazards. This list of economic problems is by no means comprehensive, but it gives the necessary insight into the fact that contemporary economics is experiencing a crisis of some magnitude, as it is still unable to meet and address the problems successfully.

In the fourth place, the crisis of contemporary economics is not a new one. From the quote it becomes evident that economics has always been in a crisis, and this crisis has been particularly acute from time to time. The important implication of this fact is that no workable long-term economic theory (including the neo-classical economic theory) has been put into practice yet. A practical economic theory that is able to withstand the onslaught of time and the consequences of its own makings still evades us.

It is not without reason that these four themes are linked. The social philosophy, which was one of liberty, equality and progress, provided the basis for, and origin of, scientific thinking during the Enlightenment, for instance, for the Industrial Revolution.[3] The economic crisis currently experienced can consequently be linked to a philosophy as well: the philosophy that prevailed during the Enlightenment. Shiva[4] is convinced that the same philosophy that steered the Industrial Revolution steers modern science:

> The rise of a patriarchal science of nature took place in Europe during the fifteenth and seventeenth centuries as the scientific revolution. During the same period, closely related Industrial Revolution laid the foundation of a patriarchal mode of economic development in industrial capitalism.
> Contemporary science and development conserve the ideological root and biases of the scientific and Industrial Revolution even as they unfold into new areas of activity and new domains of subjugation.

It is therefore neither far-fetched, nor without reason, to say that the root of the economic problems, crisis and malfunctioning lies in the social philosophy of the economic theory. Philosophies do not reveal themselves openly within economic theories and ideologies. It is therefore possible, even more than just a possibility but rather a reality, that the root philosophy (whose role is to provide a framework and world-view) will be concealed from, and most probably forgotten by, those who are working and dealing with the science itself.[5] It is the task and role of the philosophy to set the framework for scientific thought, but, as noted above, this is not the direct common goal. Actually ideologies serve as the common goal. Ideologies are sought after at great length – to such an extent that Goudzwaard[6] claims that the current generation lives in a world possessed by ideologies. Humankind is daily occupied in trying to maintain ideologies – for the sake of ideologies. In this way humans become a slave of their own creation. In the process of maintaining the ideology, the solutions that ought to 'save' the world and solve the problems at stake actually intensify the problems, and consequently the situation deteriorates. Maintaining these ideologies has become so important to humankind that the ideology has taken possession of its maker. In being possessed, humans are not able to see beyond the limits of the ideology that possesses them. Nor do they perceive its consequences. And they also don't see the philosophy behind it. What, then, is the origin and nature of the present philosophy that is driving the world economy?

As was noted earlier, modern science originated in the period of Enlightenment, and current economic thought depends heavily on the Enlightenment as regards its philosophy. It is therefore useful to analyse the nature of the Enlightenment and the thoughts that prevailed during that period before one can come to terms with current scientific thought. The Enlightenment period stands in the light of the thoughts of freedom and the works of the philosophers, especially Rousseau (1712 to 1778), whose influential *Social Contract* was published in 1762. Some of the strategic events, for instance, in the political, economic, social, natural and literary spheres of life emphasised and added to the credibility of the work of the philosophers. These were, among others, the works of Copernicus, Galileo and especially Newton, Bacon and Descarte's new method of reasoning, the declaration of American independence in 1776, the fall of the Bastille in 1789, the abolition of royal rule in France in 1792, and the invention of the steam engine in 1796.

These developments were deeply rooted in a humanistic philosophy, which engraved a specific theme on the hearts and minds of the people of the late eighteenth and early nineteenth centuries. This philosophy prevailed in all the disciplines of science, including economics.[7] Myrdal supports this view when he concludes that the value basis for economic study was provided by the moral philosophy of that time, which was based on hedonistic associational psychology.[8] The philosophers emphasised the importance of the individual and his or her freedom and liberation. The individual could decide for his- or herself what was best in accordance with the pleasure he or she expected to derive from a given matter or situation. Self-interest was the driving force, and the norm was what was useful to the community in general. The Enlightenment furthermore emphasised the importance of humankind's rationality, our ability to think. The basic themes of the philosophy of the Enlightenment evolved from this elated view that humankind had of itself, together with its vision of the purpose and place of nature. The themes of the Enlightenment can therefore be summed up in four words, namely rationalism, individualism, naturalism and utilitarianism.[9]

It was in this philosophical and psychological environment and atmosphere that one of the most important and influential economic textbooks of all times, *An Inquiry Into the Nature and Causes of the Wealth of Nations*, 1776, by Adam Smith (1723 to 1790), was published. This book radically and irreversibly changed humankind's idea of economic concepts and their functioning. The time slot in which the book was written gives a better understanding of Smith's arguments, as the prevailing line of thought influences one's perceptions to a large extent. Smith was no exception to that rule.

Smith argues that the economy is driven and steered by an 'invisible hand' – the market mechanism – which operates perfectly with no shortcomings, and that the markets clear. In other words, all production, allocation and distribution questions will be solved at optimal levels of efficiency.

The well-known economist, Robert Heilbronner,[10] describes this 'invisible hand' process as follows:

> This leads us to the larger picture that Smith had in mind. We would call it a growth model, although Smith used no such modern term himself. What we mean by this is that Smith shows us both a propulsive force that will put society on an upward growth path and a self-correcting mechanism that will keep it there.
>
> First the driving force. One of the fundamental building blocks of Smith's conception of human nature was what he called the 'desire for betterment' – what we have already described as the profit motive. And what does the desire for betterment have to do with growth? The answer is very important. It impels every manufacturer to expand his business in order to increase his profits.
>
> And how does this business expansion result in a higher division of labour? The answer is very neat. The main road to profit consists in equipping the workmen with the necessary machinery that Smith mentions in his description of the pin factory, for it is this machinery that will increase their productivity. Thus, the path to growth lies in what Smith called accumulation, or in more modern terminology, in the process of capital investment. As capitalists seek money, they invest in machines and equipment. As a result of the machines and equipment, their men can produce more. Because they produce more, society's output grows.

It is important to notice that Heilbronner describes Smith's model as a growth model, though Smith might not have intended it to become one as such. Unqualified economic growth and therefore output formed the end – the result of the accumulation process. The means was personal gain. The road to national prosperity through unqualified economic growth was via the mechanism of self-interest. In economic terms, the self-interest mechanism was the personal profit motive.[11]

The themes of naturalism, individualism, utilitarianism and rationalism belonging to the Enlightenment, mentioned earlier, are found quite clearly in the thoughts and writings of Smith, as is shown above. First of all, there is a propulsive, self-correcting force in society and in the economic system. This refers to the natural science of the day, where it was reasoned that if the natural order was found and followed, the intrinsic natural rhythm in the cosmos would see to it that markets cleared. This was the case because the world was seen as an infallible machine, and as soon as it was able to function according to its natural rhythm, everything would work out for the best and society would be functioning at optimal efficiency levels. This concept is known as naturalism.

In the second instance, the propulsive, self-correcting driving force in the rhythm of the cosmos is the 'desire for betterment', in other words the profit motive through which material prosperity will be realised. Each and every individual had to strive for his or her own 'betterment'. If every individual worked for his or her own account only, the total sum of the economic activity would be a society at its optimum level of productive efficiency. It is therefore clear that a strong individuality prevails in Smith's mechanics of an economic system.

Thirdly, the use of labour and machinery in the process of profit maximisation and for the improvement of its relative position illustrates the concept of utilitarianism. This concept can also be described as a subject-object relationship.[12] Humankind is the subject and it sees all other things as given objects. The objects are subjected to the subject's will and decisions. Humans are thus able to dictate to all objects, which includes nature, autonomously. Humans may utilise all natural resources and other resources in their 'desire for betterment', regardless of the fact that it may be detrimental to the resource that is utilised. As it has been stated:[13]

> At the outset it is clear that a dichotomy has been created: people vs. nature ... The dichotomy between humanity and nature is not the only one that has been imposed or supported by a humanistic way of thought. There is also the logic vs. emotion dichotomy, which although found in fact has been exaggerated and distorted by humanism.

Rabie and Fuggle[14] place this dichotomy in a historical perspective when they comment as follows:

> For millennia moral philosophies have informed relationships between individuals and between social groups, but both ethical norms and legislation regulating human use of the environment have been slow to develop.

Lastly, the way in which the economic process is linked together stands in the light of a rationalistic approach. Rational human thought has moulded a certain world-view and economic concepts into an economic model.

It is very clear that the 'founder' of modern economics, Adam Smith, in all respects underwrote the philosophical principles of the Enlightenment. It is therefore not strange that he was, in religious terms, a deist who believed that God had made the world like an enormous clock. God had built it and wound it, then took His hands off it and it is now ticking on its own. The world is functioning in a purely mechanically orchestrated way. This relationship is strikingly expressed as follows:

> The Newtonian paradigm underlying classical and neo-classical economics interpreted the economy according to the pattern developed in classical physics and mechanics, in analogy to the planetary system, to a machine and to clockwork: a closed autonomous system ruled by endogenous factors of a highly selective nature, self-regulating and moving to a determined, predictable point of equilibrium.[15]

Since the Enlightenment period, no change of philosophy has occurred. Human conduct was, and still is, supposed to be governed by 'natural laws' rather than by metaphysical ones. In doing so, humankind's analysis will be 'value free' and truly 'scientific'.[16] But then, the pursuit of self-interest is by definition value laden; hence it implies an intrinsic dialecticism in neo-classical economic theory. The objective of this dialecticism is the predictable and predestined outcome when adhering to the 'natural laws' of the economy, namely progress – in other words, economic growth.

As was highlighted earlier, Heilbronner states that one of the fundamental building blocks of Smith's model is the 'desire for betterment' or, as it is called today, material prosperity. How does one go about achieving this goal? Economic growth will bring prosperity, supply jobs and answer the quest of the human race. Humankind must pursue growth in order to be more affluent and to live in greater abundance. In the meantime, the propulsive self-correcting force will put humankind on a growth path and keep it there. Unqualified economic growth and development is, and was, one of the main ideologies served, if not the most important one (for individualistic reasons, though). This is stressed further by the fact that both neo-Keynesian and classical economists, despite their differences concerning fiscal balances, believed in the perennial necessity for economic growth. Economic growth is pursued mainly by means of industrialism, with humans, whether as individuals or as social beings, as the highest entity, the central focus of being, the pivot of the world, with ensuing significant ecological effects.[17]

The factors of production – land, capital and labour – must be utilised in such a way as to serve humankind and its ends. Under capitalism, they serve as the necessary inputs for production, while under Marxism the factors of production serve as the energy to equalise social relationships through industrialisation – the same means as capitalism, but to different ends. The factors of production, especially land (natural resources), are therefore seen as an object, as a given entity, and humans have the final and autonomous word.

Joranson and Butigan express themselves clearly when saying:

> The exploitation of the natural world has been possible on such a massive scale because humans have set themselves apart from it and have therefore been encouraged by the intoxication of its distance to dominate, control, and recreate nature in their own image. Nature has been scaled down to fit humankind's physical, but also psychological, requirements.[18]

2.3) Economic growth theories and modelling

Economic growth is one of the most extensively studied areas in economic theory. Growth theory and modelling tries to shed light on the factors that contribute (and constrain) changes in economic growth.[19] As models are approximations of (the analyst's) perceived reality, it can be expected that such approaches closely follow the ideologies exposed in the previous section.

In general, two approaches can be distinguished in growth theory: exogenous growth and endogenous growth. Exogenous growth models include one developed by Ramsey[20] and endogenous growth models include the models of authors such as Barro, Lucas, Rebelo and Romer.[21] It was Romer's article in 1986 that started the revival of (endogenous) growth theory. His thesis was that research leads to new knowledge, which is a positive externality to other firms. This increasing-returns-to-scale is the perpetuating engine of growth in the economy. In exogenous growth models the long-term growth is determined solely by population growth and technological progress, defined as constants *ex ante*, while in endogenous models the long-term economic growth rate is also influenced by parameters which describe technology and preferences. Solow[22] observes that the novelty of the endogenous growth model is that each particular version rests on a strong assumption about production that gives investment decisions very great leverage on growth rates. In almost all cases, the suspension of diminishing returns on some factor of production that can be accumulated is a key assumption. The two novel results of these models are firstly, that an increase in investment can create a permanent increase in the growth rate and secondly, that even temporarily adverse shocks to investment or a one-time loss of capital leave major scars that never heal or may get worse.

In some cases environmental concerns have been included in both exogenous and endogenous growth models. Keeler *et al.*[23] argue that a model specification depends on the way in which pollution manifests itself. Pollution either enters the model as an inevitable side-effect (externality) of economic activity or as an input to production. In exogenous growth models, environmental preservation would always result in lower economic growth rates, because technological and preferential changes on the short term are assumed to be constant. Preservation and conservation is calculated as a cost to human welfare. However, the results of endogenous environmental growth models show more lenient outcomes when both economic growth and environmental preservation are to be achieved. If there is more environmental preservation, resources are diverted from consumption and investment to the control of pollution. However, if the long-term costs of environmental damage are internalised in preferences and technological progress, the opportunity cost of environmental preservation is relatively low when compared to the results of exogenous growth models. People will benefit in the long term from more environmental preservation. Some endogenous growth models, where more types of capital other than human-made capital is included in the production function, indicate that investment in the environment will lead to short-term costs, while the long-term outcome of the decision might still be preferred.[24] In another endogenous growth model nature is assumed to be constant in the long term, which is a reflection of the ecological economic carrying capacity argument as developed in the discussion on ecological limits to production. In these models the influence of nature on the marginal utility of consumption will determine the substitutability or complementarity of natural and environmental resources and economic growth. Therefore, in these models environmental preservation will only improve economic growth when nature influences the marginal utility of consumption positively. In these models there is the danger of limiting the possible outcomes, solely due to the specification of the model. There is a need for better modelling of natural phenomena and for recognition of spatial differentiation (for example, more sectoral analysis) in these endogenous growth models.[25] When exhaustible resources and environmental issues are included in endogenous growth models, the situation looks slightly different. When capital accumulation, which leads to pollution, is not discouraged enough, a non-optimal situation will occur. In these situations environmental preservation is a function of a broader preservation of the environment rather than individual preferences; either voluntarily or through governmental policing or incentive structures. Despite the limitations, environmental endogenous growth models help to provide two important insights:[26]

- The endogenous growth literature, by neglecting the environmental dimension, may be wrong when predicting the possibility of sustained growth.

- Increasing returns to scale in the R&D or abatement sector (such as increasing impact of technical progress on emissions per unit of production) are the crucial factors that may enable economies to reach sustainable development, consistent with the preservation of the stock of natural and environmental resources.

These growth models, whether exogenous or endogenous, have objective functions that should be maximised subject to a set of constraints. None of these models include parameters for emergent realities. Time is treated as being symmetrical. Sengupta[27] did include evolutionary dynamics in his discussion on new growth theory. The sources of complexity and chaos have to be included in models on evolutionary economic systems. In the case of chaotic, unstable dynamics, the growth models have to account for some kind of positive feedback behaviour. According to Sengupta, this recognition makes the more conventional methods of econometric equilibrium modelling totally useless.

In summary, endogenous environmental growth models have the potential to include environmental concerns and technological progress. In the endogenous environmental growth models too many ecological complexities are specified *ex ante*, with no adequate underlying ecological modelling results. The potential for mitigation of environmental degradation through technological progress, invention and innovation is also not clear from the modelling results. These models do not describe patterns of development, but are still rooted in the tradition of formulating an objective function subject to a set of constraints.

2.4) Environmental, social and ethical limits to growth

It has been illustrated above that the world, also the subject of economics, is possessed by ideologies. This is reflected in the theories and models that economists have developed; unable to answer the question whether economic growth or development is sustainable or not. However, when reality is asking for solutions outside the realm of neo-classical thinking, it is worth exploring beyond the traditional boundaries of economic theory and ideology. To paraphrase Galbraith:[28]

> In assessing the future of economics, no one will wisely discount the service and therewith the durability of the classical/neo-classical tradition. Its influence is not, however, plenary, nor will it be in the future. Reality also has its claims on thought, a persisting, obtrusive presence that commends itself by its practical relevance and, to some, by its very inconvenience.

Heilbronner[29] argues as follows:

> All industrial nations face an era in which exponential growth is beginning to absorb resources at rates faster than we may be able to provide them with new technologies: and all industrialized societies – indeed, the whole world – may soon be entering an era in which environmental limitations will impose a scaling-down of expectations of growth.

The natural environmental processes are not perpetual by definition, but are determined by the laws of thermodynamics. In the economic literature, the aspects of environmental services to human beings are described by the material balance principle and the entropy principle. Ayres and Kneese[30] provide the first onset towards the development of the material balance model with a discussion on material flowing from the environment to the economy and back. This model is an application of the first law of thermodynamics, which states that the total amount of mass/energy is conserved in all processes, also in the transformation of materials. Energy is neither created nor destroyed. This means that production and consumption must require some inputs of material and energy from the environment and generate some waste.

Although the total amount of energy does not increase or decrease, the quality of the energy deteriorates over time. A measure of this increasing relative disorder is entropy. This is the subject of the second law of thermodynamics. This law states that entropy increases in any irreversible process. Boulding[31] refers to this law as the bathtub theorem – a system that is steadily running down without replenishment. This second law is based on an isolated, closed system, in which there is no exchange of energy or matter between the system and its surroundings. A closed system tends to run down, an open system does not. Thus, for making entropy a useful concept, the thermodynamic system and the boundaries of such a system have to be defined.[32] The earth, however, is not a closed system as long as the sun shines, so in principle energy availability is not a problem. Therefore, even in the case of increasing entropy a stationary state can be achieved in the long run, if solar energy is used to its potential.[33] This thermodynamic vision implies that there are limits to the throughput of resources into production and consumption processes and back into the environment as pollution or waste.[34] This notion of ecological or biophysical limits has become a premise from which the largest cluster of work in ecological economics has been done.[35] However, given the complexity of ecosystems, the absolute levels of these limits are still uncertain.

Besides environmental limitations, the negative outcomes of the present economic system also suggest that there are ethical and social limits on the interactions between the economy and the environment. This means that the use or pollution of the natural environment could be contained for reasons other than economic or ecological arguments.[36] The rationale for ethical and social limits to growth is exemplified in the literature on ethics and economics and the social effects of economic growth.[37]

The erosion of moral standards due to self-interest is interpreted by some as demonstrating the need for ethical limitations on economic growth. For instance, Goudzwaard and de Lange[38] developed the economics of care and of enough. The unlimited accumulation of capital, dictated in traditional economic theory as an increase in welfare, is perceived to be a fallacy. Welfare is measured against a higher set of norms; therefore individuals and organisations should be guided by normative principles when making choices, not by self-interest (see Chapter 18).

The social limits of economic growth have also received attention in recent years. Economic growth has not brought an equitable distribution of income or a clean and healthy environment. The expected high level of human happiness has not been achieved (at least not for most). Money does not necessarily buy happiness. When and where it does, it does so at a decreasing rate, a situation often referred to as the Easterlin paradox.[39] Further social limits to the economic growth phenomenon include:

- The inclination of economic growth to mass production and specialisation takes away pleasure in working.[40] A recent addition is repetitive strain injury (RSI). An example of RSI is the carpal-tunnel syndrome associated with working at computer keyboards.[41]
- Wealth is essentially a question of relative wants. Growth does not lead to an absolute increase in welfare; it is only important to keep up with the Joneses.[42] Daly[43] refers to this struggle for relative shares as a zero-sum game and compares it to the self-cancelling trap one finds in the arms race.
- In countries where basic needs are still difficult to meet, economic growth is often seen as the mechanism to improve the situation. Economic growth does not necessarily lead to development. Poverty, unemployment and inequality have frequently increased in the presence of high rates of economic growth.[44]
- Despite economic growth, income inequality is still on the rise.[45] A study of 56 countries found a strong negative relationship between income equality and economic growth.[46]

As was stated earlier, Smith did not call his model a growth model, and he probably never intended his work to have such far-reaching consequences. Elsewhere Smith even argued that those who attained wealth through the working of the invisible hand, should at the same time practice prudence, frugality, industry and parsimony.[47] Without elaborating, the key issue is that ethical and moral dimensions of any human being and/or institution are an integral part of economic actions. Real democracy, in fact, can only function when there is mutual interest, fair relationships, and a respect for human and environmental rights. The state can provide the setting and context where individuals and organisations can live up to being responsible producers and consumers of our natural resource wealth, but the ultimate responsibility lies with producers and consumers themselves.

This growth model is built on a set of values derived from ideologies embedded in a world-view, which delivered an abundance of goods and services, but failed to calculate the price thereof appropriately. Furthermore, humankind impacts heavily on the earth's natural resources and seemingly ignores social and ethical limits in the single-minded pursuit to serve ideology. The consequences of unqualified economic growth for nature and the quantity and quality of natural resources have been overlooked in the past (however untenable that may seem now, it stems from valuing natural resources as 'free gifts of nature'). This has resulted in the application of the wrong measure of welfare.

2.5 GDP: Measuring growth

The gross domestic product (GDP), or its subregional counterpart, gross geographic product (GGP), is an excellent measure to determine changes in income from one period to another in a country (GDP) or specific area (GGP)[48] for those activities that are recorded through the conventional national accounting measures. In addition, the GDP is internationally recognised and calculated according to a generally accepted international methodology.[49] The GDP therefore provides analysts with a very good instrument for country comparisons as well as trend analysis when considering monetary income.

Simultaneously, though, the GDP is the wrong measure to determine societal progress. But, unfortunately, a change in GDP is generally equated to a change in progress, or a growth in welfare. Why is it wrong? The following (non-exclusive) list gives some of the main reasons:

- The GDP does not make provision for changes in the quantity of environmental assets.
- The GDP does not make provision for changes in the quality of environmental assets.
- Increase in health expenditure due to changes in environmental conditions is seen as a contributing factor to GDP growth (e.g. higher medical expenditure due to chronic exposure to air pollution is considered economic growth).
- Environmental clean-up expenditures are seen as a contributing factor to GDP growth (e.g. the clean-up costs of a beach estuary after an oil spill).
- Net operating surplus excludes return on the natural environment.
- Since the GDP does not take any changes of environmental quality or quantity into consideration, the notion of abundant (infinite) resources is being perpetuated.
- Since the environment does not contribute to the GDP as being the return on an asset, but only as being an input cost item where used (for example, water

and subsoil assets), there is a real incentive to keep the price as low as possible, reinforcing the notion of abundance.

- The GDP does not recognise that the human race is dependent on the environment as the all-important life-support system. But, with the utilisation of its assets being free of charge, a change in the life-support system is not registered as a change in GDP, whereas the increase in health and clean-up costs, as mentioned above, are recognised as GDP growth.
- The replacement of people due to the need for infrastructure development contributes positively to the GDP, not including any social or cultural losses or losses of means of income not accounted for directly.

Why is it that the GDP, arguably the most important variable in economics, could have evolved in such a way as to be so misleading when it comes to measuring progress? The answer lies in what is defined as capital (see also Chapter 3). The abovementioned concepts of income, value added and expenditure are based mainly on what Hicks[50] says, namely:

> The purpose of income calculations in practical affairs is to give people an indication of the amount which they can consume without impoverishing themselves. Following out of this idea, it would seem that we ought to define a man's income as the maximum value which he can consume during a week, and still expect to be as well off at the end of the week as he was at the beginning. Thus, when a person saves, he plans to be better off in the future; when he lives beyond his income he plans to be worse off. Remembering that the practical purpose of income is to serve as a guide for prudent conduct, I think it is fairly clear that this is what the central meaning must be.

El Serafy[51] captures the essence of these words in the following statement:

> The fundamental principle that is flouted by applying conventional national income accounting to depletable resources is the separation that must be maintained between income and capital. This principle tells us that if you liquidate your assets and use the proceeds for consumption, you are living beyond your means, and in doing so you are undermining your ability to create future income.

In sum, if the current income stream from a resource is lower than the net present value of the resource, the country is worse off. However, Hicks only includes human-made (fixed) capital in his original definition – environmental resource and ecological economics expand this to include natural capital as well. As Solow,[52] the 1987 Nobel prize winner in economics, indicates:

> When it comes to measuring the economy's contribution to the well-being of the country's inhabitants, however, the conventional measures are incomplete. The most obvious omission is the depreciation of assets. If two economies produce the same real GDP but one of them does so wastefully by wearing out half of its stock of plant and equipment while the other does so thriftily and holds depreciation to 10 per cent of its stock of capital, it is pretty obvious which one is doing a better job for its citizens. Of course the national income accounts have always recognized this point, and they construct net aggregates, like net national product, to give an appropriate answer. Depreciation of fixed capital may be badly measured, and the error effects net product, but the effort is made. The same principle should hold for stocks of non-renewable resources and for the environmental assets like clean air and water.

The main source of the problem of conventional national accounting practices (used in calculating the GDP) is that since they exclude environmental (and social) capital from their ambit, they do not take into account the consequences of both market and government failure appropriately and adequately.

The current national accounting framework does not include any form of depletion or degradation of natural capital, since the market does not attach an apt price for these resources – they are consumed at liberty. By disregarding the depletion of natural assets and environmental quality stocks and non-market values of environmental goods and services, conventional measures of macroeconomic performance convey no information on the state of the environment and are hence considered inappropriate for evaluating long-term welfare aspects and sustainability. Where the conventional System of National Accounts (SNA) is the major source of information for planning and policy design, the said omissions may lead to wrong policies and development plans resulting in suboptimal allocation and unsustainable extraction and use of natural resources.

This may have serious and long-lasting consequences that can cause irreversible ecological disasters and the breakdown of sensitive ecosystems and biological functions crucial to human life. These predictions could realise simply because the information contained in the conventional SNA (and the SNA items discussed above) implies that economic growth measured in terms of increments in total value added (GDP) is desirable, regardless of its impact on the natural resource base and environmental quality. This implies that economic growth, for which resource depletion and environmental degradation have to pay the price, is valid.

Why are these aspects of concern? Simply put, by ignoring them, wrong decisions based on inadequate information are possible, which might lead to litigation, based on clauses 24, 32 and 33 of the constitution[53] against the state or the decision maker. Moreover, ignoring these issues creates the illusion of welfare amongst possible environmental and social decadence.

2.6 Conclusion

Economic growth, measured in terms of a percentage change in the GDP, is not a problem *per se* when considered as the change in economy-wide income of a country during a specific period and in the context of other environmental, social and ethical limits. When economic growth becomes the sole welfare objective (ignoring environmental, social and ethical objectives), however, progress, and hence development, are accounted for and modelled erroneously. Various attempts have been made to address this mistake, though none of them to the extent that they have entered mainstream economics. In Chapter 3 these attempts will subsequently be considered.

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49 The GDP can be calculated either as the return to factor income (capital, labour and entrepreneurship), or the net value added during production, or, lastly, total expenditure on final demand by the private and public sectors. These three measures of GDP yield the same value (or result) within a specific country for the same period under consideration since income, expenditure and value added will always be equal.
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Clause 24 of the Constitution states:
Everyone has the right:
(a) to an environment that is not harmful to their health or well-being; and
(b) to have the environment protected for the benefit of present and future generations,
    (i) through reasonable legislative and other measures that prevent pollution and ecological degradation;

(ii) promote conservation; and

(iii) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.

Clause 32 of the Constitution states:

Everyone has the right of access to

a) any information held by the state; and

b) any information that is held by another person and that is required for the exercise or protection of any rights.

Clause 33 of the Constitution states:

(1) Everyone has the right to administrative action that is lawful, reasonable and procedurally fair.

(2) Everyone whose rights have been adversely affected by administrative action has the right to be given written reasons.

CHAPTER 3

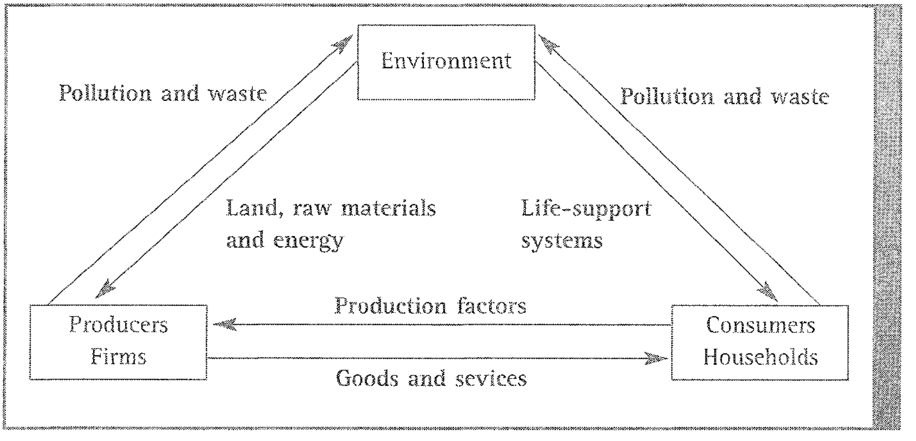
The economics of the environment

James Blignaut and Martin de Wit

3.1 Natural resources and development

In the course of the discussion in Chapter 2 of the inappropriateness of the GDP as a measure of economic welfare, it was identified too narrow an indicator. The change in GDP measures change in recorded income, but that does not translate directly to a change in economic welfare of the same proportion and in the same direction. The reason for this is that, amongst others, the economic and ecological systems interact in a variety of ways. For example, to produce and consume goods and services one needs energy and material inputs (i.e. natural resources) from the natural environment. These economic activities are also often accompanied by pollution and waste streams that have to be absorbed in the natural environment. These interactions are not appropriately accounted for in the conventional Systems of National Accounts, as was discussed earlier. The focus in conventional economics is on the allocation of limited resources among competing needs or desires, where this allocation process takes place through markets or other institutions, or on solving unlimited needs and wants through limited means or resources. When trading takes place, goods and services flow from producers (firms) to consumers (households), while labour and other factors of production flow from consumers to producers. Nevertheless, these transactions have definite economy-environment interactions. What is more, ecological systems operate within certain finite parameters and have to be included in any economic analysis. A more inclusive approach is therefore necessary to harness these ecological changes as well.[1]

Coddington[2] has developed an elementary, but, because of its simplicity, also appealing model, which captures the aforementioned economy-environment interactions. This is done as an expansion of this economic circular flow model of production and consumption to include the environment, as illustrated in Figure 3.1.



Source: Adapted from Coddington, A. 1970. The Economics of Ecology. New Society. 15 (9 April):595-97.

Figure 3.1: Economy-environment interactions

The environment provides various services to human activities, namely:

- the provision of life-support systems (environmental services);
- the supply of land, raw materials and energy (environmental sources); and
- the absorption of pollution and waste (environmental sinks).

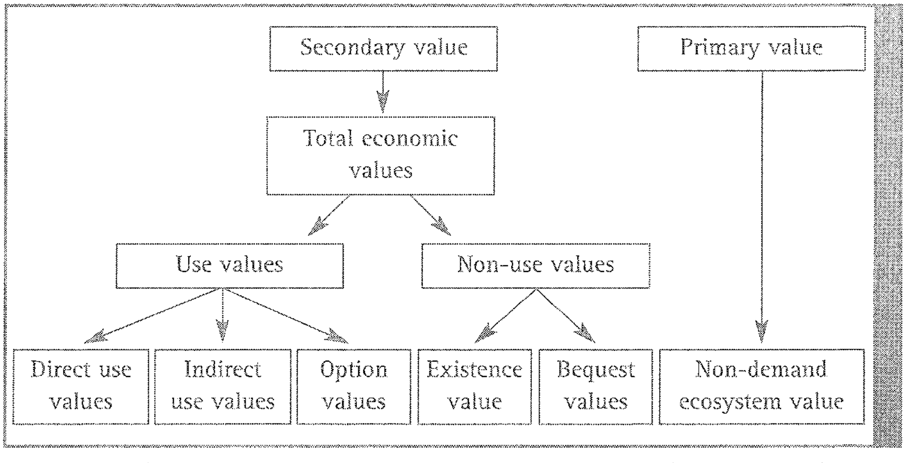
Institutions such as markets or governments often fail to take account of the value of natural and environmental resources. *Policy failure* can be defined as the situation where government itself is the source of failure in the economy. This could be corruption or patronage, but even well-meaning policies can lead to a worsening environment or reduction rather than an improvement in the overall well-being of society.[3] Market failure can be defined as the inability of the market to allocate resources efficiently due to the presence of imperfect competition, imperfect information, public goods, inappropriate government intervention and externalities (positive or negative).[4] Given the focus here, externalities will be considered in more detail.

The word 'externality' almost speaks for itself: an externality is something that comes from outside. An externality is an incidental side-effect of either consumption or production, and it may be either positive or negative. The market prices of products do not always reflect the total benefits or costs of the product to society as a whole.

The most familiar example of an externality is air pollution. A factory makes a product and in the process emits smoke through a chimney, which is inhaled by everyone in the vicinity. This is a negative externality which arises during the production process. It is incidental, because the factory does not pollute the air intentionally. Its intention is just to make its product, but in the process it also pollutes the air and thus inflicts a nuisance – or cost – on the immediate neighbourhood. From society's standpoint, this is a cost from outside, i.e. externally, inflicted on the people. The market usually cannot solve the problem of externalities automatically because of the presence of incentive and institutional structures that act as barriers to change. There might, for example, be a laundry next to the factory in question. The factory soot soils freshly washed laundry, which compels the laundry firm to redo the washing process – at extra cost. The factory does not compensate the laundry for this extra cost.

The fictitious factory described above is actually calculating its costs incorrectly. It takes into account all its private input costs, like wages and rents, but does not include the costs of the laundry and other aggrieved parties, known as social costs. It only takes account of its own production costs, not the total costs that it imposes on society. It is therefore necessary that rules are made relating to pollution, or that a tax is levied on the polluter. Theoretically, it may be argued that the factory's market price is too low and that it therefore produces a greater quantity of output than warranted, that is, if social costs were in fact taken into account.

Figure 3.2 illustrates a useful breakdown of the various environmental values, often not accounted for in market prices that should typically be accounted for to determine a change in welfare. This breakdown of total economic values (TEV) into use and non-use values, or more specifically: direct use, indirect use, option, existence and bequest values, is a powerful conceptualisation of the secondary values of the environment. Direct use values can be categorised as consumptive (for example, commercial/industrial market goods such as timber and firewood) and non-consumptive uses (for example, recreation, cultural and spiritual use).[5] Direct use values are conceptually straightforward but not necessarily easy to measure in terms of money. The value of medical plants, for instance, is intensive, but possible, to measure.[6] Indirect use values correspond closely to so-called 'ecological functions' (for example, watershed protection, carbon sequestration, nutrient recycling, etc.). Option values are an expression of preference, a willingness-to-pay for the preservation of an environment against the probability that the individual will make use of it later.[7]



Source: Adapted from Turner, R.K., Pearce, D. and Bateman, I. 1994. Environmental Economics. An Elementary Introduction. New York: Harvester Wheatsheaf.

Figure 3.2: Values of the environment

Bequest value measures an individual's willingness-to-pay to ensure that an environmental resource is preserved for the benefit of his or her descendants. Bequest values are non-use values for the current generation, but a potential future use or non-use value for their descendants.[8] Existence value measures the willingness to pay for the preservation of the environment that is not related to either current or optional use, thereby being the only true 'non-use' value. Existence values are based on the concept of the *environment being there*. In some cases, bequest values are treated as part of existence values as it is often cumbersome to differentiate between the two on an empirical level. Determining use values is more common than to calculate the non-use and primary values of a resource. Should only the use values be calculated, the value of the resource would grossly be underestimated but it would render an estimate of the lower bound value of the resource.

Chapter 4 considers various valuation techniques according to the principles of environmental economics. These techniques, however, have inherent problems due to some strong assumptions regarding interpersonal comparisons of utility. Figure 3.3 points out why environmental factors must be valued, and offers some objections to these arguments.

The importance of valuing the environment:

- It is a reminder that the environment is not a free good.
- In the trade-off between development and the environment, it helps to redress the balance between quantifiable and non-quantifiable effects.
- It reduces the reliance on pure judgement.
- Quantification, when carefully applied with a clear understanding of its limitations, can provide a more secure base for policy-making.

Objections to valuing the environment:

- Certain things have an absolute value that makes them not quantifiable, for example, life and beauty. The suggested approach is to treat these non-quantifiables as 'off-bounds'.
- It is often argued that cost and benefit values are sometimes manipulated by interested parties to produce a certain result. However, although the truth of this allegation cannot be denied, it must be pointed out that this objection applies to any objective decision criterion.
- Valuation needs a great deal of technical and economic data, which is often lacking, especially in developing countries.
- Valuation techniques have evolved to deal with environmental problems in developed countries. They are less applicable to developing countries with a different institutional set-up.

Source: Winpenny, J.T. 1991. Values for the Environment. A Guide to Economic Appraisal. London: HMSO: pp. 6-7.

Figure 3.3: The importance of and objections to valuing the environment

3.2 Linking economics and the environment: Defining economic approaches

Although most will agree on the concepts of market and policy failure, externalities and total economic value discussed above, the subject-area of economics and the environment is characterised by many different approaches that are important to understand when assigning values to environmental and other assets and the value of flows (services, sources and sinks) in economy-environment interactions. Different economic theories have different interpretations of the workings of the economy and the environment. Proponents of different theories will therefore recommend different economic policies towards sustainable development. It is therefore necessary to highlight the key issues differentiating the different approaches.

3.2.1 Defining theories on economy-environment interactions

Environmental economics is the study of economic choice, including the functioning of the environment, with the ultimate aim of satisfying human wants. It is an applied field of neo-classical economic theory focused on determining the optimal levels of pollution and waste. The degradation of natural and environmental resources is perceived to be caused by market failures, opportunity costs that are not well-defined and choices that are misinformed. The required solution is the allocation of private property rights.

Resource economics is also an extension of neo-classical economics, focusing on the supply of raw materials and energy as physical inputs in production and consumption. The objective is to derive an optimal depletion path for non-renewable resources[9] and an optimum time for the use of renewable resources.[10] Both environmental and resource economics are built on concepts in welfare economics. The underlying question to welfare economics is whether an economic policy would lead to an improvement in human welfare. Since a change in environmental quality has a direct impact on human welfare, it is necessary to compare such changes with other costs and benefits of certain economic policies.

Ecological economics is a relatively new discipline, addressing the relationships between ecosystems and economic systems in the broadest sense. It includes neo-classical environmental and resource economics, environmental impact studies and conventional ecology as subsets, but encourages new ways of thinking in bridging the gaps between ecological and economic systems. The central question is one of biophysical limits and the ability of technology to circumvent them.[11] Not every change in environmental quality can be traded off against other societal objectives, as these are governed by the laws of thermodynamics, as discussed in Chapter 2. Combining the concepts of the rate of resource harvesting and the laws of thermodynamics, Daly[12] suggests three simple rules to help define a long-term sustainable limit to the production process. These rules are:

- renewable resources: the sustainable rate of use can be no greater than the rate of regeneration;
- non-renewable resources: the sustainable rate of use can be no greater than the rate at which a renewable resource, used sustainably, can be substituted for it; and
- pollutant: the sustainable rate of emission can be no greater than the rate at which that pollutant can be recycled, absorbed or rendered harmless by the environment.

Institutional and co-evolutionary economics is far removed from the philosophy underlying neo-classical economics. Institutional economics encompasses a broad field and could possibly be categorised in terms of the old, new and neo-institutional economics.[13] The old institutional economists concentrated on a methodological criticism of the neo-classical paradigm mainly from an evolutionary perspective, thereby providing much descriptive material.[14] The new institutional economics rejects some elements of the hard core of neo-classical economics, such as the rational choice model. Neo-institutional economics follows the neo-classical hard core, but includes subsets such as the property rights school, transaction cost economics, the new economic history, the new industrial organisation, the new comparative economic systems and law and economics.[15] Institutional economists argue that some (not all) value systems are too complex for simple monetary reductionism. They emphasise the classical dichotomy between price and value in what has become known as the social value theory based on universal principles of social value.

Co-evolutionary economics suggests that changes in environmental quality and other societal objectives are not only interdependent, but have evolved together and will continue to evolve in tandem into the future.[16] None of the environmental and societal objectives can be addressed in isolation. Any attempt to rectify environmental or economic problems cannot ignore that this will require new social constructs that provide the framework for change.

Approaches building on neo-classical economics (environmental economics, resource economics and welfare economics) suggest a monetary valuation of the environment, ideally in all cases. Ecological economics supports the principle of monetary valuation, but in cases where biophysical limits or thresholds are apparent, no trade-offs in environmental quality can be allowed. Institutional and co-evolutionary economists suggest a holistic approach to decision-making in which monetary and non-monetary impacts are kept separate and presented in that way to decision makers.[17] Table 3.1 summarises a selection of economic theories in terms of its principle authors, its view on capital, and what determines value. These aspects will be deliberated subsequently.

Table 3.1: Economic theories and Fundemental Principles determining value

Economic theory	Examples of principal	Capital	Fundamental principle of value authors	Normative value
Classical economics	Malthus, Ricardo	Limits on natural capital (land), human-made and financial capital	Scarcity of production factor (especially labour, land and human-made capital)	Productive efficiency
Neo-classical economics	Smith, Marshall, Jevons, Menger, Walras	Substitution possible between human-made, financial, human capital	Real exchange value	Economic efficiency in exchange

Table continued on next page >>

Economic theory	Examples of principal	Capital	Fundamental principle of value authors	Normative value
Environmental economics	Pigou, Pearce	Substitution possible between human-made, financial, human and natural capital	Imputed exchange value	Economic efficiency in exchange inclusive of environmental externalities
Neo-institutional economics	Coase, Eggertson	Entitlements to human-made, financial, human, social and natural capital	Real or imputed exchange value with inclusion of transaction costs	Economic efficiency in exchange inclusive of transaction cost
Ecological economics	Daly, Costanza	Substitution between human-made, financial, and human and social capital on the one side and natural capital on the other is not possible	Economic rent of natural and environmental resources	Sustainability
Evolutionary economics (especially old institutional school)	Veblen, Schumpeter	Human-made, financial, human, social and natural capital used in the evolutionary process of production	Instrumental principles of social value, focusing on the continuity of human life	Continuity (survival or systems norm)

Source: Adapted from de Wit, M.P. 2001. Economic Policy Making for Complex and Dynamic Environmental Problems: A Conceptual Framework. Unpublished DCom thesis. Pretoria: University of Pretoria.

3.3 Understanding capital

3.3.1 Introduction

Environmental resource economics (ERE), neo-institutional economics and ecological economics all share the perception that the environment comprises a stock of natural capital (both qualitative and quantitative) that depreciates. One of the main differences between these schools is the views concerning the degree of asset substitutability.[18] On the other hand, the evolutionary approach to economics sees the environment as an integrated part of a holistic and dynamic process of development together with many other factors, and the question of substitutability between various asset categories is therefore not relevant since an integrated system cannot be divided into various compartments. To appreciate the issue of capital substitution, however, an understanding of the concepts of capital and economic value is necessary.

Conventionally only three forms of capital are distinguished in economic literature, namely human-made, financial and human capital. These forms of capital are well documented in the classical and neo-classical thought on economic development and growth and will not be discussed here in detail. It is sufficient to say that these forms of capital, mixed with the clinical growth factors, such as saving and investment, provide the basis for all mainstream economic growth models, such as the endogenous growth model (as discussed in Chapter 2).[19] It is the exclusion of the natural environment (or ecological systems) as well as social and organisational behaviour that has led to them being neatly treated under the *ceteris paribus* assumption. This assumption implies that the economic performance of a country is indifferent to any possible changes in ecological or social systems. It therefore suggests that changes neither in quality nor quantity of ecological resources will have an impact on the economic processes. Therefore the assumption supports the notion that ecological resources are infinite inputs to the economic production process. As is illustrated by the Coddington model, this is not correct, since the economic processes of production and consumption do interact vigorously with the natural environment. It is, therefore, worthwhile to consider natural and social capital here in more detail.

3.3.2 Natural capital

Natural capital expands beyond the concept of *land*,[20] to include all natural systems, such as the atmosphere, biological systems, and processes such as photosynthesis and pollination. These natural systems affect the quality of capital. For example, sulphur dioxide released into the atmosphere becomes part of negative environmental capital. The natural activity of precipitation (rain) converts the sulphur dioxide into acid rain, which adversely affects the quality of lakes and forests, respiratory health and buildings. On the other hand, the natural activity of the sun affects the environment both positively and negatively, by creating power in solar systems and causing many human-made materials to perish. From a production point of view, very little substitution is possible between environmental capital and other reservoirs of wealth such as financial or manufactured capital. Although environmental capital can be self-maintaining and even self-generating, other forms of capital simply cannot replace much of the wealth in environmental capital, such as the ozone layer or complex ecosystems like tropical rainforests.[21]

3.3.3 Social and organisational capital

Social and organisational capital comprises the interpersonal 'software' that enables societies and organisations to function, including habits, general perceptions, norms or values, traditions, regulations, policies, ethics, etc. – in other words, the non-physical part of culture.[22] It includes the way in which the legal system operates, the functioning of government, the psyche of the community, the dynamics within families, as well as all art and knowledge that have become part of culture. Social and organisational capital differs from human capital in the respect that, while the latter is attached to a particular individual, the former is transpersonal and non-exploitable. However, similar to the case of human capital, social and organisational capital cannot be depleted, but is, in fact, enhanced by use and development, and is therefore not constrained by the normal economics of scarcity. Since social and organisational capital is communal and collective by nature, one should not only focus on private or individual macroeconomic variables (such as savings and investment) as growth engines, but also the tacit assets which give value and quality to life.

Changes in societal welfare should, therefore, be measured while focusing on all five forms of capital, namely human-made, financial, human, natural, and social and organisational. Should one of these be omitted from the equation, as is currently the case, wrong answers to the wrong kind of question are likely to come up, leading to results that are, though perhaps factually correct, improper.[23]

3.4 Understanding economic value

In the real world there are many sets of value categories. All human values are influenced by perceptions, with the implication that any valuation of the environment cannot be made absolute across all temporal and spatial coordinates. Some values are not part of the economist's perception of values. An example is intrinsic value, where states of affairs are judged by an environmental ethic. This environmental ethic can be judged according to its instrumental usefulness to human beings or by valuing an object independently from humanistic values. The economists' approach takes account of a change in environmental quality and the implications for human welfare. It is not necessarily in competition with other value systems, but can easily be if the claim is that economic values encompass all values.

Why is it necessary to derive economic values for the environment? Bishop[24] gives a good, practical answer to this question: *In the policy arena, those things without a market value are often assumed to have little or no economic value.* It may often be better to have explicit values for analysing changes in the environment rather than to leave them to the implicit value judgements of policy makers. This view is further enhanced by the fact that natural resources are scarce and hence impact on societal welfare; it should therefore be part of the core business of economists. Furthermore, deriving values for resource use and depletion helps to understand the causes of depletion of non-renewable and critical zone resources and the over-exploitation of renewable resources.

According to the classical economists, production is a set of sequential activities that includes the extraction of material. They view labour as the dominant, but not only, source of wealth creation and value added. Additionally, the classical perception of value includes the other factors of production as well, namely capital, entrepreneurship and land (thus, the environment and environmental constraints) as important to value determination. With regard to the latter, the value determination occurs primarily through the scarcity of natural resources or land, which underlies the theory of diminishing marginal returns. With the focus on production factors, classical economics can be viewed as supply driven, with *production efficiency* as norm for decision-making. Classical economic theory derived by, among others, Malthus and Ricardo during the early 1800s, was predominantly concerned with macroeconomics. However, this changed during the 1870s, as neo-classical economics is mainly focused on microeconomics.[25]

The neo-classical theory of production is based on the work of Smith, but has shifted its emphasis from macroeconomic production to microeconomic exchange, and combines a marginal utility theory of demand with a marginal productivity theory of supply. A further difference between classical and neo-classical economic theory is that, whereas the former was predominantly concerned with production, the latter is concerned with demand or consumption. The determination of price and income (thus, value determination) was based on the outcome of exchange in the markets, the interaction between the market forces (supply and demand). The market forces determine the market prices of goods and services, and the market price of an item is a reflection of its value. It is not surprising, then, that the dominant decision-making norm was based on *economic efficiency through exchange*. Additionally, Walras argues that final products are obtained by combining raw materials, labour and capital, but that raw materials themselves are obtained by combining land, labour and capital and can therefore be excluded from the representation of production. Marshall also omits raw materials, which he regards as incidental expenses.

Neo-classical theory is therefore not based on a physical analysis of production activity, but rather on individual preferences which drive consumption, and initial endowments as determinants of prices. Strictly speaking, according to neo-classical economics, the natural environment has no determinable monetary value beyond the market price of commodities as determined by trade; hence also the easy use of the *ceteris paribus* (keeping everything else equal) clause.[26] According to neo-classical economic theory, optimum resource allocation will lie at Pareto optimum. The price determination process will determine the optimum position of resource allocation where producer and consumer are in simultaneous equilibrium. Producer equilibrium will occur where a producer produces a maximum output given the inputs at his or her disposal (capital and labour). Consumer equilibrium will occur when a consumer consumes a maximum of consumable items given his or her budget constraint. Pareto optimum will exist when the producer produces at producer equilibrium and the consumer consumes at consumer equilibrium. The quantities produced and consumed are exactly the same, and there are no surpluses or shortages at the price determined in and by the market.

Environmental economics is an extension of neo-classical economic theory by incorporating environmental externalities into the economic analysis. Various studies give comprehensive accounts of neo-classical approaches to environmental economics.[27] The total economic value of the environment, as calculated by environmental economic valuation techniques (discussed in Chapter 4), is generally an imputed value leading to a change in welfare, in a partial equilibrium framework, due to a change affecting natural and environmental resources. With the fundamental principle of value being one in exchange, neo-classical economic theory and environmental economic theory both focus on a change in consumer surplus as a measure of change in welfare. The neo-classical measurement of a change in welfare is based on the concepts of consumer and producer surpluses and rests on the very strong assumption of perfect competitive markets. Even if all other market factors operate optimally, it is highly unlikely that the natural and environmental resources will be allocated optimally because of market failures and the exclusion of ecological system activity from these analyses. Pareto optimality cannot be applied in a situation of failing markets. In the absence of market prices there is no way in which to measure the trade-offs between different groups (consumers and producers) affected by the change. Market failure is the general norm, rather than the exception, in the case of natural and environmental resources, providing the rationale for the imputed demand for environmental quality. Neo-institutional economics does not explicitly focus on natural and environmental resources, but is focused on the rules and contracts of exchange, the concept of transaction costs and a multi-dimensional approach to economic organisation. It follows the neo-classical hard core, meaning that the principle of value is one of economic efficiency in real market or imputed exchange (to take account of externalities), but with the important difference that transactional costs are added to the analysis.

Ecological economics perceives value in terms of production rather than consumption, very much in the tradition of classical economics. The economic rent flowing from the production of natural and environmental resources, including the value of nature itself and not only the costs of production factors, is perceived to be the principal source of value, with an emphasis on the long-term maintenance or sustainability of natural and environmental systems. Due to the short-term focus of market decisions and a lack of information on the consequences of increasing entropy in ecological systems, the exchange value or price of a product does not necessarily capture that value, and some provision is necessary to account for that economic rent not included in the market price. These economists argue that the economic surplus derived from natural and environmental resources does have an impact on society because it supports life-support systems and cannot be substituted for other forms of capital. Ecological economists view environmental degradation as a natural entropic law, based on the laws of thermodynamics (see Chapter 2), and aggravated by some irresponsible actions of human beings. It cannot be treated as an incidental externality. Over and above the traditional classical claims of capital, labour and government to a change in welfare, the natural environment should be taken into account as well. The decision not to let the environment share in the distribution of the economic surplus is short-sighted in the sense that it might become critical in supply, threatening the longer-term *sustainability* of ecological and economic systems.

In evolutionary approaches, value is not rooted in an unchanging principle, but is subject to the reality of change itself. Although not representative of all evolutionary economic approaches, institutional economists emphasise the classical dichotomy between price and value in what has become known as the *social value theory*. The conceptual components of the so-called instrumental principles of social value are generally accepted by modern institutionalists, namely the importance of the continuity and sustainability of human life, the recreation and importance of community and social life, a pursuit of non-invidious change or non-discrimination, and the instrumental use of knowledge. These instrumental principles illustrate that life is a dynamic process and that economic activity is flexible and in continuous interaction with society. Economic performance is judged against these instrumental principles, sometimes called the search for higher efficiency. The bottom line is a continuous societal review of market allocations with regard to the *instrumental principles of social value.*

In summary, although it is conceptually straightforward to include the value of natural and environmental resources in economic analysis, it needs to be highlighted that various different philosophies exist on how this should actually be done. In many cases there are fundamentally different positions on what constitutes value and what does not. It is our view that a careful exposition of the monetary value of the environment is a very important step forward, but that these results should be generated and interpreted within the context of the specific problem. This is the focus of the next section.

3.5) Economics of the environment in developing countries: Valuation in context

The added value of an application of environmental economic tools is that it provides a framework for including the trade-offs between environmental and developmental values in one, integrative process. Such an approach, however, cannot uncritically be copied from developed countries. In the case of developing countries, the poverty, inequality and environmental degradation nexus is an essential theme of analysis. An economic analysis, including an economic analysis of the environment, therefore cannot be lifted out of its environmental, institutional, social and political context, especially when one deals with the human dilemmas of hunger, poverty and ill health[28] and where there are distinct impacts on ecosystems.[29] In the South African 'double-decker' economy, both 'developing country' and 'developed country' characteristics can be found. This will have important implications for how the environment is valued and how it is included in socio-economic analysis.

The *context* for applying environmental economic tools can be defined by including the values of different actors, the complexity and uncertainty of different ecosystems and the political choices that have or have not been made.

The context can firstly be defined by including different actors and their respective values. In the context of developing countries it can be expected that more *polarisation* exists between rich and poor, and between the perceptions of environmental and developmental benefits than in developed countries. In the context of monetary valuation of the environment, the issue of intra- and inter-generational equity can be interpreted as the question: Whose values count? Different current and future groups will be affected positively, negatively or not at all by a change in environmental quality. An economic valuation of the environment will be made easier with fewer interest groups. Environmental practitioners will find that they seldom have the time or expertise available to deal with very complex valuation frameworks. The general guideline is to select those interest groups that would be affected in a major way by the proposed change in environmental quality, adding other groups as time and resources permit.[30] Different people have different value perceptions about a particular resource. Despite these differences, it is the perceptions of the *de facto* decision maker that drive decisions. No matter how many value perceptions there are, what fundamentally matters in practical assessments are the value perceptions of those who will ultimately determine what will happen to environmental quality.[31]

Secondly, inclusion of different levels of complexity and uncertainty on affected ecosystems will further describe the context. This is not an entirely developing country issue, but one deserving more interest in developing countries as most of the world's relatively pristine ecosystems are found in developing countries. If a change in this resource is irreversible the long-term sustainability of the ecosystem might be threatened. A traditional monetary valuation of the trade-off between changing environmental quality and other societal objectives is in this case inappropriate. Decision makers should make a judgement on the relative importance of competing value systems and the relative importance of the sustainability of the resource. Economic values for the environment could be included in the decision-making process, but in conjunction with other considerations such as potential irreversibility.[32]

Finally, the need to include parameters on political systems and decision-making enhances the contextual understanding. In situations of a high probability for ecological irreversibility or highly polarised value perceptions by different interest groups, it is possible that a political limit on the trade-offs between a change in environmental quality and other societal objectives is set. This can either be done through the allocation of relative weights to environmental quality and other societal objectives or through an absolute political decision (for example, standards on maximum change in environmental quality). The nature of policy constraints does have an influence on the type of monetary values that need to be generated, derived and used. Policy decisions impose limitations and provide opportunities for remaining choices that can be made. When decisions on environmental quality and other societal objectives have been made already there is no need to conduct comprehensive monetary valuation of the change in environmental quality. The rationale would be to reach the policy decision as cost-effectively as possible. When policy decisions are only proposed and changes are reversible, choices are not limited in the strictest sense. The economic valuation of a change in environmental quality should focus on testing the value of a change in environmental quality as perceived by the proposed policy decision. In the case where policy makers recognise that a certain resource has various legitimate claims, the different value perceptions should be taken into account in the decision-making process. The policy context influences the type of valuation information that is required and appropriate. Table 3.2 provides an overview of the applicability of monetary valuation in different policy context scenarios.

Table 3.2: The influence of policy context on monetary valuation

Policy context	Implications for economic valuation of a change in environmental quality
Political decisions already made	No need for monetary benefit estimation. Need to achieve political standard as cost-efficiently as possible

Table continued on next page >>

Policy context	Implications for economic valuation of a change in environmental quality
Political decisions are proposed and a change is reversible	Valuation should focus on testing the value of a change in environmental quality against the political benchmark
Policy recognises legitimate claims by various user groups	Valuation should take values of different user groups in account
Policy recognises irreversibility of decisions	Monetary valuation focus on achieving a policy-set safe-minimum standard as efficiently as possible

Source: CSIR. 2001. Guidelines for the Use of Environmental Economic Tools in Environmental Assessments – 2001. CSIR report ENV-P-I 2001-037, adapted from Gregersen, H.M., Arnold, J.E.M., Lundgren, A.L. and Contreras-Hermosilla, A. 1995. Valuing Forests: Context, Issues and Guidelines. Food and Agricultural Organisation of the United Nations (FAO) Forestry Paper no. 127. Rome: FAO.

3.6) Economics, the environment and development policy

As has been established in the preceding chapters, South Africa, like so many other middle income developing countries, is constrained simultaneously by economic, social and environmental problems. The mainstream economic solution that is offered is to outgrow these problems, but, as indicated, this solution is fundamentally flawed since the ideology of growth does not recognise social, ethical and ecological limits. There are, however, various other theoretical approaches and models, as has been discussed in this chapter, and these insights need to be translated into a country-specific economic policy on natural and environmental resources.

According to Clause 33 of the South African Constitution, every citizen has the right to an administrative action that is lawful, reasonable and procedurally fair.[33] Additionally, all citizens' rights to an environment which is clean, healthy and not harmful to their health or well-being, and to have the environment protected, for the benefit of present and future generations, are protected by Clause 24.[34] Constitutionally, the government is therefore responsible for environmental policy that, amongst others:

- Internalises all externalities as far as possible, i.e. the values (both positive and negative) of those coincidental side-effects due to a development, for example, the social cost of resettlement and the option or bequest value of a pristine ecosystem lost.
- Provides incentives to foster and enhance desirable economic transactions that are environmentally benign.
- Amends for the deficiencies of the GDP as a measure of welfare in an effort to determine the true value of a project.
- Considers the opportunity cost, the cost of the best forgone opportunity, by investing in the specific project, i.e. the impact and value of a water-efficiency project or the value of investment in a housing scheme of similar proportions.
- Determines how inter- and intra-generational equity can best be served through a system of compensation or otherwise, should the need arise.

Other reasons contributing to the pressure on the environment in the South African context by human activities are mainly the following:

- In many cases the natural environment is not protected adequately by a system of property rights, leading to the classical problem of the commons, free-riders and rent-seeking behaviour by those who have the institutional right to exploit the resource.
- Currently the tax system allows input cost to be subtracted for tax purposes, providing an incentive to use more (cheap) resources than required, thus stimulating wastages to occur.
- By taxing profit, the system penalises performance (or output) rather than the lack of efficiency.
- Many resources are made available inclusive of subsidies, for example, energy, water and waste removal, thereby stimulating the use and abuse of the resources.
- Taxes and subsidies with unsustainable outcomes have a strong impact on resource prices that, in turn, has a strong signalling effect commending the use of these resources.
- A strongly entrenched paradigm, supported by various vested interests, exists, namely that development and poverty alleviation should occur first only after which one could be concerned about the environment. The paradigm clearly neglects the potential of integrating development, poverty relief and environmental objectives in the initial design of a policy, plan or project.

Given these issues, the challenge to policy makers is to choose an appropriate mix of the following response options:

- price-based (economic), quantity-based (command and control) and/or less intervening (self-regulation, educational or free market) solutions; and/or
- *ex ante* or *ex post* policy instruments.

This not a once-off choice, but entrenched in a process of policy design. In the next few paragraphs the various instruments and their relationship with different approaches to economy-environment interactions are highlighted, while the process of public policy-making receives further attention in Chapter 17.

In Table 3.3, an attempt is made to categorise environmental policy instruments. Several other sources refer to lists of economic and non-economic policy instruments for environmental management, but this one is the most inclusive.[35]

Table 3.3: Environmental policy instruments

Policy instrument	**Examples of environmental policy**
1. Command-and-control	Technology-based standards (best available technology); Performance-based standards; Land-use controls (zoning); Process-based standards; Permits and licences; Environmental covenants (if enforced through permit system)
2. Self-regulation	Organised group regulates behaviour of members, for example Responsible Care, Sustainable Forest Management Certification System
3. Voluntarism	Unilateral action without any basis in coercion, non-mandatory action
4. Education and information instruments	
4.1 Education and training	Environmental information through government sponsored education and training. Real examples are the training and certification of private contractors who service CFC holding refrigerators and toll-free help-lines for industry on environmental performance

Table continued on next page >>

Policy instrument	Examples of environmental policy
4.2 Corporate environmental reports	Environmental accounting and reporting, e.g., eco-balance sheets and full-cost accounting
4.3 Community right to know and pollution inventories	Legislation intended to inform community on environmental impact of a firm's activities and pollution abatement policies, e.g., Emergency Planning and Community Right To Know Act (EPCRA) in the USA
4.4 Product certification	Eco-labelling schemes
4.5 Award schemes	Publicity on environmental compliance, for example the European Better Environment Awards for Industry
5. Economic instruments	
5.1 Property rights	Provide right system of property rights
5.2 Market creation	Creating property rights in the form of tradable permit certificates, hybrid between free market environmentalism and direct regulation. Examples are tradable water rights, acid rain permit trading programme (SO_2 permits) and fishing quotas
5.3 Fiscal instruments and charge systems	Encourage environmentally responsible behaviour through full (or partial) cost pricing of consumption and production. Examples of fiscal instruments are energy and carbon taxes, emission charges, effluent charges on water pollution, phosphates, the collection and treatment of waste, hazardous substances such as lubricant oils, fertilisers, pesticides and batteries, and financial subsidies such as tax credits schemes upon desired environmental conduct
5.4 Financial instruments	Mobilise additional financial resources for conservation and environmental protection, including measures such as revolving funds, green funds, subsidised interest rates and soft loans
5.5 Liability instruments	Civil liability on those who despoil the environment can provide an economic

Table continued on next page >>

Policy instrument	Examples of environmental policy
	incentive for environmental management. In negligence-based rules a liability is imposed on failure to meet a predetermined standard. In strict liability rules liability is imposed regardless to the level of care
5.6 Performance bonds	A security deposit is posted which is redeemable upon satisfactory completion of a given task. Examples are performance bonds to mining company for the rehabilitation of land
5.7 Deposit refund systems	Provide individuals and/or firms with a financial incentive to dispose of waste in an environmentally preferable way, e.g., by refunds on beverage containers
5.8 Removing perverse incentives	Removal of subsidies on environmental bads, such as production of coal-fired electricity. Other examples are administered resource prices, output pricing, irrigation subsidies, below-cost timber pricing, subsidised crop insurance, agricultural support programmes
6. Free market environmentalism	Free markets instead of legislative solutions – environmental outcomes are determined by the accumulation of bargains struck between individual owners of natural-resources property rights

Source: Adapted from Gunningham, N. and Grabosky, P. 1998. Smart Regulation. Designing Environmental Policy. Oxford: Claredon.

Following on this table and to clarify definitions, most of the economic instruments are also price-based solutions (for example, environmental taxes), with the exception of property rights allocation, market creation and negligence-based liability rules. Quantity-based instruments are all command-and-control instruments (for instance, performance standards or technology standards), while tradable permits is a hybrid between price- and quantity-based instruments.

In the economic theory of optimal Pigouvian taxation, it is argued that environmental externalities will have to be internalised with the right level of taxation.[36] Environmental economists have been more inclined towards such price-based solutions, while ecological economists accept quantity-based solutions more readily. Ecological economists, with the emphasis on environmental degradation as a natural entropic law, often argue for safe-minimum standards (especially when long-term ecological damage is anticipated[37]) which in turn should be reached at least cost. A marketable permit system is a possible hybrid between the two schools of thought, as standards within which the market can operate are pre-defined.[38] Neo-institutional economists would argue that the choice between price and quantity based approaches is not that relevant in the first instance, as the ultimate choice would depend on the costs of establishing and sustaining any policy framework. In addition to these schools of thought, free market economists argue that the focus should not be on government intervention, but if private property rights can be extended, the problem will be solved. The Austrian school of thought, for instance, argues:[39]

> The problem of 'external costs' ... is a consequence of failure to enforce fully the rights of property ... Hence external costs (e.g., smoke damage) are failures to maintain a fully free market, rather than defects of the market.

However, the mere extension of property rights might solve the problem to some extent when markets can be clearly defined and demarcated. In most cases in developing countries where markets are not always well defined, especially in the case of common property, the problem becomes more complicated.

A second meta-choice of policy makers, so to speak, is one between *ex ante* and *ex post* policy instruments. *Ex post* instruments become operative at the time that damages from that activity occur, in contrast to *ex ante* instruments which are operative at the time that a polluting activity occurs.[40] Referring to Table 3.3, liability instruments recover damages *ex post* while most other economic instruments are *ex ante* instruments. When both *ex ante* and *ex post* intervention is possible a decision has to be made on the relative attention to each possibility. Barrett and Segerson[41] examine this choice, of what they call prevention (*ex ante*) and treatment (*ex post*), in the context of real objectives of policy makers, such as a budget constraint, the minimisation of costs or the maintenance of a certain safety level. In the case of an increase in the likelihood of damages occurring, the optimal level of treatment increases under this damage constraint.[42] When the effectiveness of treatment is uncertain, and given a limited budget, the optimal level of prevention could be increased and the optimal level of treatment decreased. The joint use of *ex ante* and *ex post* policy instruments would enhance economic efficiency under a few specific conditions, namely:[43]

- If there is great uncertainty in the determination of the legal standard. *Ex ante* policy instruments can only be used without any combination with *ex post* instruments if the probability of a successful suit against the injurer (polluter) is zero. This raises the question what rules are in place and what rules are expected to be in place. To answer this question requires a positive analysis on the political process itself.
- If there is uncertainty about the marginal damages of environmental degradation and *ex post* rules cannot be defined according to reality.
- If the injurer's marginal cost of precaution is large at the social optimum. *Ex post* instruments that do not adequately take account of the relative welfare losses of a particular societal group namely the polluters, need *ex ante* policy instruments for helping to achieve a solution.

The policy makers' choice between these options is again largely dependent on a country's economic development context. Neither traditional command-and-control instruments, nor the free market on its own provide answers to increasingly complex environmental problems. The challenge is to regulate smartly, to develop an optimal policy mix – *a convenient short-hand to signify our aspiration to design the best possible environmental policy ... using a broader combination of instruments and actors.*[44] Not only the policy instrument in itself, but also the process of policy design needs to be made explicit – asking the right questions at the right time and ensuring that the resulting information is used optimally. This chapter served to highlight the options available to the policy maker, options that will have to be informed by an acceptable valuation of environmental quality (the subject of the next chapter and case studies in Part B) and that will have to find meaning in the process of public policy-making on natural and environmental resources (the subject of Chapter 17).

3.7 Conclusion

It was argued in this chapter that the natural environment, despite playing an important role in economic development, is often not accounted for properly. Most economists working on environmental problems will agree that the valuation of these external environmental costs is important to rectify this situation. However, fundamental differences do exist on the basic questions: What constitutes value? And, to what extent are natural and other assets or capital substitutable?

An integrated approach to economic development, poverty alleviation and environmental management is best served by taking the developing country context into account. This means that prior to analysing the value of environmental assets and the flow of environmental goods and services, the right questions are asked of the actors involved and their level of polarisation, the perceived complexity and uncertainty of impacts and on affected ecosystems, and the political decision-making context are established. When such an assessment has been carried out and valuation studies performed, policy makers will have to weigh the options on the best policy mix so as to internalise environmental impacts within a just economic development framework.

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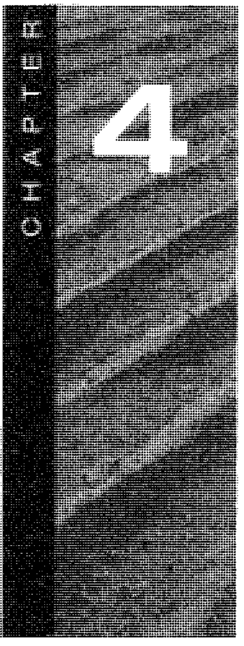


Economic valuation

James Blignaut and Anthony Lumby

4.1 Introduction

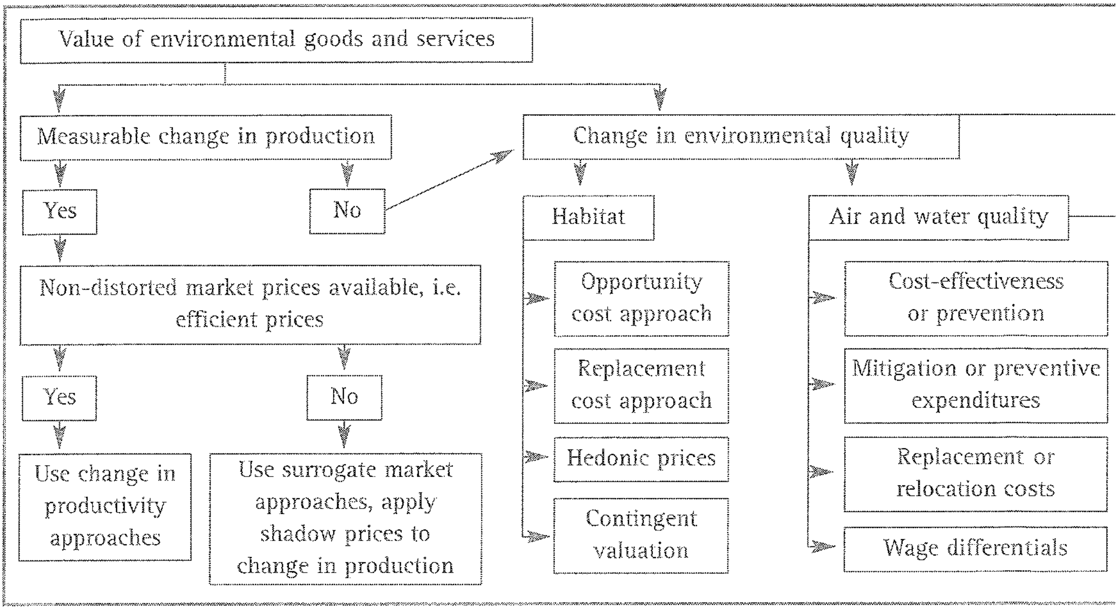
As has been indicated in Chapter 3, one of the main reasons for the non-optimal allocation of natural resources – which leads to environmental degradation and depletion – is that of market failure. Market failure occurs, among others, when the price of a product does not reveal the true cost of producing a specific good or service, in this case excluding the cost of degradation and depletion. This might result from the non-existence of formal markets for pollution or natural resources. As a solution, it has been proposed that these side-effects of the economic production process should be quantified and included in the analysis in what is called the internalisation of externalities. Internalising all externalities, both positive and negative, would imply the determination of total economic value. (For an outline of the structure see Chapter 3, Figure 3.2). Various valuation techniques or methods are available to enable the calculation of total economic value. A selection of these is discussed below.

4.2) Taxonomy of valuation methods

In Figure 4.1 a classification of the more commonly used valuation methods relative to the specific environmental impact to be quantified is set out. It is important to note that it is possible to distinguish between these valuation techniques on the basis of their use of market or shadow prices, of direct or indirect proxies, or of any proxy whatsoever. These categories are:[1]

- changes in productivity when efficient market prices are available;
- when non-efficient market prices are available, shadow price techniques could be used within surrogate markets;
- when market prices are not available, but direct proxies are, one could use various techniques, such as replacement cost, cost of illness, loss of earnings, treatment cost, substitute prices, shadow projects, opportunity cost methods, productivity losses, human capital cost, mitigation cost, aid cost, cost-effectiveness approaches, relocation cost and benefit transfer techniques;
- when indirect proxies are available, one could use the travel cost method, hedonic prices and wage differentials (these techniques are also called the revealed preference methods); and
- when no proxy is available, one could use contingent valuation methods or conjoint analysis (these techniques are also called the stated preference techniques).

Although the scheme depicted in Figure 4.1 provides a logical and clear flow and indication as to the proper valuation method to apply under particular circumstances, only in exceptional cases will a natural resource or environmental impact on such a resource be adequately valued by using a single technique. Usually a combination of valuation exercises is required to quantify the true value of such a resource or the environmental consequences of a development activity. In such cases care should be taken that no double counting or misrepresentation occurs. Another important issue for consideration is that of the scope of the intended valuation. Does one consider the impact of the project or impact subject to valuation as a lone-standing event or effect, or in the context of a life-cycle assessment, taking all impacts into consideration? The issue at stake is: Where and why does one draw the line when quantifying an environmental concern? In



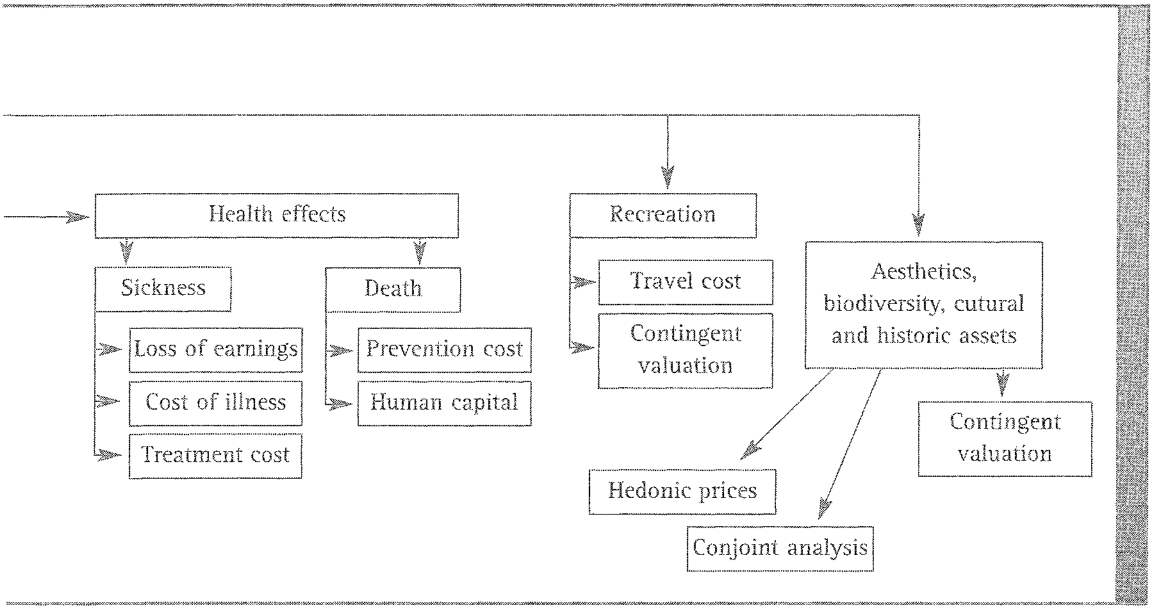
answering this question the analyst will have to be guided by the purpose of the valuation and the question whether inclusion or exclusion of an impact would alter the outcome of the study.

4.3) Valuation methods

4.3.1 Productivity changes

The change-in-productivity approach is applied when the project has an identifiable externality and a known relationship exists between the scale and activity of the project and the environmental impact.[2] For example, the positive effect of reducing siltation in a river system is a direct benefit of soil conservation. This 'off-site' impact of, for example, a soil conservation project, should be included in the analysis of the project as a benefit. To apply the change-in-productivity technique, various steps should be followed.[3] They are:

- *Collect the data*: The first step is to formalise the observed cause-and-effect relationship with supporting data. This relationship can be either direct or indirect. For example, a direct relationship may be the effect of soil conservation on crop yields, whereas an indirect relationship may be the effect of soil conservation on run-off, which in turn, has an effect on downstream water quality.



Source: Adapted from Dixon, J.A., Scura, L.F., Carpenter, R.A. and Sherman, P.B. 1994. Economic Analysis of Environmental Impacts. London: Earthscan.

Figure 4.1: Taxonomy of various environmental valuation techniques

- *Establish the dose-response relationship*: Once data for the cause-and-effect relationship has been collected, it can be used to establish a relationship between the two variables. This relationship can then be used to predict the level of output corresponding to a level of impact. The analyst will probably have to make simplifying assumptions to facilitate this procedure. A typical outcome of this step would be an equation stating that a certain change in soil loss leads to a specific change in crop yield.
- *Calculate expected productivity*: Once the relationship has been established, the change in productivity associated with a level of impact can be calculated. In project analysis, this corresponds to the difference in impact with and without the project. This impact is calculated by multiplying the volume of expected change in soil loss by the abovementioned dose-response function.
- *Integrate results into the cash flow analysis*: The expected change in productivity calculated above can then be included in a cash flow table once it has been assigned a monetary value based on the non-distorted efficient market price that is observed for the specific crop. When efficient market prices are not available, use shadow prices (see below).

The change in productivity technique could also be used for goods and services that are not traded in markets (see an application in Chapter 6), but that would imply a calculated price using another valuation technique (see below). It should be noted, however, that the change in productivity approach is not without its problems.[4] The most serious one is related to identifying the appropriate dose-response relationships to be included in the analysis. A problem frequently encountered is that of the information available being inadequate to include all indirect impacts in the analysis. The use of a sensitivity analysis could mitigate this concern. This could be done by testing a range of assumptions pertaining to the parameters used in the dose-response function to produce different outcomes, such as high, medium and low estimates.

4.3.2 Shadow prices

When the observed prices are not equal to the efficient market price, one should apply the productivity change technique discussed above, but utilising shadow prices rather than the observed prices. Shadow prices represent true economic scarcities more correctly than observed or estimated market prices do.[5] The difference between the observed and the shadow price is the result of market failure, such as monopoly power, information asymmetry, high levels of unemployment and exchange controls, or government intervention, such as subsidies and indirect taxes. Shadow prices therefore reflect the true, undistorted price of a specific good or services (see also the related discussion in Chapter 8). When these prices are used in the context of a project or product they should reflect the actual opportunity cost of such a project or product. Such an opportunity cost could either be higher or lower than the observed price.

The use of shadow prices allows for a clear distinction between economic and financial analysis. The former is concerned with opportunity cost whereas the latter is more concerned with cash flow and profitability issues. Generally speaking, therefore, a financial analysis tends to be associated with private or individual costs whereas an economic analysis tends to include broader issues as well.

4.3.3 Direct valuation techniques

- *Opportunity cost approach.* Opportunity cost may be defined as the best alternative sacrificed. The opportunity cost of spending R100 on leisure is, for example, buying fuel for the motor car with that R100. Fuel has been sacrificed in return for pleasure. Since economics is the subject of studying choices between various alternatives and the relevant trade-offs that arise, this concept is fundamental to economics. The term opportunity cost as used in the *opportunity cost valuation approach* has, however, a much narrower meaning. Here it refers specifically to the value of lost opportunities due to environmental protection. It is therefore a measure of the opportunity cost of environmental protection.[6]

  An example would be the conservation of land for the express purpose of putting it into service as parks and reserves used mainly for wildlife-based tourism and biodiversity conservation. The main alternative uses, which are then by definition disallowed in these protected areas, are, among others, agriculture and livestock production. The opportunity cost of the environmental protection afforded by leaving the land undeveloped in parks, reserves and protected forests, therefore, can be estimated by the forgone net returns to agriculture and livestock production. One could use this method to calculate the loss to livelihood if the land had belonged to rural communities who were dependent on the land for subsistence agriculture. Alternative forms of compensation would therefore have to be sought, quantified and implemented, with community participation.
- *Cost-effectiveness analysis.* In a typical cost-effectiveness analysis the most cost-effective solution should be selected to achieve an externally set prescribed environmental objective, such as water or air quality standards.[7] This approach does not, however, tell us whether the benefits realised justify the costs incurred.
- *Replacement cost approach.* The replacement cost approach is often used as an estimate of the cost of pollution. This approach focuses on potential damage costs as measured by *ex ante* accounting estimates of the costs of replacement or restoration if damage from pollution were to occur. For example, the costs of air pollution-related acid deposition in urban areas can

be approximated by the restoration and replacement costs from damaged infrastructure.[8] The major underlying assumptions of this approach are that:

- the nature and extent of physical damage expected is predictable (an accurate damage function is available); and
- the costs to replace or restore damaged assets can be estimated with a reasonable degree of accuracy.

These costs can be used as a valid proxy for the cost of environmental damage; that is, the replacement costs are assumed not to exceed the economic value of the asset. For example, the replacement cost technique can be used to estimate the costs of pollution of potable water supplies. An all too common occurrence in many countries is the pollution of water resources by agro-chemicals, resulting in drinking water of below acceptable health standards. Quantification of the aggregate health impacts, or estimation of a damage function for this type of water pollution, is often difficult because of the complex relationship between ambient quality, exposure and illness. However, it is often possible to estimate an order of magnitude of the cost of providing alternative safe water supplies. The incremental investment cost of alternative water supply can usually be derived from proposed water supply investment projects containing data on total investment cost and the quantity of incremental water supply. An estimate of the annual cost of pollution of potable water can be made by using the replacement cost technique.[9]

- *Relocation cost.* Similar to the replacement cost approach, the relocation cost approach makes use of estimated costs of a forced relocation of a natural or physical asset due to environmental damage. The government or a water board, for example, could have established a water treatment plant in an area that became increasingly industrialised over time. The situation could have deteriorated to the extent that the supply of safe potable water could be at risk. The option is either to relocate the plant upstream, away from the polluting industries, to an area of unpolluted water supplies, or to enforce effluent reductions. The cost of relocation could then be considered the direct cost of the current condition.[10] However, this does not address the problem of effluent generation in principle and might only postpone an obligatory bigger problem.

- *Mitigation or preventive expenditure.* Rather than using an objective measure of damage, i.e. the cost to replace or relocate a damaged asset, this method focuses on perceptions of potential damage and the measures people actually take to protect themselves and their property from such damage. The expenditures people make in an attempt to avert damage from an offending activity are used as subjective values of the minimum costs of environmental damage caused. While using incurred costs, one could use it to determine the possible future impact of an activity; hence the method becomes much more forward-looking. Actual expenditures made in these cases (preventive or mitigatory), are thought to represent a subjective valuation of the cost of potential damage.[11] Two assumptions underlie the preventive expenditures method:
    - It is assumed that the full cost of environmental damage is reflected in the mitigation expenditure. This assumption is sometimes violated because of a misperception of the damage risks, resulting in either inadequate or excessive expenditures. Even when damage risks are correctly perceived, at times only a portion of the damage can be prevented through pre-emptive measures or corrected through mitigatory measures.
    - It is assumed that there are no additional benefits associated with the expenditure. However, in some cases expenditures may not have been made exclusively or even primarily to avert damage costs. For example, while people's expenditures for air-conditioning systems may be partially related to the value they place on filtering air of poor quality, thereby reducing related health effects, they receive the primary benefit of cooling.
- *Cost-of-illness, treatment cost and loss-of-earnings approaches.* The cost-of-illness approach is used to quantify the impact of a change in environmental quality on human livelihood, as measured by changes in the frequency and severity of illness. This method is best to apply when several conditions are met,[12] namely:
    - When the illness is of short duration and discrete: The technique is best used when a direct cause-and-effect relationship can be established and the aetiology of the disease is clearly identifiable. This technique is also facilitated if the illness is relatively short, discrete, and does not have negative long-term impacts. Other important considerations are that the

illness is not life threatening and has no chronic effects, and that an accurate estimate of the economic value of earnings and medical treatment is available. These health effects can then be readily measured by using available hospital admission data, or survey data, where respondents recall health ailments over a specified period.

- Information on the cost of treatment is available: Ideally, this approach should be based on estimates of the willingness to pay for reducing health risks, however, this information is rarely available. Therefore, cost estimates are based on wages forgone due to illness, and expenses related to medical treatment, including doctors' fees, medicines and hospital stays.

To estimate the economic value associated with changes in air pollution, four factors must be determined:[13]

- *Estimate the dose-response relationship*: The first step is to develop estimates of the effect of different pollution levels on various health outcomes. These health outcomes are usually presented as the number of cases of illness in a population, such as 1 in 1 000 individuals, or 1 in 100 000 individuals. Dose-response functions that relate health impacts to ambient levels of air pollution have to be established. This can be done by gathering data on pollution from monitoring stations and data on health effects from hospitals, or by consulting the relevant literature. Through regression analysis, these data can be used to establish a dose-response relationship that will allow the analyst to predict changes in health outcomes from changes in air pollution levels.
- *Estimate the expected level of air pollution*: Once the dose-response relationship has been established, this information can be used to provide an estimate of the change in the prevalence of a given health effect associated with a change in an ambient pollution level. The change in ambient pollution is equal to the difference between current ambient levels and expected ambient levels after implementation of a project or policy to control pollution. Once this difference in pollution levels is established, the dose-response relationship is used to estimate the resulting change in the incidence of different illnesses.

- *Identify the exposed population and estimate health outcomes*: The third step involves identifying the population that will be affected by any change in ambient pollution levels. Once this is known, one can calculate the expected change in illness (measured as some health outcome per some population number, for example, asthma attacks per 10 000 people) based on the total population exposed to the pollutant under consideration. Multiplication of the change in pollution (the dose) by the exposed population provides an estimate of the response of the population to the level of pollution.
- *Estimate the economic value of health endpoints*: To complete the estimation of health effects, the analyst must estimate the economic value of the health outcomes. Often some form of damage function is used that simply converts the health impacts on the affected population to monetary values by multiplying the number of individuals by the loss of earnings resulting from illness, medical costs such as for doctors, hospital visits or stays, medication, and any other related out-of-pocket expenses.

It should be noted that problems could arise in connection with the cost-of-illness approach. The two most serious problems are:

- *Individuals who do not earn a wage*: One problem with the cost-of-illness technique is the treatment of individuals that do not earn a wage, like unemployed labourers or subsistence farmers. This problem can be circumvented by developing a 'shadow price' for their earnings. A common way of doing this is by estimating the opportunity cost of their labour or using an average wage rate. One concern with this approach, though, is that the willingness to pay for reduced health risk is expressed in terms of income, as has been discussed above. This raises ethical concerns, more so where large income differences occur. One way to address this is to scale the value of a person's willingness to pay relative to his or her income to the GDP per capita ratio.
- *Different air pollutants cause different health effects*: Another problem is that exposure to different air pollutants causes different health effects. This means that dose-response relationships differ between pollutants and that analyses have to be made for each pollutant. Moreover, the combined

effects of two pollutants or more are usually greater than the sum of their individual contributions. The synergistic effect is complicated and not well understood, mainly because so many factors of the atmosphere's chemistry are involved.

- *Human capital cost.* The human capital approach is an extension of the cost-of-illness approach since it estimates the value of the increased risk of chronic illness and mortality to an individual. Conventionally, the discounted present value of that individual's earnings over the remainder of his or her expected life is used as the basis for valuation. A person's income becomes the proxy of his or her return on human capital, hence the name of the technique. As was discussed above, the use of income as a monetary proxy to value human life is ethically controversial, but not insurmountable. Since the value of life obtained with this method is based on the statistical estimation of a change in the probability of death due to an environmental change, the monetary value derived by using this technique is the value of a 'statistical life'.[14] It could also be expressed as the monetary opportunity cost (forgone income) due to the 'illness of death'. Similar to the cost-of-illness approach, a dose-response function would be required, but linked to the number of chronic illnesses and/or induced deaths due to the change in environmental quality and not only short-term illnesses. The steps to follow when using this technique are:
  - determine the pollution load from all sources;
  - determine the ambient concentration by using dispersion models or other forms of monitoring;
  - define the population at risk with specific reference to its demographic composition in terms of, for example, age, income and gender;
  - establish the dose-response relationship;
  - determine the link between morbidity and mortality and a decline in output and resultant treatment cost; and
  - calculate the value of the output lost due to morbidity and mortality effects linked to the pollution load, and add the relevant treatment cost.
- *Shadow projects.* The shadow-project technique is an application of the 'with' and 'without' project analysis. Under the 'with' scenario, the analysis includes all environmental externalities, both positive and negative, using information from other projects (see benefits transfers).[15] The 'without' scenario analyses the situation within the intended project.

- *Aid-cost.* Aid-cost provides a proxy for the preservation or restoration of an environmental attribute as reflected in the willingness to pay for the conservation of an area by a donor or NGO. These institutions could buy land, for example, to preserve its biodiversity. The purchase price could be considered the minimum value of preserving the biodiversity of that land.[16]
- *Substitute price.* This technique is applied by seeking the market price of a marketed environmental good or service that could act as substitute of a non-marketed good or service and applying the price of the substitute environmental good or service for the non-marketed one. One should take cognisance of the differences between the marketed and the non-marketed good or services as well as the technical rate of substitution that might be applicable between the two items.[17]
- *Benefits transfer.* The valuation techniques described thus far are dependent on the collection of primary or secondary data. An alternative to collecting data is to transfer existing estimates of benefits from an existing study elsewhere to the project site. This approach has been termed 'benefits transfer', because the estimates of economic benefits are 'transferred' from a site where a study has already been done to the current project site.[18] There are three advantages to benefits transfer:
  - values can be estimated more rapidly than by undertaking a new valuation study;
  - it is relatively cheap; and
  - it is one of the few approaches that can be used to estimate benefits from a new or previously unused environmental resource.

The benefits transfer method can normally be used for valuation estimates when the project site is closely similar to the location where the 'transferred benefit' was estimated, and when the impact of the project at the two sites is also similar (see the related discussion in Chapter 14). The various forms of benefit transfer are subsequently discussed.

- *Direct benefits transfer.* The simplest way of transferring benefits from one location to another is to assume that the change in environmental quality experienced at the existing study site is the same as that experienced at the project site. The transfer involves three steps: (a) the analyst must determine the environmental impacts that will occur at the project site; (b) the analyst must find previously completed studies that estimate the economic value of these impacts and then derive a mean unit value for them; and (c) the mean unit value is then used to value the appropriate impact at the project site.

- *Adjusted benefits transfer.* A more sophisticated approach to transferring benefits is to adjust the mean unit value for the study location before transferring it to the project location. The reason for doing this is that the unit value at the initial study site may be biased or inaccurate. In this case, the unit value may have to be adjusted or corrected before it can be transferred to the project site.

  This method of adjustment should address three potential differences between the study site and the project site: (a) differences in socio-economic characteristics between households in the study site and project site; (b) differences in the policy, project or regulation at the study site and the project site; and (c) differences in the availability of substitute goods and services at the project site and the study site. The number of units affected at the project site can then multiply the adjusted value.
- *Demand transfer.* The most sophisticated application of benefits transfer involves transferring of the entire demand function from the study site to the project site. This requires three steps: (a) finding an existing study where an appropriate demand relationship has been estimated; (b) determining the 'extent of the market' at the project site, that is, the geographic area over which households will benefit from the change in environmental quality; and (c) the analyst must substitute the values of the independent variable for the individuals at the project site into the equation of the willingness to pay at the initial study site, in order to calculate the benefits to individuals at the project site. Then the analyst must aggregate these estimates for all individuals affected to obtain the full estimate of benefits at the project site. It should be noted that the benefits transfer technique relies heavily on the existence of high quality studies that produce data that can be transferred to the project site.

4.3.4 Revealed preference techniques

Hedonic pricing method The theory of hedonic prices is based on an alternative consumer theory in which goods and services are defined by the attributes they embody, and the values of these goods and services are the sum of the values of these attributes. For example, two motor cars would be perfect substitutes for each other and would have the same market value if they both possessed exactly the same set of characteristics. Likewise, the fewer characteristics two motor cars have in common, the more 'imperfect' they are as substitutes for each other, and the less likely they are to have the same market value. The difference in the characteristics of the motor cars and consumers' preference for these characteristics explain the difference in the market value of motor cars.[20]

When goods or services contain an environmental characteristic, the same logic follows: the market value of the environmental characteristic is 'embedded' in the market price of the specific good or service. In this context, observed prices, for example, housing prices and the levels of various structural, physical and environmental attributes contained in each (such as house age, construction, number of rooms and location variables such as view, noise level, air quality and population density) provide a measure of the implicit values placed by consumers on each of the characteristics or attributes that make up the good or service, including the environmental attribute.

The hedonic pricing method focuses primarily on the property-value approach.[21] The property- or land-value approach relies on real estate prices as an implicit measure of the indirect effects of changes in environmental quality. The theory is that, all other things being equal, people tend to prefer homes in quiet, clean neighbourhoods to those in polluted, congested and noisy ones, and they are typically willing to pay a premium for a home meeting their preferences.

In these cases, market prices for housing reflect the aggregate value that people place on all housing attributes. Among the attributes that are relevant to housing values are the level of environmental quality and amenities in the vicinity of the house and the structural and physical characteristics of the house itself. The value of environmental quality implicit in the housing prices can be determined by controlling for the other relevant housing characteristics, such as house design, construction and size (which influence housing prices), and examining the change in property value attributable to various levels of environmental quality.

The general approach is that of regressing housing or land prices on a group of explanatory variables, such as house age, size, design, type of construction and a number of location variables, including one or more 'environmental variables', such as air quality, or proximity to an environmental amenity. The approach focuses on the statistical estimation of the relationship between environmental amenities and land or house prices.[22] The assumption is that individuals and households reveal their preference for environmental quality through their choice of and payment for, residential housing. For example, the hedonic property-value approach has been used to value the proximity to natural water bodies and water-related open space, coastal waterfront and proximity to wetlands (see Chapter 10 for a discussion).

It should be noted that the hedonic pricing method is based on the assumption that the housing and land market functions well, and that market prices are not distorted by market or policy failures. An important point to note in this regard is the crucial distinction between willingness and ability to pay; the latter may well affect the former. This is a serious weakness in the hedonic pricing method. The following steps[23] should be followed when conducing a hedonic price analysis:

- collect house price data and their associated physical and environmental features;
- collect socio-economic and demographic data of the applicable residential area;
- estimate a house price function, based on a variety of applicable characteristics;
- determine the implicit marginal value of the relevant environmental attribute by means of a first order derivative function;

- estimate the demand function for the environmental good; and
- calculate the consumer surplus.

- *Wage differentials.* An alternative form of the hedonic pricing method is to consider wage differential across different locations of employment and residence to determine the value preferences for environmental benefits. By this means it is assumed that there is a correlation between an accepted wage level and various environmental or risk characteristics. For this technique to be applied successfully, individuals should be able to choose between various levels of income and wealth. This is necessary because the outcome of the labour market process is not only a certain level of employment associated with a level of income, but also includes a set of job-related characteristics such as, age, skills level, education, and exposure to environmental or occupational risk. To conduct such a wage risk or wage differential study the following steps should be taken:[24]
  - estimate an income function with various job-related characteristics (working conditions, number of weeks/year and location), socio-economic characteristics (income, age, education and experience) and mortality or morbidity risk as independent variables;
  - collect the relevant data as specified above from various industries and locations;
  - using statistical techniques, such as multiple regression analysis, calculate the risk coefficient, i.e. the change in income relative to a change in risk; and
  - calculate the value of a change in the morbidity or mortality risk.

  Strong assumptions for this technique to work are:
  - efficient and optimal functioning labour markets;
  - people are free to choose where to work and are mobile to move from one option to another;
  - the specific risk that one wishes to measure can be isolated and its impact on income be determined; and
  - availability of good information based on the data collection process.
- *Travel cost method.* The travel cost method depends on information about the amount of money and time people spend in getting to a site, in order to establish a value for that site. Although the travel cost method can, in theory,

be used to value almost any non-market good or service, in practice, however, it is only used for the valuation of recreational sites such as parks and beaches. It can also be used to value changes in environmental quality at recreational sites, such as changes in water and air quality. The premise of the travel cost method is that users travel from various places to spend time at a site.[25] Although no fee, or only a nominal fee, may be charged for access to the site, there is a cost involved in travelling to and from the site. This cost, which is the amount of time and money spent in getting to and from a site, can be used to derive a demand function for the site. Once demand has been derived, it is possible to estimate the benefits associated with the site.

It should be stressed that the cost of travelling to a site is not directly used to value the site. The cost of travel is used to establish the relationship between the cost of travelling to the site and the number of visits to the site. This information is then used to derive a demand for the use of the amenities of the site, by assuming that visitors will respond to increases in admission costs in the same way as they do to increases in travel costs.[26] The four steps involved in a travel cost study are the following:

- *Identify travel cost zones.* The first step is to identify the site to be valued, to divide the surrounding area into zones and to and group visitors into these zones. Within each zone, individuals are assumed to have equal travel costs to and from the site. Different zones have different travel costs to the site. It is assumed that individuals in each zone have similar preferences.
- *Estimate travel cost and visitation rates for each zone.* Visitors to the site are sampled to determine: (a) zone of origin and other demographic and attitudinal information; (b) the number of site visits they make per year; and (c) travel costs. Travel costs should include the money spent in getting to and from the site on items such as fuel and tolls, and the opportunity cost of time spent in travelling to and from the site.
- *Derive aggregate demand for the site.* The observed total visitation under existing travel cost conditions represents one point on the aggregate demand curve for the site. By assuming that an admission fee has the same effect on visitation as an increase in travel cost, other points on the demand curve can be identified.

- *Calculate benefits.* Once the aggregate demand curve has been derived, it can be used to estimate the total willingness-to-pay for the site, which can be considered an estimate of the recreation benefits of preserving the site.

It should be noted, however, that there are problems associated with the travel cost method.[27] The two most likely ones are:

- The cost of visiting a site consists of direct transportation costs plus the costs of the time taken to get to the site. The latter issue must be handled with caution because time has an opportunity cost, but considerable dispute exists as to how to measure the opportunity cost of leisure time, although forfeited income could be used as proxy.
- The data requirements of this approach are substantial. A survey must be carried out to establish the number of visitors to a site, their place of origin, socio-economic characteristics, the duration of the journey and time spent at the site, direct travel expenses, values placed on time by the respondent, the total population in each zone, purpose of the visit other than visiting the site (multi-purpose visits raise problems for the technique), and a whole range of environmental quality attributes for the site and substitute sites.

4.3.5 Stated preference techniques

- *Contingent valuation method.* Contingent valuation is used to obtain values for non-market goods or services for which no direct or nearby proxy exists. It is the only practical means of estimating some types of benefits, such as existence and option value. It is a survey technique that attempts to elicit information about the preferences of individuals (or households) for a good or service by asking an individual how much he or she values a good or service. The technique is termed 'contingent', because the situation that the respondent is asked to value is hypothetical.[28] Contingent valuation should not be confused with market research or opinion polls. Contingent valuation typically focuses on individuals' preferences for non-market goods and services. Market surveys and opinion polls focus almost exclusively on marketed goods and services. The hypothetical situations that are described in contingent valuation surveys are often complex and much more difficult for people to understand than the questions in these other survey instruments.

A contingent valuation questionnaire generally has three parts, discussed below.[29]

- *Hypothetical description of terms.* The first part of the questionnaire presents sufficient information for the respondent to consider the value of the proposed good or service. Pictures or diagrams should be used to convey information on matters such as when the service will be available, how the respondent will be expected to pay for it (or be compensated for a possible loss in environmental value), and what institutions will be responsible for delivery of the service. Survey designers face a trade-off between providing respondents with sufficient information to make a reasoned decision and confusing respondents with too much information.
- *Willingness to pay or accept.* In the second part of the questionnaire the value placed by the respondent on a good or service is determined. Questions are set to ascertain how much an individual is willing to pay for the service or to accept in compensation for its loss. Generally, the analyst can elicit the respondent's value for these goods or services through one of three questions: a single Yes/No question, a series of Yes/No questions as to whether the respondent would want to purchase the good or service at a specified price or not (also known as a bidding game), or a direct question about the maximum price the respondent would be willing to pay for the good or service or their willingness to accept compensation for a possible loss (open-ended question). Bidding games and open-ended questions can also be combined. Finally, present the respondent with a list of values in the form of a payment card and ask for their selection from the list.
- *Characteristics of respondents.* The third part of the contingent valuation survey includes questions about the socio-economic and demographic characteristics of the respondent and his or her family, such as income and education. This information can be used to relate the answers given by respondents to the willing-to-pay questions to the other characteristics of the respondents.

The information obtained from a contingent valuation survey is analysed in three ways (discussed below), and the purpose of all three types of analysis is to determine whether respondents' answers are consistent with theory and common sense and to establish statistical relationships or models that can be used to aggregate responses to the overall population under survey.

- *Frequency distribution of contingent responses.* Respondents' answers to the willingness-to-pay (or to accept) questions yield a data set of individual willingness-to-pay (or receive) 'point estimates'. Answers to Yes/No questions (bidding games) place each respondent's willingness-to-pay (or receive) in an interval defined by the last value accepted and the last value rejected. This information can be used in two ways: (a) to predict the distribution of the willingness-to-pay (or to accept) responses in the total population; and (b) to predict the willingness-to-pay (or to accept) for the good or service at a specified price.
- *Cross-tabulations of willingness-to-pay or to accept responses with socio-economic characteristics.* Cross-tabulations can be used to determine whether different groups of people in the same sample gave different responses to the valuation question(s). This addresses the question of who is willing to pay (or to accept) the most (and the least) for the good or service, and why. Suppose, for example, that willingness-to-pay bids were grouped based on the value of respondents' houses (a proxy for income). The analyst would expect willingness-to-pay to increase with income. When cross-tabulation of willingness-to-pay bids and socio-economic or attitudinal information reveals the effects one would hypothesise based on demand theory and common sense, then the analyst has greater confidence in the quality of data and greater insights into the factors that may determine an individual's willingness-to-pay.
- *Multivariate analyses of the determinants of willingness-to-pay or to accept responses.* Multivariate analyses can provide better information and greater insight into the factors that affect willingness-to-pay responses than simple cross-tabulations. The general approach is to estimate a valuation function that relates the hypothesised determinants with the willingness-to-pay (or to accept) responses. The decision on what determinants of willingness to pay (or to accept) should be included in the valuation function is typically based on the consumer demand theory. The results of such analyses can indicate that the willingness-to-pay (or to

accept) estimates are systematically related to the variables suggested by economic theory.

Once the analysis has been done, one has to calculate the total willingness-to-pay or accept, which is the total economic benefit or cost of the project. The frequency distribution of willingness-to-pay (or to accept) bids can be used in project analysis in two ways, namely:

- *Total willingness-to-pay (or to accept).* This can be calculated by multiplying the frequency distribution of the sample by the total population to get the estimated population in each willingness-to-pay or to accept interval. Then, by assuming that the mid-point of each interval is the mean willingness-to-pay (or to accept), the population can be multiplied by this mean to estimate total willingness-to-pay (or to accept).
- *Estimating total revenue.* The frequency distribution of willingness-to-pay (or to accept) bids can also be used to provide a rough estimate of the revenue that might be expected from providing the good or service at a specified price. This is done by first predicting the total number of individuals that would be willing to pay (or to accept) for the good or service at a specified price and multiplying this by the price.

Given the nature of the technique underlying contingent valuation, it is not surprising that the possibility of errors and biases has to be addressed. Three categories of errors can arise, namely:

- *Individuals answer contingent valuation questions inaccurately.* Individuals may be tempted to understate, for example, their true willingness to pay for public goods in the hope of a 'free ride', while others pay for the provision of the good or service. Alternatively, if the price to be charged for the public good is not tied to an individual's willingness-to-pay response, but the provision of the public good is, the respondent may over-report willingness to pay, in order to ensure the provision of the good. In both cases, the bid would be systematically different from the respondent's 'true' willingness-to-pay. This difference is termed *strategic bias*. Systematic differences between respondents' answers to willingness-to-pay questions and their 'true' willingness-to-pay can arise for other reasons.

Respondents in a particular cultural context may feel it inappropriate to answer some kinds of questions in specific ways or may attempt to give answers that they think will please the enumerator. This *compliance bias* can result in substantial differences between reported and 'true' willingness-to-pay values. Another issue to be aware of is that bidding games that contain stipulated bids for respondents to choose from have the benefit of avoiding distortion from outliers, but suffer from *starting-point bias.*

- *Miscommunication (or information bias) between the enumerator and the respondent.* If a survey is not well designed, it may easily happen that the enumerator asks a question that he or she thinks is clear, but that the respondent interprets it differently from what was intended. In some cases, respondents may interpret the hypothetical offer of a specific good or service to be indicative of an offer for a broader set of similar goods and services. For example, if respondents were asked for their willingness-to-pay for improved water quality in a specific river, some might misinterpret this question to mean their willingness-to-pay for cleaning up *all rivers* in a region or country. In this case, their answer(s) to the question(s) would not reveal the value sought by the enumerator. This is referred to as the 'embedding problem', because the value of the good or service which the contingent valuation researcher is seeking is embedded in the value of the more encompassing set of goods or services reported by the respondent.
- *Testing for biases and errors in contingent valuation studies.* There are two ways of minimising the risk of some of the errors and biases described above: (a) minimising the occurrence of some types of errors and biases; and (b) even if the probability of the occurrence of certain types of errors and biases cannot be reduced, the cost of being misled by poor-quality estimates can be reduced by finding out whether a particular bias exists, or not.

Conjoint analysis

Conjoint analysis is a technique that may be used to determine individuals' preferences across various characteristics of a multi-attribute choice. The respondents are asked which of two alternatives they prefer, with both having a stated level and range of specific characteristics, one of which is price.

Respondents are then asked to rank the various characteristics and to make a final choice regarding the specific alternative. This implies that, for example, a respondent, confronted with two alternatives, must first compare the various characteristics, state his or her preferences of the various individual characteristics, and then, based on all the individual selections, make a final choice of the preferred alternative. Statistical techniques are then used to derive a relationship between characteristic and preference for a specific alternative. Since one of the characteristics is price, one can derive a preference function indicating the willingness-to-pay for changes in other characteristics. Once this is done, conjoint analysis resembles the hedonic pricing method where hypothetical prices substitute actual market prices.[30]

An application of this technique could be used to value forest quality, defining characteristics such as age of trees, diversity of organisms, soil productivity, water quality, etc. By means of conjoint analysis one could then determine the importance of and the preference for, each of these various characteristics. Furthermore, respondents could be asked to value alternative environmental policy scenarios. An example could be that of various waste removal options, with as characteristics water quality, land use and tax burden. One can then determine the respondents' willingness to be taxed for a certain waste removal alternative.

One major advantage of conjoint analysis above contingent valuation is that respondents are not asked to make direct trade-offs between money and environmental quality or to express environmental quality in terms of a hypothetical value. In the context of conjoint analysis, respondents are asked to state their preference between two different bundles of environmental characteristics but at varying tax burdens (or another form of cost). Statistically, the trade-offs between environmental quality and a hypothetical monetary value are made, but the respondent is not confronted with this value judgement during the interview. Intuitively, respondents should be more familiar with answering the conjoint analysis questions than contingent valuation-type questions, since few respondents would be able to value their willingness-to-pay for a specific environmental (non-marketed) quality.

Conjoint analysis is therefore much less subjective.[31] It remains an indirect method of deriving a monetary value for environmental quality and is as such always subject to a variety of external factors. Therefore, results should preferably be stated in terms of a range of values for each level or form of environmental good or services rather than single answers.

4.4) Conclusion

It would be appropriate to conclude with a word of caution. Although it is possible to value the impact of almost all forms of environmental degradation and depletion, one should never lose sight of the socio-economic and political context within which such a valuation exercise might be conducted. This context will have both an influence on the assumptions made and a meaningful bearing on the way in which the valuation results should be interpreted. The reason for this note of caution is simply because one is dealing with non-marketed values that have been translated into monetary terms to make comparison possible. The comparison will, however, always be bound by the relevant contextual setting. This implies that it would be meaningful, where possible and appropriate, to integrate the valuation process with a sensitivity analysis and to report the outcome of this analysis as being the final result. Practically, this would imply that for most cases the final summary table would contain a range within which the possible value lies, rather than a single point entry.

Furthermore, where possible and appropriate, one should not rely on the outcome of one valuation technique only. Application of a number of techniques to one research problem would be beneficial in determining the degree of convergence validity of the outcome, or the lack thereof. Such an approach will increase the credibility of the outcome.

Lastly, it could be advantageous to consider a number of case studies where certain techniques have been applied before embarking on a valuation exercise. To this end a number of valuable sources are available.[32]

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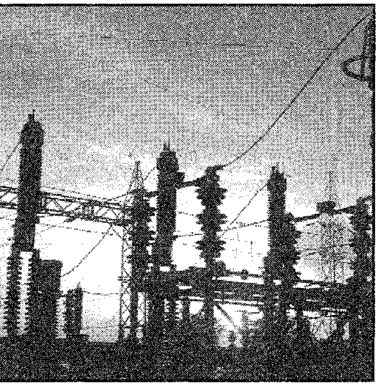
part b

interlude



As was indicated in Part A, South Africa is a typical middle-income developing country with a strong, developed industrial economy supported by sound fiscal and monetary policy. Side by side, however, one finds an economy characterised by significant socio-economic challenges. While this 'double-decker' economy operates in the context of increasing pressures on environmental systems and services, mainstream economic theory and economic indicators fail to show the magnitude and impact of socio-economic pressures on the environment. This can largely be ascribed to the fact that the accounting structure for economic development is too narrow, focusing mainly on stimulating economic growth as measured by a change in gross domestic product.

Viewed from a natural resource perspective, there are various theoretical approaches (and ensuing policies) to redress such environmental challenges, despite significant basic differences. One common understanding among these theoretical approaches is that the environment interacts with the economy by providing various ecological services and inputs (or sources), on the one hand, and by absorbing pollution and waste (or act as a sink), on the other. The internalisation of environmental impacts through appropriate policy instruments (as discussed in Chapter 3) into household and enterprise decisions could potentially lead to sustainable options. These flows are highlighted in Figure 1 by means of the solid arrows in the box.

The question posed at the beginning of the book, namely whether South Africa has options for sustainable interaction between the economy and the

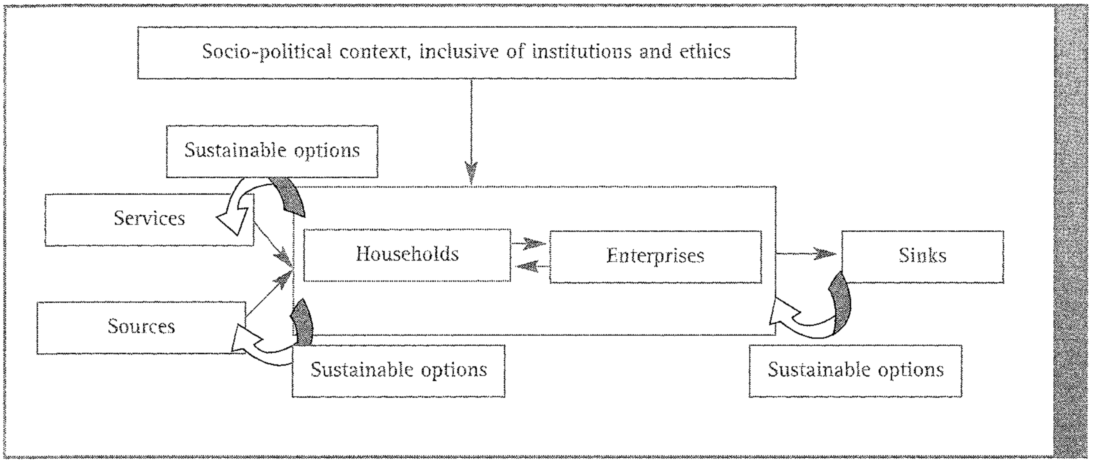


Figure 1: Framework for sustainable options

environment, refers to the adequacy of responses (indicated by the block arrows in Figure 1) to the overexploitation of environmental services, sources and sinks. This economy-environment interaction occurs within a specific socio-political context. Aspects regarding the socio-political context, such as the interaction between policy-making and science, the role of institutions, and ethics, are addressed in Part C. Part B will focus on case studies that reflect an improved understanding and internalisation of aforementioned economy-environment interactions based on the Coddington framework discussed in Part A. A framework to provide context to the various selected case studies is presented in Table 1, which also serves as an expanded classification system for ERE in general.

Following this classification, Part B introduces four case studies on the subject of services (ERE1), two about sources (ERE2) and four on the issue of sinks (ERE3). In each of these ten case studies, the various policies and the role of the applicable institutions will be highlighted (ERE4). Part B concludes with two chapters regarding tools and methods (ERE5). Classifying a case study in a certain category does not, however, imply that it does not have linkages with other aspects and categories as well. For example, all the case studies have policy and institutional linkages but the relevant processes involved might differ. A further note of clarification is that the service-source-sink framework provides an alternative

Table 1: Classification system for environmental and resource economics (ERE)

Category I	Code	Category II	Code	Category III	Code
Services (Life support systems)	ERE1	Regulation functions	ERE11	Soil formation	ERE111
				Nutrient cycling	ERE112
				Water regulation	ERE113
				Biological and disease vector control	ERE114
				Detoxification/waste treatment	ERE115
				Climate regulation	ERE116
				Atmospheric composition regulation	ERE117
				Flood, erosion and storm control	ERE118
				Pollination	ERE119
		Organisation and structural functions	ERE12	Biodiversity (genetic to landscape)	ERE121
				Landscape interconnection and structure/refugia	ERE122
				Reproduction habitat	ERE123
				Space – availability and pattern of use of land and water (including urban centres, transport, industry)	ERE124
Services (Human development support)		Information functions	ERE13	Aesthetic	ERE131
				Recreation	ERE132
				Cultural and artistic	ERE133
				Spiritual and historic	ERE134
				Science and education	ERE135
Sources (Supply of raw materials and energy)	ERE2	Non-renewable resources	ERE21	Mineral resources (coal, oil, natural gas, copper, tin, iron, silver, gold, etc.)	ERE211
				Non-renewable energy	ERE212
		Renewable resources	ERE22	Renewable energy	ERE221

Table continued on next page >>

Category I	Code	Category II	Code	Category III	Code
				Forests and woodlands	ERE222
				Fisheries	ERE223
				Livestock	ERE224
				Fauna	ERE225
				Flora	ERE226
				Freshwater (quantity)	ERE227
				Food and fibre	ERE228
				Biochemicals, medicines	ERE229
				Ornamental	ERE230
Sinks (Absorption of pollution and waste)	ERE3	Pollution and Waste	ERE31	Air	ERE311
				Water	ERE312
				Soil/Land	ERE313
				Radioactive substance	ERE314
				Toxics	ERE315
				Metals	ERE316
Policy and institutions	ERE4	Government	ERE41	National	ERE411
				Provincial	ERE412
				Local	ERE413
		Business	ERE42	Sector	ERE421
				Firm	ERE422
		Science-policy interactions	ERE43	Political decision-making process, policy design processes, decision analysis	ERE431
		Institutions	ERE44		ERE441
		Policy instruments	ERE45	Economic instruments, command and control, education and information, instruments, voluntary agreements, self-regulation, policy mixes	ERE451
Tools and methods	ERE5	Valuation methods	ERE51	Expressed preference (contingent	

Table continued on next page >>

Category I	Code	Category II	Code	Category III	Code
				valuation, choice methods, conjoint analysis, contingent ranking, participatory appraisal)	ERE511
				Revealed preference (travel cost method, hedonic price method – property and wages)	ERE512
				Assumed preference technique (change in productivity, cost of illness, human capital, replacement costs)	ERE513
				Benefit-transfer method	ERE514
		Economy-environment analysis/modelling	ERE52	Macroeconomic (general equilibrium)	ERE521
				Sectoral (input-output, social accounting matrix)	ERE522
				Firm (value chain analysis, life cycle modelling)	ERE523
		Evaluation tools	ERE53	Cost-benefit analysis (including Multi Criteria Analysis, Cost Effective Assessment, risk assessment, other evaluation methods, e.g., shadow pricing)	ERE531
		Environmental indicators	ERE54	National, sectoral or provincial environmental accounts (including Natural mineral accounts, renewable resource accounts, environmental asset accounts)	ERE541
				Corporate environmental accounting (including Integrated bottom-line, triple bottom-line)	
				Other methods (e.g., genuine savings, national wealth estimates)	ERE543

Sources: Adapted from World Bank. n.d. Estimating pollution load. The Industrial Pollution Projection System (IPPS).: www.worldbank.org/nipr/ipps/ippsweb.htm (accessed 18 January 2002); De Groot, R.S., Wilson, M.A. and Boumans, R.M.J. 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics, 41:393-408.

perspective to thematic issues such as water and air, illustrating their various different interfaces with the economy and need for integrated response options.

In Chapter 5, the value of ecosystem services is considered with the focus on carbon sequestration. Though carbon sequestration programmes are by no means a solution to the problem of global climate change, they illustrate the value of ecosystem services in general. By not considering the value of ecosystem services, the economy will incur costs, some of which are addressed in Chapters 6 and 7 by focusing on the impacts of global climate change on society. In an arid country, such as South Africa, invasive alien vegetation obstructs proper ecosystem functioning, which leads, *inter alia,* to a decline in water supply services. This is addressed in Chapter 8. The value of water and of aesthetic and amenity attributes of land are investigated in Chapters 9 and 10, respectively. Chapter 11 develops a framework for evaluating water quality. Chapter 12 considers the social cost of declining air quality while Chapter 13 deals with solid waste and Chapter 14 with noise pollution. Chapter 15 considers the application of natural resource accounts as an improved accounting framework and database to evaluate economic development. While these case studies deal with, *inter alia*, various aspects of resource and environmental valuation, Chapter 16 focuses on one aspect of project evaluation through a critical discussion of the role of economics in the environmental impact assessment (EIA) process. EIAs in themselves are not reflected in Table 1, but cut across aspects mentioned under ERE5.

CHAPTER 5

Capturing the value of environmental services

James Blignaut, Max Döckel, Roland Mirrilees, Rudi van Aarde and Nathan Wilson

5.1 Introduction

Biodiversity, as an intrinsic feature of natural ecosystems, supplies humanity with an array of services upon which society depends.[1] These services include the provision of food resources, water purification and cycling, nutrient cycling, the regulation of atmospheric composition and the development and protection of soils. Negative impacts on biodiversity are therefore likely to have negative consequences for ecosystem processes and functions.

The question of whether a decline in the world's biodiversity will hamper, or even result in the loss of, ecosystem functions and processes has been a major issue in ecology in the past decade.[2] Community respiration, decomposition, nutrient retention, plant productivity and water retention have been identified as five major ecosystem processes that may be affected through changes in biodiversity.[3] At interest here in a southern African context is that the loss, transformation and/or reduction in ecosystem services appear to be closely associated with rural poverty induced by past land-use practices. These practices seem to have ignored the dependence of rural living on ecosystem services and the consequences of ecosystem erosion for atmospheric and climatic stability. An increasing interest in the ability of humans to harness science and technology to reverse ecosystem degradation is providing special opportunities to restore ecosystem functions and services. This has the potential of alleviating rural poverty through the orderly marketing of some of these services, also in southern Africa.

The focus of this chapter is on one such programme, namely the economic benefits of a regional carbon sequestration restoration programme directed at alleviating rural poverty through the reversal of environmental degeneration. Carbon sequestration, as a result of photosynthesis, involves the uptake and conversion of atmospheric carbon dioxide into sugar, starch and complex molecules like cellulose and lignin, forming wood, branches, roots, leaves and bark.[4] Carbon sequestration means that anthropogenic and natural greenhouse gases are converted into structural carbon, which is stored in biomass and only released when the trees or their products decay or are incinerated. Forests, both tropical and others, account for more than 75 per cent of the carbon stored in terrestrial ecosystems.[5] As forest regeneration can be a natural process, it has the advantage of being relatively cheap and being able to conserve biological resources that benefit soil and water resources. This makes the sequestering of carbon in forests and forest products a potentially useful mechanism in global efforts to offset expanding greenhouse gas emissions. It should be acknowledged, though, that a carbon sequestration programme on its own would be inadequate to address global climate change. Long-term solutions should come from a change in technology and producer and consumer behavioural patterns. Carbon sequestration programmes do however lend themselves to illustrate the value of ecosystem services in general and provide a point of entry for the rural and marginalised communities of developing countries to the benefits of the formal economy.

5.2) Environmental services and positive externalities

Ecosystem services are not included in the calculation of GDP since such services are not captured within conventional markets (see Chapter 2). This leads to market failure because ecosystem services are considered public goods with no commercial value.[6] Ecosystems render services that benefit people and these services can therefore be seen as positive externalities. This also holds for carbon sequestration as a positive, co-incidental side-effect of the process of photosynthesis and biomass accumulation.

As the polluter-pays principle is already embedded in legislation[7] to deal with negative externalities, so should the provider-gets principle be applicable in the case of positive or collectively beneficial externalities. The provider-gets principle is based on providing support or the necessary incentive structure to promote the delivery of these public goods and services.[8]

Rural landowners could gain significantly from the provider-gets principle since their economic activity is directly linked with ecosystems and the services provided by these systems. Until now, farmers and/or communal landowners have not received any remuneration for the provision of ecosystem services such as carbon sequestration, as these are considered public goods. Accordingly, such goods are likely to be provided at a sub-optimal level. In extreme cases, this may lead to what has popularly been known as the *tragedy of the commons*[9] hence resource depletion or degradation. This will particularly be true where there is a trade-off between the provision of public goods and services and the production of marketable, private produce. In the absence of the provider-gets principle, any incentive lacks to produce beneficial public goods or restrict the production of detrimental goods. On the contrary, it is easy to justify private gains and public losses, since the private welfare gains are clearly demarcated and promoted through incentive schemes, while the public welfare losses are obscured because of market failure. Typically, agri-environmental schemes aim at reducing negative externalities, preventing the generation of further negative externalities, preventing the loss of features which have a public good character, and generating positive externalities.[10] Optimal policy therefore requires an economic value for these public goods and services that are not traded in the market-place. Contingent valuation techniques[11] are generally used to value ecosystem services.[12]

Funding the provider-gets principle does not necessarily imply an increase in tax burdens, since public goods can be funded in a variety of other ways. One option may be that of taxing a negative externality to fund a positive externality. By doing so, a double dividend may be realised (reducing a negative externality while encouraging a desirable outcome) through a single policy action. Such taxation may become revenue neutral by reducing other taxes. For example, revenues raised from the introduction of a carbon tax could be used to fund environmental reconstruction, not unlike the Costa Rica system discussed later in the chapter. Another option would be to allow infrastructure and commercial development in one area if the impact of this development is mitigated through ecosystem rehabilitation elsewhere. Such a policy would, however, require a well-managed land-use policy.

Two examples of the provider-gets principle that already operate in South Africa are:

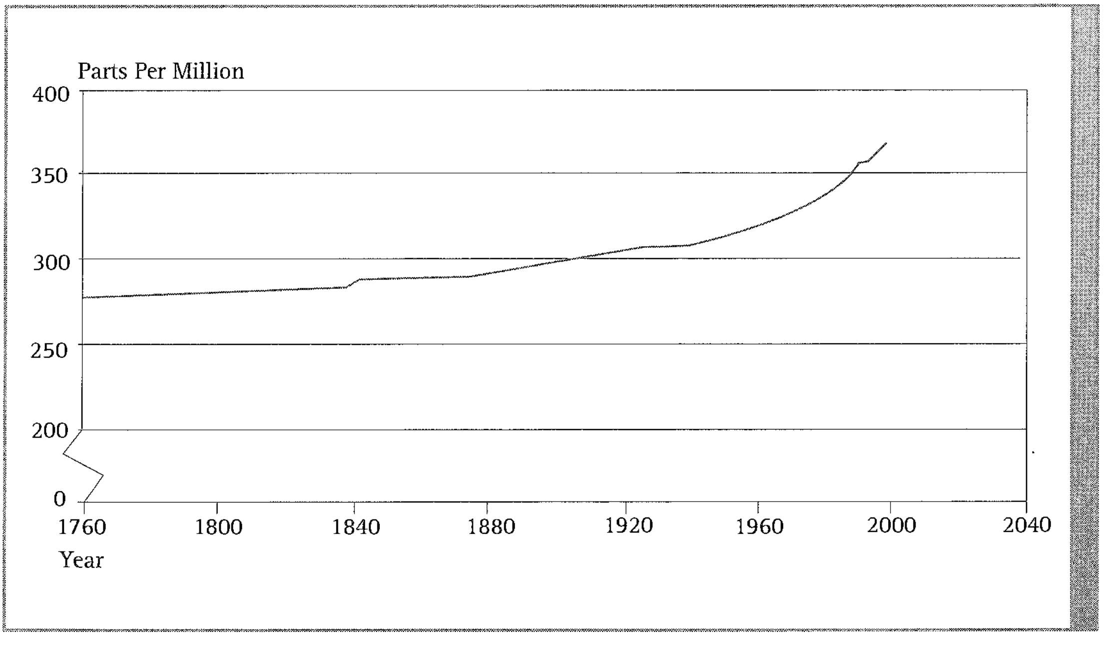
- a levy charged on the use of plastic bags, this levy being used to fund labour-intensive waste removal operations; and
- the Working-for-Water programme, which is a public works programme aimed at the eradication of invasive alien vegetation through labour-intensive programmes.

As far as plastic bags are concerned, the public good is a clean, bag-free environment, with the associated health and aesthetic benefits. The provider of this service is the person involved in collecting the waste and a user charge on plastic bags is applied to fund this public good in an effort to prevent and reduce the negative externality. During this process, some unemployed may have another means of earning an income.

It is generally accepted that invasive alien plants reduce water runoff[13] (see also Chapter 8). The aim of the Working-for-Water programme is to provide water through the eradication of invasive alien vegetation and to compensate those who are involved in providing these services. Poverty alleviation money coming from the national treasury is used for this purpose.

5.3 Global climate change and South Africa

Anthropogenic greenhouse gas emissions, for example, carbon dioxide and methane, contribute to climate change.[14] The increased use of fossil fuels is responsible for the increase of approximately 70 per cent of one of these gases, namely carbon dioxide,[15] and has pushed its atmospheric concentration to unprecedented levels (see Figure 5.1). As concern has grown about the possible impacts of climate change, so has the possibility presented by the potential increase in the storage of carbon (C) in terrestrial vegetation through forest conservation, afforestation and other methods of land management, although this provides only a partial and also short-term solution to the problem.[16] Unfortunately Africa, including South Africa, is highly vulnerable to changes in climatic patterns. The ability to adapt to these changes is also very low (Table 5.1).



Source: Brown, L.R. 2001. *Eco-Economy*, New York: Norton.

Figure 5.1: Global carbon dioxide concentration

Table 5.1: Global regional adaptive capacity and vulnerability to a variety of environmental factors affected by climate change

Concerns Regions	Food & Agricultural Yields	Droughts & Desertification	Infectious Diseases & Thermal Stress	Species Extinction	Floods & Sea-Level Rise on Coasts
Africa	Food scarcity	Water scarcity (North, West & Southern)	Extended range of vector-borne diseases	Significant	Floods & Erosion (West, Egypt, East & Southern)
	Vulnerability high due to heavy reliance on rain-fed agriculture, frequent floods & droughts, & poverty; Adaptive capacity low				
Asia	Decreased productivity in dry, tropical & temperate; Increased productivity (North)	Water scarcity (arid & semi-arid) Increased water (North)	Vector-borne diseases Heat stress (many parts)	Exacerbated by permafrost changes (North), land use, sea-level rise	Floods (tropical & temperate)
	Developing countries: Vulnerability high, Adaptive capacity low; Developed countries: Vulnerability low, Adaptability high				
Oceania	Improved yields Food scarcity in some areas	Water scarcity		Significant (corals, arid & semi-arid, SW, wetlands)	Floods
	Indigenous peoples: Vulnerability high, Adaptive capacity low; Australia & New Zealand: Adaptive capacity high				
Europe	Improved yields (North) Food scarcity (South, East)	Glacier retreat Water scarcity (South)		Alpine & permafrost disappearance	River & coastal floods
	Vulnerability moderate, high in South & Arctic; Adaptive capacity high				
Latin America	Food scarcity Subsistence farming threatened	Glacier retreat Water scarcity Droughts	Extended range of vector-borne diseases	Increased loss	River & coastal floods
	Peasant farmers & indigenous peoples: Vulnerability high; Adaptive capacity low				
North America	Improved yields	Water shortage Droughts	Extended range of vector-borne diseases	Prairie wetlands, alpine tundra, cold-water ecosystems	River & coastal floods

Source: Intergovernmental Panel on Climate Change (IPCC). 2001. Summary for Policymakers. Climate Change 2001: Impacts, Adaptation, and Vulnerability. Working Group II. Bonn: Intergovernmental Panel on Climate Change.

South Africa is contributing more than its rightful share of carbon emissions, mainly because of the country being heavily reliant on coal-fired power generation, as discussed in Chapter 12. Additionally, the population growth of more than 2 per cent[17] and prevailing poverty underlie ecological degradation throughout most of the human-dominated landscapes of South Africa. Some 25 per cent of terrestrial habitats of the South African landscape have been altered ecologically for the cultivation of crops, forestry, industry and human settlements,[18] further degrading the landscape of intact ecosystems. This includes 30 per cent of the fynbos biome, 26 per cent of grasslands and 10 per cent of the savanna biome.[19] Furthermore, 15 000 km^2 of indigenous grasslands and forests have given way to forestry,[20] where exotic pine and bluegum plantations are devoid of structural biodiversity that stabilises ecosystem function. For example, Mpumalanga (the most afforested province in the country[21]) had 25 per cent of its grasslands converted to exotic plantations.[22] This comprises about 7 per cent of the area of the province.[23]

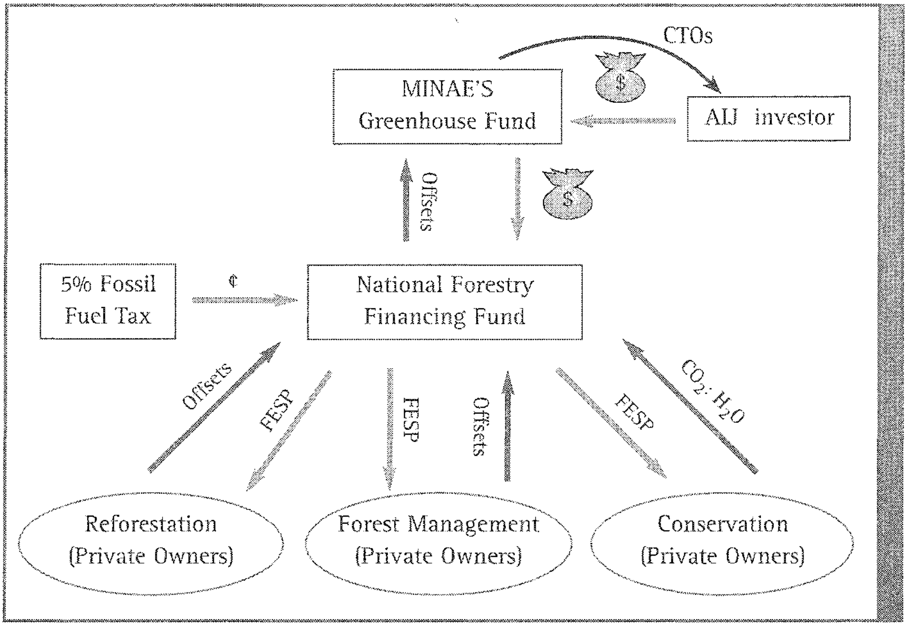
Communal land, which accounts for approximately 14 per cent of the area of the country[24] appears ecologically degraded and is in serious need of action directed at recovering ecological integrity.[25] In all, the major part of the South African landscape beyond the protection of formerly declared conservation areas seems to be degraded to some extent.

In economic terms, degradation to the extent illustrated above is accompanied by the loss of the positive externalities intrinsic to indigenous vegetation, as discussed in the first section. For the people living in the degraded rural areas of South Africa, the degradation leaves them even more vulnerable than they would otherwise be. They are excluded from the mainstream economy and have eroded the goods or services that could provide them with opportunities within the formal economy.[26] Costa Rica, a small, open-economy lower-middle income developing country, faced a situation not unlike the one described here. By applying the provider-gets principle, Costa Rica was able to stop and reverse the condition.

5.4) The provider-gets principle in action: The case of Costa Rica

In 1950, more than half of Costa Rica was covered by forest, but by 1986 only 29 per cent of the country still enjoyed forest cover. Decades of deforestation driven by the rapid expansion of the road system, cheap credit for cattle, and land titling laws rewarded deforestation. The underlying policies that supported the harvest of the forests were embedded in the conventional wisdom that growth in human-made capital equates development and is an indicator of progress. This implies that the environmental services rendered by forests were taxed on behalf of human-made capital, or, viewed differently, that the investment in human-made capital was subsidised by the forestry services by not valuing them appropriately.[27] At that stage the Costa Rican authorities realised that drastic measures were necessary to reduce the rate of deforestation. This decision was based on a new understanding that it was necessary to preserve forests because of the many environmental services that they provided. These include: biodiversity or the diversity of species, hydrological services, carbon sequestration, ecotourism and scenic views. Biodiversity is important to conserve for its bioprospecting value (various products that use material from natural flora and fauna, including perfumes, cosmetics, pesticides and pharmaceutical products), its ecotourism value and its ecosystem services, such as the provision of healthy habitats for animals. Well-functioning watersheds also provide important hydrological services, as the loss of forests in important watershed areas can result in soil erosion and subsequent sedimentation in rivers and streams.[28] This sedimentation can reduce the quality of drinking water and cause losses in hydroelectric production potential. It also increases the risk of flooding, which in turn can result in further losses in potential electricity generation.[29] The loss of forest cover had therefore major negative economic implications, over and above the services that forests provide, while the carbon sequestration value of primary forests was estimated to be between $60 and $120 per ha in 1989.[30]

After realising the importance of their forests, and in an effort to conserve and promote the ecological services rendered by these, Costa Rica developed legal instruments and institutional arrangements that enabled the internalisation of these benefits (see also Figure 5.2). In this way, landowners have an incentive to conserve their forests and safeguard the integrity of their land. By 1998, the payment for Forestry Environmental Services Programme (FESP) compensated three types of activities: reforestation, natural forest management and forest protection, and provision was made for a fourth activity, namely forest regeneration. In return for the payments, the landholders had to cede their carbon and other environmental service rights to the government through the National Forestry Financing Fund (FONAFIFO), while they promised to manage or protect the forest for a period of 20 years (or 15 in the case of reforestation). This obligation was registered in the public land register and would apply to any future purchasers of the land. Monitoring is the responsibility of each participant's supervising forester (who was also responsible for drawing up the forestry management plan for the property).[31]



Source: Salazar, C.R., Tattenbach, F., Gamez, L. and Olson, N. 2000. The Costa Rican experience with market instruments to mitigate climate change and conserve biodiversity. Environmental Monitoring and Assessment Journal. 61(1):75-92.

Figure 5.2: The Costa Rican Forestry Environmental Services Payment Scheme

The main source of funding for the programme is a tax of 15 per cent on fuel sales, dedicated to the reduction of greenhouse gases and the protection of biodiversity. One third of this (5 per cent) is dedicated to forestry through FONAFIFO.[32] Additionally, the government (MINEA) established a Carbon Fund in 1997 to distribute 'rights' or 'credits' in exchange for monetary deposits from domestic and international sources. The secondary source of funding is the sale of Certifiable Tradable Offsets (CTO) (the Costa Rican version of a certifiable emission reduction (CER)), a financial instrument designed by Costa Rica to transfer (sell) greenhouse gas (GHG) offsets in the international market.[33]

5.5 Marketing environmental services: A South African case study

Based on the Costa Rica case study it seems possible to reverse the process of environmental degradation and resource depletion through the application of the provider-gets principle, thereby internalising the positive externalities yielded by ecosystem service delivery. The economic value of these ecosystem services could be quite substantial, also in South Africa. It is estimated that the value of carbon sequestration from South African woodlands amounted to R362 million in 1998 (current prices).[34] Subsequently it has been estimated that the net present value of carbon sequestration resulting from ecological rehabilitation is between R5 000 and R7 000 per hectare,[35] while that of other environmental services that will be restored simultaneously amounts to about R5 000 per hectare.[36] While these values are currently non-marketed, it is possible to design a programme, not unlike the one described for Costa Rica or, alternatively, that of Mexico and elsewhere,[37] in an attempt both to rehabilitate the environment and contribute substantially to poverty alleviation by compensating those rural communities that provide ecosystem services through the restoration of degraded land.

The results from a hypothetical case study are provided in Table 5.2, below, focusing only on the carbon sequestration value of rehabilitating 1 000 ha through a community-based indigenous rehabilitation initiative, thereby reducing costs considerably. At the same time, local economic benefits are maximised, in addition to the benefits of capacity building and education. The calculations are based on assumptions (listed in the table), but include the cost of acquiring the trees, project management, maintenance and technical assistance.

The net present value over 15 years of the direct cost (assuming a discount rate of 10 per cent) is hence estimated at approximately R6.7 million, or, on average, R446 per hectare per year. Additionally, an intrinsic component of the programme is the provision of an alternative energy source (such as solar systems) to reduce the need for biomass fuel. Assuming 20 households to be involved in the programme, it is estimated that the cost of providing these rural solar systems would be approximately R150 000, implying a total cost estimate of about R6.85 million in NPV terms.

Selling the carbon sequestration services on the international market at $15 per ton carbon, assuming a carbon absorption rate of six ton per hectare,[38] would yield a revenue of approximately R5.48 million in NPV terms (given an exchange rate of R8 to the dollar). This implies a shortfall of R1.37 million prior to the disbursement of wages. Non-carbon benefits are, however, estimated to yield a net present value of R5 000/ha,[39] or R5 million for 1 000 ha, which is more than sufficient to cover the shortfall and disburse wages. A restored environment could then act as base for secondary industries such as nature-based tourism.

International carbon funding through carbon markets and carbon development funds exists, mainly because of the Kyoto Protocol and the Clean Development Mechanism.[40] The carbon content of the expenditure highlighted above could, therefore, be funded from non-taxpaying external sources. Since indigenous afforestation yields much more positive externalities than carbon sequestration, viz. an increase water retention, a reduction in dam siltation and a restored habitat, it may be argued that alternative sources under the provider-gets-principle could be used to leverage funding from public sources to pay for the other services and for disbursement. Payment for the provision of ecosystem services is also worlds apart from welfare transfers and other forms of ad hoc handouts. It is possible to integrate previously marginalised communities with the formal economy, thus leading to their market participation and empowerment.

Table 5.2: Rehabilitation expenditure and possible revenues from carbon sequestration services rendered for a 1 000 ha case study

Years	Assumptions	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
EXPENDITURE																
Section A																
300 trees/ha for 1 000ha	300 000															
Cost per tree	R5															
1. Cost of trees		500 000	500 000	500 000												
2. Programme Management	10%	100 000	110 000	121 000	133 100	146 410	161 051	177 156	194 872	214 359	235 795	259 374	285 312	313 843	345 227	379 750
3. Operation and maintenance	10%	150 000	165 000	181 500	199 650	219 615	241 577	265 734	292 308	321 538	353 692	389 061	427 968	470 764	517 841	569 625
4. Technical assistance	10%	150 000	165 000	181 500	199 650	219 615	241 577	265 734	292 308	321 538	353 692	389 061	427 968	470 764	517 841	569 625
5. Total expenditure		900 000	940 000	984 000	532 400	585 640	644 204	708 624	779 487	857 436	943 179	1 037 497	1 141 247	1 255 371	1 380 908	1 518 999
NPV	10%	6 697 971														
Section B																
Renewable energy: 20 households																
Number of households	20															
Cost per household	R 7 500,00															
6. Total (once off)		150 000														
7. NPV cost (excluding disbursement)		6 847 971														
REVENUE																
Ha	1 000															
$/t CO_2	15															
Exchange rate	R8															
t CO_2/ha	6															
8. Total income (R)		720 000	720 000	720 000	720 000	720 000	720 000	720 000	720 000	720 000	720 000	720 000	720 000	720 000	720 000	720 000
9. Net present value	10%	5 476 377														
10. Shortfall prior to disbursement and revenue from other, non-carbon, ecosystem service payments		-1 371 594														

Source: Own analysis.

5.6 Conclusion

The restoration of the carbon sequestration abilities of indigenous vegetation may internalise positive externalities and provide the incentive to conserve natural ecosystems. This can be achieved by the selling of carbon sequestration activities that will provide rural communities with the incentive to rehabilitate indigenous vegetation by planting indigenous trees, reseeding grasslands and reversing soil erosion. Carbon sequestration can be safeguarded through the maintenance of firebreaks, the eradication of invasive alien vegetation and by controlling levels of grazing by livestock. Finally, the restored natural vegetation can provide a base for a variety of new industries, including nature-based tourism.

The economic implications of the restoration of indigenous biomass are self-evident: an improved base for subsistence livelihoods accompanied by sustainable direct employment in the rehabilitation-maintenance-secondary industries process, as well as indirect employment through multiplier effects. Clearly, this would represent a turnaround in the economic prospects of the people living in the affected rural areas.

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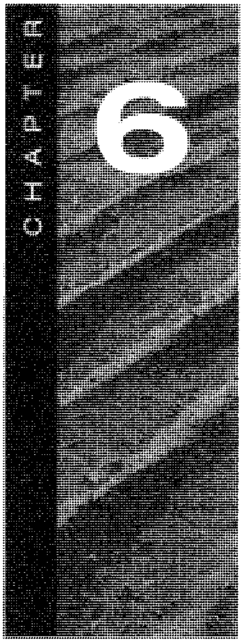


Economic impacts of climate change in South Africa: A preliminary assessment of unmitigated damage costs

Jane Turpie, Harald Winkler and Guy Midgley

6.1 Introduction

Studies on the economic impacts of climate change have mostly been carried out for developed countries, such as the USA in particular. Moreover, most of these are partial impact studies, concentrating on areas such as agricultural impacts or the cost of sea level rise. Comprehensive monetary valuations are rare and are usually restricted to the USA.[1]

The Vulnerability and Adaptation study for the South African Country Study on Climate Change (SACS)[2] recently made qualitative and quantitative predictions of the biophysical impacts of climate change up to 2050. Predicted impacts include changes in terrestrial and marine ecosystems which will have profound impacts on agriculture, forestry, rangelands and fisheries, as well as on biodiversity. Furthermore, changes in river flow may have immense consequences in terms of human health by increasing suitable habitat for water-borne diseases as well as affecting water supply and the maintenance of ecosystem functioning. A combination of a reduction in freshwater inputs and sea level rise is expected to impact on estuaries, affecting the production of estuarine and inshore marine fisheries. The economic implications of these changes have never been estimated in South Africa, and SACS provided the opportunity to produce some first-cut estimates.

SACS included the following impact studies: water resources, agriculture, human health (malaria and schistosomiasis (bilharzia)), commercial forestry, rangelands and biodiversity (plant, animal and marine). However, it must be noted that it was a vulnerability and adaptation assessment. The impacts of climate change were described in terms of sensitivity (how much change in sector indicators may occur?), vulnerability (do the potential changes cause increased risk for the sector or associated populations?), and potential adaptation responses (what options are available to counteract any negative effects?). The authors were not pushed to provide highly quantitative estimates, mainly due to the levels of uncertainty involved, especially concerning the key drivers such as temperature and rainfall. Indeed, the question is not so much of whether or how the climate is changing, but how much it will change over a given period of time. The behaviour of many of the response variables was also difficult to predict, often since the type of scientific research required to make such predictions has not been done yet. Therefore, in general, SACS tends to give rather rough, and often only qualitative, predictions of the biophysical impacts of climate change.

This study provides 'order of magnitude' estimates for unmitigated damage costs of climate change, based on the outputs of SACS and other available material. It gives a broad-brush estimate of the magnitude of potential damages in the absence of adaptive or preventative action, which can therefore be seen as a worst-case estimate of the impacts of climate change in the event of a government policy failure, such as a *laissez faire* approach. An economic analysis of the costs and benefits of mitigation has not been attempted here.

In an effort to standardise the measurements of different impacts, SACS, as is done in this study, estimates impacts for the year 2050 as far as possible. This is also consistent with analogous studies. The year 2050 corresponds to the doubling of CO_2 from pre-industrial levels, and all biophysical changes predicted are based on this doubling. Higher concentrations and greater impacts are entirely possible. There is nothing magic about the $2xCO_2$ level, but it has become a figure often used in the literature, though the Intergovernmental Panel on Climate Change (IPCC) has not identified a safe level of atmospheric CO_2. Values are reported in year 2000 Rand and compared to nominal 2000 GDP. Note that this assumes that the structure of the economy in 2050 is basically the same as it is today, and that any real growth in the economy would be impacted by proportionately larger losses from climate change damages.

6.2) Categorising the impacts of climate change

Most studies, including the IPCC working group III (WGIII) study, tend to classify the economic impacts of climate change into market and non-market impacts[3] (Table 6.1). Market impacts include, for example, the change in output of economic sectors such as agriculture and forestry, damages such as property losses, and impacts leading to increased expenditure such as the earlier provision of water-supply schemes. Non-market impacts are those that affect intangibles and are associated with the loss of ecosystems, habitats and species, and with the impacts on human amenity. Impacts on health and the loss of human life are usually also considered as non-market impacts.

However, this categorisation tends to de-emphasise, or fails to recognise, the connection of not only the market impacts, but also non-market impacts to ecosystem damages. It is asserted here that all kinds of damages, whether to functional or human-made ecosystems, infrastructure, or human health, have both market impacts, reflected in conventional national accounting statistics such as GDP, and non-market impacts, such as discomfort and other less tangible impacts on human well-being.

Table 6.1: Typical classification of the economic impacts of climate change

Market impacts	Primary sector impacts	Agriculture
		Forestry
		Fisheries
	Other sector impacts	Water supply
		Energy demand
		Leisure activity
		Insurance
		Construction
		Transport
		Energy supply
	Property loss	Dry land loss
		Coastal protection
		Urban infrastructure
	Damage from extreme events	Hurricanes, droughts, storms, floods, etc.
Non-market impacts	Ecosystem damage	Wetland loss
		Forest loss
		Species loss
		Other ecosystem loss
	Human impacts	Human life
		Air and water pollution
		Migration
		Morbidity, physical comfort
		Political stability
		Human hardship
	Damage from extreme events	Hurricanes, droughts, storms, floods, etc.

Source: IPCC (Intergovernmental Panel on Climate Change) 2001. Contribution of Working Group III to the Third Assessment Report of the IPCC. Cambridge: Cambridge University Press for IPCC.

A new primary classification of impacts, based on the direct source of value: natural, agricultural, human-made or human capital is offered here (Table 6.2). Losses of water supply have not been valued separately, since it is included as a critical input to other economic activities, for example, agriculture, and is essential to ecosystem functioning. Impacts are presented according to this classification in the following sections.

Table 6.2: Summary of the impacts considered and the approaches to estimation of economic valuation used in this study

Damage to	Impacts	Study approach
Biodiversity (ecosystem functioning, species richness, etc.)	Consumptive use values (harvesting of resources)	Collation of existing data on value of the commercial and subsistence use of resources, such as indigenous forestry and fisheries; assessment of losses in terms of predicted loss of extent and/or productivity of relevant biomes/habitats. The market value of grazing is considered separately, for all areas combined, on the basis of expected changes in primary productivity of grasses.
	Non-consumptive use values (tourism and recreation)	Collation of existing data on extent and value of nature-based tourism; assessment of losses in terms of predicted loss of habitats and biodiversity.
	Impacts on option and existence value	Existing case study.
Agricultural systems	Rangelands	See consumptive use values of ecosystems above.
	Crops	Impacts predicted by the country study on crop productivity per unit area for different crops and in different parts of the country are extrapolated to the country as a whole and valued on the basis of current agricultural statistics.
	Plantation forests	Maps presented in the country study showing predicted changes in the suitable ranges of plantation species are analysed in their original GIS form to produce quantitative data, and impacts are valued on the basis of recent estimates of the contribution of forestry to the national economy.
Infrastructure	Property losses due to sea level rise	Predictions on the impacts of selected sites around the coast are converted into monetary terms. These data could not be extrapolated to a country level.

Table continued on next page >>

Damage to	Impacts	Study approach
Human health	Health and loss of life due to malaria	Increased incidence of malaria predicted by the country study is valued on the basis of cost-of-illness and human capital approaches, the latter valuing the temporary loss of earnings due to illness. Loss of human life is valued on the basis of average contribution to GDP (see Chapter 7).

6.3 Impacts of biodiversity loss

6.3.1 Predicted biophysical impacts

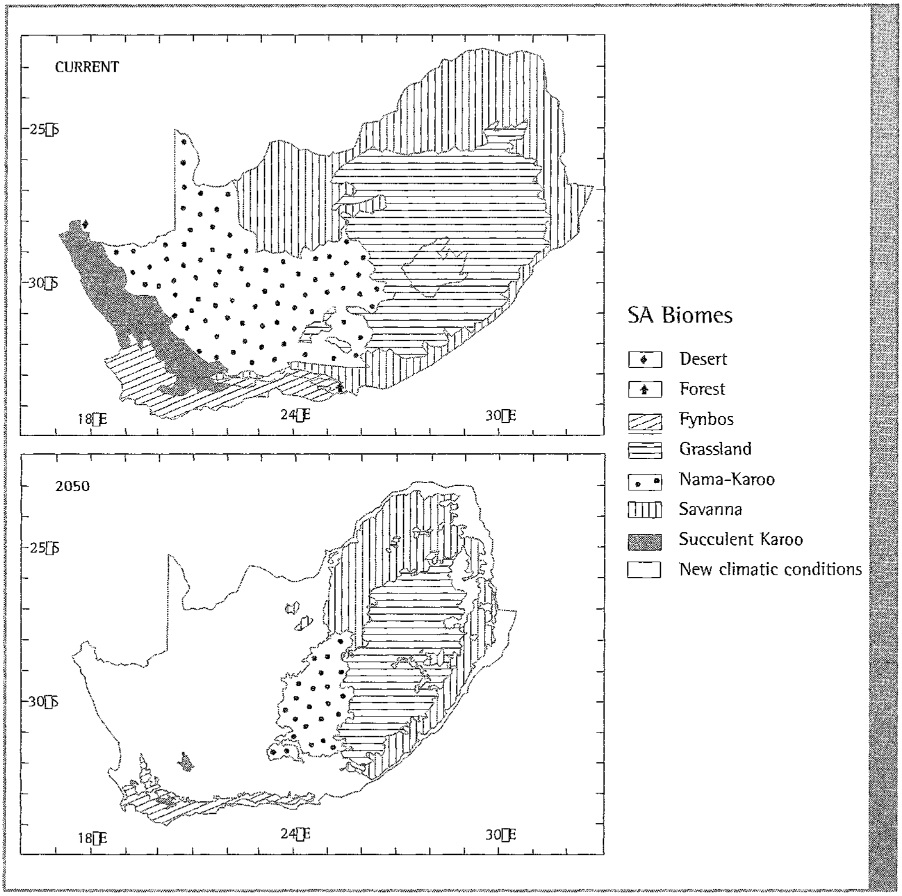
The HadCM2 model, favoured by SACS, predicts an increase in temperatures of about 2.5˚C by 2050. Along with this, major changes in rainfall are expected, most notably a decrease in precipitation in the western half of the country. These patterns tend to mean that most of the biophysical impacts predicted by the country study will be more severe in the western half of the country. Changes in rainfall and temperature patterns are expected to lead to significant shifts in hydrological functioning in South Africa.

Projections of mean annual runoff (MAR) and groundwater recharge varies widely among models, with only one model projecting significant increases of these measures over the entire country. The HadCM2 suggests reductions of MAR especially in the western parts of the country, HadCM2N projecting catastrophic reductions of up to 70 per cent, and HadCM2S reductions of between 10 and 30 per cent.

Changes in terrestrial plant diversity were predicted with the use of bioclimatic modelling techniques, providing spatially explicit predictions of the future distributions of South African biomes and selected key plant species. The study suggested significant shifts in habitat ranges and species losses. The warming and aridification trends will result in shrinkage of the areas amenable to the country's biomes (Figure 6.1). The 'vacated' areas would support much more arid-adapted and relatively species-depauperate vegetation. The largest losses will occur in the western half of the country, and the findings suggest a complete loss of the unique Succulent Karoo Biome by 2050 (which contains 5 500 endemic species). The Nama Karoo biome is also radically contracted. The Fynbos Biome does not contract as much as these, but stands to lose a large number of species. Modelling suggests that 33 per cent of the endemic Proteaceae will lose 100 per cent of their current ranges, and are therefore likely to become extinct. If this family is representative of the entire biome, the costs can be calculated for related industries. Much of the existing Grassland Biome will be susceptible to a potentially large number of invading savanna tree species. Elevated CO_2 may encourage bush encroachment in much of the eastern part of the country. In combination with the increasing minimum temperatures this will lead to a switch from grassland to woodlands and savannas, with concomitant loss of grassland specialists. It is also speculated that increasing temperatures may increase the incidence of fire, which is an important determinant of habitat structure and species diversity, but no studies have quantified this effect.

As with the plant study, the terrestrial animal diversity study suggested significant species losses and shifts in species ranges. The animal study used a modified climate envelope model to explore the consequences of climate change for the distributional ranges of 179 selected species. The results showed that 17 per cent of species expanded their ranges, while 80 per cent displayed range contractions of up to 98 per cent, and only 3 per cent did not respond to climate change. Most of the range contractions were due to eastward retreat from aridification in the western half of the country. The study also suggests major species losses from the Kruger National Park, with 66 per cent of species having a high probability of extinction, including 97 per cent of bird species. However, because the models did not allow for the filling of 'vacated' areas due to range shifts from areas to the north of South Africa, the degree of species extinction is probably seriously overestimated in this report.

The prediction of biophysical impacts on the marine environment is poor in comparison to that for terrestrial environments. This is due to marine systems being heavily dependent on atmospheric and oceanic circulation systems, which are likely to be affected by climate change. Unfortunately, existing information with which to model marine systems accurately is incomplete. Moreover, the interaction between marine biodiversity and these systems is still in itself rather poorly understood. This part of SACS was unable to provide many quantitative estimates, and in many cases even the direction of the potential impacts is uncertain. Although range changes are expected, with tropical species moving southward along the coast, these could not be modelled, due to their close association with ocean currents, whose change in movements has not been predicted. Estuaries will be impacted by a decrease in freshwater runoff, particularly those whose main catchment areas are in the western half of the country.



Source: Kiker, G.A. 1999. South African Country Study on Climate Change Synthesis Report for the Vulnerability and Adaptation Assessment Section. School of Bioresources Engineering and Environmental Hydrology, University of Natal, Durban.

Figure 6.1: Current and predicted future distribution of biomes in South Africa. The future scenario is based on climate changes brought on by an increase in the concentration of atmospheric carbon dioxide to 550 ppm

6.3.2 Impacts on consumptive use values

- *Forest and Savanna Biomes.* Forests and woodlands are notable areas for yielding multiple resources such as timber, fuelwood, medicinal and food plants, for commercial or subsistence purposes. In addition, woodlands are managed as extensive livestock-ranching areas throughout much of South Africa (discussed below). The value of forests tends to be predominantly commercial, while that of woodlands includes a significant subsistence value component.

  Indigenous forests have their main value in timber extraction, worth at least R3.3 million in 1998, or over R4 million if commercial harvests of non-timber resources are included.[4] However, the impact of climate change on forests has not been modelled, making estimation of economic impacts impossible. The Savanna Biome, on the other hand, is predicted to shrink to about 72 per cent of its current extent.

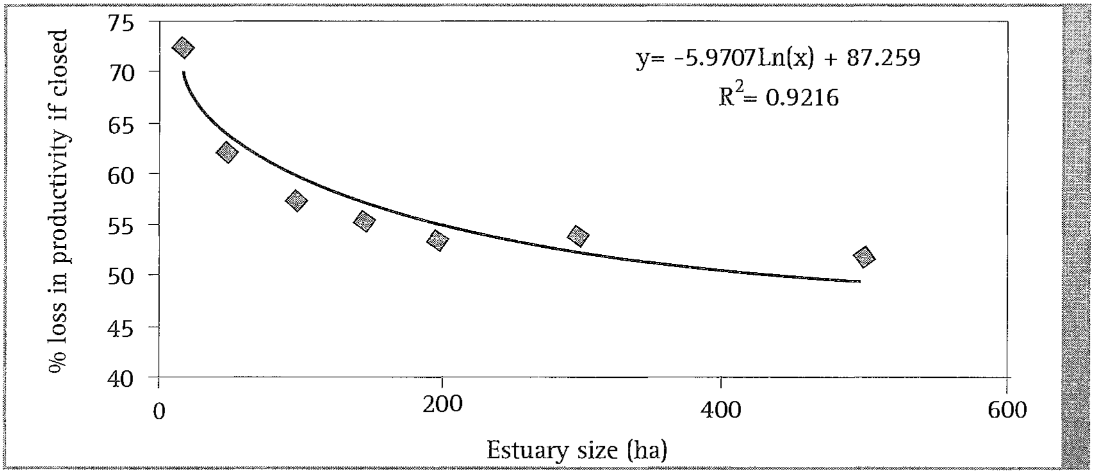
  Population densities in woodlands are high, particularly in the former homeland areas to which people were forcibly removed during the apartheid era.[5] Because of their direct reliance on natural resources for uses such as fuelwood, construction materials, medicines and foods, the livelihoods of a large number of South Africans stand to be affected by climate change impacts on savanna and forest ecosystems. In addition, the subsistence production of livestock generates direct and indirect income and social benefits. The total use value of woodlands has been estimated to be between R2 673 and R3 633 million (1998 prices).[6] With an expected loss of up to 28 per cent of the Savanna Biome, this translates to a potential loss in use value of R748 million to R1 017 million per annum. This loss is a non-market value and would not be reflected in the national accounts.
- *Grassland Biome and Karoo Biomes.* The predominant value of the Grassland and Nama Karoo Biomes is commercial livestock grazing. Most of the land area is under private commercial ownership, but significant parts of the grassland area, and some part of the Nama Karoo, lie within communal areas. In these areas, the biomes have a subsistence use value for the harvest of resources as well as for grazing. However, no studies have attempted to estimate these values.

The Succulent Karoo Biome is more arid than the Nama Karoo, and has a lower grazing value, with grazing predominantly by small stock. A significant portion of the Succulent Karoo Biome is under communal ownership. In these areas, there is a high reliance on the natural veld for harvesting of resources such as fuelwood and medicinal plants, as well as for subsistence livestock production. However, the aggregate value of these uses is unknown.

- *Fynbos Biome.* Over 100 species of wild flowers and greens are harvested from fynbos for the ornamental industry. Other resources harvested include sour figs (*Carpobrotus* spp.), honeybush tea (*Cyclopia* spp.), buchu (*Agathosma* spp.), for its essential oils used in flavouring, perfumery, medicine and brandy, and thatching reeds (*Thamnochortus* spp.). Most of the biome is under private ownership, and virtually all of this harvest is commercial, with a total contribution to the South African economy of about R74 million per year. With an estimated loss of up to 62 per cent of the Fynbos Biome, losses due to climate change could be in the region of R46 million per year.[7] However, since the use value of fynbos is not evenly distributed across the biome, but tends to be concentrated in the southernmost areas, it is possible that the loss will be much lower than this. Nevertheless, even if the shrinkage of fynbos habitats would be proportionally lower in the most productive areas, the country study also predicts a significant extinction of species such as proteas, which could be important to the wildflower trade.
- *Estuaries.* South Africa's roughly 255 functioning estuaries are productive systems which provide a valuable supply of goods and services. One of the most important values of estuarine systems is their contribution to fisheries. Resident estuarine fish populations are exploited directly in recreational, subsistence and limited commercial fisheries. In addition, estuaries provide nursery areas for numerous species of fishes which are exploited in inshore marine fisheries.

Climate change impacts on runoff are expected to have a significant impact on the functioning of estuaries, with those on the west coast[8] experiencing reductions in freshwater inputs of up to 84 per cent, and on the south-east coast about 20 per cent. Further east, estuaries might experience a slight increase in freshwater inflow. According to expert opinion, almost all permanently open estuaries west of the Mbashe that are not prevented from closing by a rocky mouth structure, are likely to become temporarily closed systems, and estuaries that are already temporarily closed will close more often.

The fishery productivity of estuaries is strongly related to their size and mouth condition,[9] and a change in mouth condition can have a major impact (Figure 6.2). Using these models, the total estuarine fish catch is estimated to reduce by 35 per cent by 2050, even though there is no reduction in catches from estuaries in the subtropical zone.



Source: Lamberth, S.J. and Turpie, J.K. 2003. The role of estuaries in South African fisheries: Economic importance and management implications. African Journal of Marine Science, 25:131-57.

Figure 6.2: Percentage reduction in estuarine fishery productivity if a permanently open estuary becomes closed, as a function of estuary size

The total value of the estuarine fish catch at present is estimated to be R433 million per year (1997 Rand), with 99 per cent of this being the value of recreational angling. At worst, the loss of 35 per cent of estuarine catches might translate to a proportional loss of value, or R151.5 million per year. However, in reality, the demand for angling is not very sensitive to catch rates, and the loss of value may be somewhat less than this. In contrast, the impacts on mariculture could be positive,[10] but they are unknown.

- *Marine resources.* South Africa's marine resources include a large number of vertebrate, invertebrate and plant species exploited along different parts of the entire coastline. The west coast supports a few highly productive fisheries, while further east productivity is lower and the diversity of fisheries is much higher. All of these fisheries are likely to be impacted by climate change,[11] but up till now it has proved too difficult to predict these impacts, due to the complex circulatory systems involved.

However, it is possible to make a rough estimate of the changes in inshore fish productivity, due to a change in estuarine functioning, since an estimate of the contribution of estuarine fishes to inshore catches has already been made.[12] The total value of all inshore marine fisheries is estimated to be R2 389 million per year.[13] Taking into account the degree of dependence of each species on estuaries, approximately 21 per cent of this value is estimated to be derived from estuaries (Table 6.3), although a much larger percentage is made up of estuarine associated fish. Taking into account the contribution made by permanently open estuaries that will not close, it is estimated that the current catch that is attributed to estuaries would be reduced by some 90 per cent.[14] This translates to an overall loss of 18 per cent of the current value of inshore fisheries, or R441 million per year (Table 6.3).

Table 6.3: Estimated value of different sectors of the inshore marine fishery in South Africa, the contribution to this value by estuary dependent species, and the estimated value of losses (R millions)

	Total fishery value (R millions)	Contribution from estuaries	%	Value lost due to
Recreational shore	1 764.93	438.36	25.3	394.53
Recreational boat	128.00	0.36	0.3	0.32
Recreational spear	68.77	1.09	0.7	0.98
Commercial boat	407.62	45.34	11.3	40.81
Seine and gill-net	20.07	5.25	26.2	4.73
TOTAL	2 389.39	490.41		441.37
% fishery value		21		18

6.3.3 Impacts on tourism value

Tourism activities in South Africa may be impacted by climate change through loss of habitat (for example, estuaries and coastal resorts), loss of biodiversity (for example, loss of species from the Kruger National Park); and increases in temperature, humidity and malaria. SACS predicts that the Kruger National Park stands to lose a high proportion of species. It is extremely difficult to estimate the actual contribution of biodiversity to tourism value, since visitors are often attracted by multiple features of their destinations. There is as yet no published quantitative work on the demand for biodiversity that would allow an estimate of the marginal tourism value of biodiversity, although a recent survey suggested that the diversity of species *per se* contributes 16 per cent of the recreational value of the Hluhluwe Game Reserve and that the demand for tourism would be reduced by a reduction in overall species numbers, and particularly by the loss of charismatic species.[15] In a survey of Western Cape households, most indicated that they would visit local reserves less often if the vegetation were to become desertified, but nearly a quarter said it would make no difference.[16] However, even with accurate demand models, the predictions of species losses in the country study are not sufficiently accurate to attempt a quantitative estimate of the impact on tourism. Ultimately, it is the amount of biodiversity and associated scenery that South Africa retains relative to other countries that will be important here.

The escalation of health risks as a result of climate change is also likely to have significant impacts on the tourism trade. The incidence of malaria, for instance, has increased in South Africa in the first half of the past decade and the impact of this on tourism is potentially visible in terms of an increasing demand for malaria-free destinations. As the risk of malaria expands into these areas under climate change, it is possible that tourists will seek their nature experiences elsewhere.[17]

Although accurate prediction is impossible, the potential loss in tourism value appears to be large. South Africa stands to lose income from a sector that contributes 5 per cent directly to GDP, and possibly as much as 10 per cent when its contributions to other sectors are taken into account.[18] With wildlife and scenery being the primary reasons for visiting the country for 36 per cent and 33 per cent of tourists, respectively,[19] this means that up to 3.6 per cent of GDP or R26.2 billion (2000), is at stake, and based on a preliminary understanding of the contribution of biodiversity to tourism values, this loss would probably be at least R4 billion per year.

6.3.4 Impacts on option and existence value

In addition to the largely tangible values cited above, the loss of ecosystem functioning and biodiversity can have a negative impact on people's welfare in terms of a loss of option or existence value. Option values include the potential development of new, as yet unknown, products from biodiversity. This value is particularly difficult to measure, although some researchers have attempted to assign values to rare species on the basis of the probability of a species being found to be useful for some purpose, such as the development of new medicines. These measures are mainly applicable to developed countries, and there is really no reliable way in which one could attach this type of option value to South Africa's biodiversity without much more thorough research. Option value, in the sense of people wanting to retain the option to enjoy or utilise biodiversity in future, is closely linked to existence value, and the two are often considered together in stated preference surveys.

The existence value of South African biodiversity threatened by climate change has been estimated[20] by using the Contingent Valuation Method.[21] The study investigated awareness of and interest in biodiversity, and elicited willingness to pay (WTP) for conservation in South Africa as a whole, and WTP to prevent the impacts of climate change.

Only 10 per cent of the 800 respondents said they had no interest in nature, while 39 per cent and 36 per cent said they had a passive or active interest, respectively, and 15 per cent said they were passionately interested. Interest in nature was positively related to income category. 72 per cent of respondents had heard of fynbos (the dominant vegetation of the province), but less than half could recognise it and much fewer could identify species or vegetation types. When respondents who had heard of fynbos were asked to estimate how many species were contained in this, the world's most species-rich terrestrial biome, only 6 per cent got within 50 per cent of the correct answer, 75 per cent of respondents were out by an order of magnitude, with the majority grossly underestimating the number of species.

Nevertheless, most respondents (76 per cent) were willing to pay towards biodiversity conservation in South Africa. The amount offered was strongly correlated both to monthly income and level of interest, with an overall mean WTP of R104 per household per year. 39 per cent was allocated to fynbos, 19 per cent to marine areas and 15 per cent to the Fynbos Biome, with roughly 7 per cent being allocated to each of the Grassland, Savanna, Nama Karoo and Succulent Karoo Biomes.[22]

When shown the map of predicted shrinkages of existing biomes under climate change by 2050, 60 per cent of respondents claimed to be very disturbed by the prospect and only 8 per cent said they were not at all concerned. Many from the latter group were sceptical of the predictions, but the majority were simply not interested in nature. Some 76 per cent of respondents said they were in favour of a policy of raising revenue to help prevent climate change by paying more for commodities such as fuel. Overall average WTP to prevent the loss of vegetation in the region was estimated to be R367 per annum, and the total existence value of the biodiversity threatened by climate change was estimated to be R393 million per year to Western Cape households and R2.63 billion per year to South Africans. WTP to prevent climate change impacts was much higher than for conservation, and is probably closer to the true existence value of natural habitats.[23]

6.4) Impacts on agricultural systems

In 1998, agriculture and forestry contributed 4 per cent of the GDP, with field crops, horticulture and animal products contributing 43 per cent, 25 per cent and 32 per cent, respectively, to agricultural output.[24] SACS gives estimates of changes in crop yield by 2050 for some crops, while animal production on rangelands is affected by changes in Net Primary Production (NPP).[25] The value of this lost production reflects the potential damages from climate change.

6.4.1 Impacts on livestock production

Livestock production is dependent on the NPP of vegetation on the rangelands. A simple estimate of the damages from climate change translates changes in NPP into lost production of livestock. Direct impacts of climate change on animals are likely to include increased water requirements and decreased lambing losses due to extreme temperatures, but neither of these has been quantified.

Impacts on NPP are sensitive to the ameliorating effect of rising atmospheric CO_2 on the potential reduction of NPP by water stress. It is assumed that in the sparse vegetation of the western half of the country, the effect is likely to be minimal, and it would tend to increase with an increasing leaf area index towards the east. A worst-case scenario assumes no ameliorating CO_2 effect, and a best-case scenario assumes an effect which has been recorded in greenhouse trials. The impact on NPP in semi-arid sweet grassland ranges from a large reduction of NPP (almost halving) without the CO_2 effect, to a modest positive impact with the effect (Table 6.4). The western part of the country stands to lose NPP and animal production in the absence of a CO_2 fertilising effect. The effect of climate change alone in the east is to increase NPP, probably because of the increasing air and soil temperatures that improve herbaceous plant growth rates and increase the supply of soil nitrogen for several decades through organic matter mineralisation. The CO_2 amelioration effect strongly counteracts increasing aridity in the western parts of the country – but this is unlikely to be effective in mixed grass- or shrub lands of the semi-arid Karoo region, and significant NPP losses can be expected there.

A simple estimate of the impact of NPP is to assume that changes in NPP translate into loss of production of livestock. Total animal production in 1999 was R47 087 million when adjusted to 2000 Rand.[26] The predicted changes in NPP for different biomes with and without the CO_2 fertilisation effect are shown in Table 6.4. Although there are strong regional differences, on balance, climate change could have a modest benefit of R191 to R1 344 million if the impact is directly proportional to changes in NPP. However, it should be noted that this excludes the Karoo regions (predominantly small stock), where rangelands are likely to be most negatively affected. Furthermore, SACS also predicts decrease in the national cattle herd of about 10 per cent,[27] which, based on gross value of cattle and calves slaughtered in 1998/99, implies a loss R329 million per year, or a loss of about R100 to 200 million per year in terms of value added to the national economy.

Table 6.4: Changes in NPP for different biomes and value of national lost animal production

Site	Biome	Biome as percentage of total %	Change in NPP %		Change in value of national animal production in R million per year	
			without CO_2 effect	with CO_2 effect	without CO_2 effect	with CO_2 effect
Bloemfontein	Semi-arid sweet grassland	4.6	-45	8	-420	75
Pietermaritzburg	Mesic, sour grassland	13.7	-5	2	-139	56
Nylsvley	Savanna, mixed grass and woodland	17.6	21	34	750	1 214
TOTAL					191	1 344

Source: CSIR 1999. South African Land-Cover Database Project: Data users' manual, final report. Pretoria, CSIR; Low, A.B. and Rebelo, A.G. 1996. Vegetation Map of South Africa. Pretoria: Department of Environmental Affairs and Tourism; Midgely, G.F. 2001. Biophysical Impacts of Climate Change in South Africa. Cape Town: National Botanical Institute.

6.4.2 Impacts on crop production

Maize is the most important field crop in South Africa, contributing 36 per cent of the total value. Other important crops are sugar (20 per cent), wheat (10 per cent), hay crops (11 per cent) and sunflower (10 per cent).[28] Changes in yields of maize, sugar, wheat, fruit, barley and sorghum were considered in SACS. Detailed predictions are available only for maize, whose production varies strongly with climatic conditions.[29] Moreover, agricultural statistics (gross margin and area planted) are less readily available for other crops. The figures should be treated as indications of the order of magnitude of economic impact, rather than as precise predictions. Taking into account these limitations, the figures can provide an indication of the potential scale of economic damages from climate change in the agricultural sector.

The impacts on agricultural crops are sensitive to the much-debated CO_2 fertilisation effect, which indicates that plants may become more productive at enhanced levels of CO_2. Carbon dioxide fertilisation tends to increase crop yield and water-use efficiency, as increased CO_2 reduces water release by leaf stomata and may increase carbon assimilation rates. However, these effects have not yet been quantified for crops grown under South African field conditions, and it is possible that the CO_2 fertilisation effect saturates at certain temperatures.

Using a sophisticated hydrological and production model, SACS suggests that with the fertilisation effect, maize production may be largely unaffected, while, without it, an average decrease of 10 to 20 per cent is expected.[30] Maize is grown in two main zones, a marginal western belt and a reliable and higher productivity eastern core. Much of the marginal western belt may become unsuitable for maize production with a decrease in rainfall and soil moisture.[31] Predicted changes in maize yield were extrapolated from the 19 sites used in SACS to the total planted maize area, based on geographic proximity to the sites, and were valued based on enterprise budgets.[32] Without the CO_2 fertilisation effect, it is estimated that losses in terms of maize production would amount to some R681 million. However, if the CO_2 fertilisation effect is taken into account, the loss is estimated to be considerably smaller, about R46 million. These estimates do not account for areas that may become unviable.

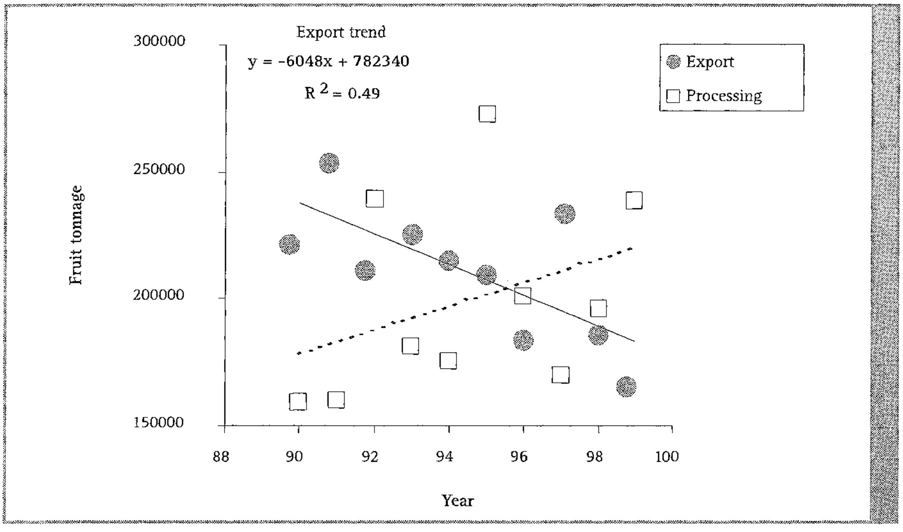
Wheat and sugar cane are not covered in SACS. If losses from climate change were similar to those for barley at 10 to 20 per cent, the value of damages from climate change to wheat production would be between R60 to R120 million per year by 2050 in present-day values, based on the current gross value of production.[33] Possible impacts on sugar production in the range of 10 to 20 per cent would amount to R150 to R300 million per year in terms of lost exports.

For barley, yield reductions of 20 to 50 per cent are predicted for warmer regions, but this effect might be somewhat compensated for by rising atmospheric CO_2, suggesting a reduction in the order of 10 to 40 per cent.[34] Warming will also lead to a reduction in malting quality. The value of this lost yield would range from R9.5 million to R38 million per year in 2050, in 2000 Rand. Impacts on sorghum have not been estimated, but if losses were assumed to be 10 to 20 per cent, the value of damages from climate change to wheat production would be between R6.4 to R12.9 million per year by 2050 in present-day Rand.

The major industries in the winter rainfall region are the fruit and wine industries. Rising minimum temperatures present a problem to the fruit industry, especially apple farming. Certain amounts of chilling units during autumn and winter are needed to ensure coordinated budburst and subsequent harvest. In their absence, hormone sprays are used to ensure this coordination, but EU countries demand that these be phased out within the next few years, due to possible health problems. Developing and replanting appropriate cultivars less sensitive to this effect may take several years, although this analysis has not been carried out.

An accelerating increase of minimum temperatures during autumn (1 to 2°C since the 1960s)[35] has also led to reduced fruit quality due to sunburn and heat stress, and this appears to have decreased the critical export-grade apple production in this region (Figure 6.3). Export-grade tonnage has decreased during the last decade, with tonnage supplied for processing (mostly juicing) having increased concomitantly. Export-intended fruit which does not make grade (mean value over the decade of R1 900/ton) is processed at a value to the producer of R286/ton, which is an 85 per cent reduction in value. An analysis of the summer minimum temperatures over this decade indicates an increase of roughly 0.08 to 0.1°C per year for the main apple-producing areas. Therefore, one can interpolate an export-grade tonnage loss of 6 000 tons per 0.1°C temperature increase (at the current planting intensity), representing a loss to the producer community of R9.7 million per year during the 1990s.

The above estimates are summarised in Table 6.5. Large damages can be expected with a reasonable degree of certainty in the maize sector, mainly relating to the CO_2 fertilisation effect. A reasonable estimate for barley is possible, but this is a relatively small contributor to agricultural GDP. Estimates of damages for other crops are very rough and require further research.



Source: Own calculations based on data compiled from Deciduous Fruit Producers Trust Annual Report 2001.

Figure 6.3: The decrease in tonnage of export-grade apples produced in the Western Cape and the concomitant increase in processed fruit in the decade of the 1990s. This period was associated with a warming of monthly temperature means in summer of roughly 0.1˚C per year

Table 6.5: Summary of estimates of climate change damages from field crops, with assumptions

Crop	Low estimate	High estimate	Confidence	Comments/Assumptions
Maize	-46	-681	Good	Based on detailed modelling, low estimate assumes CO_2 fertilisation effect, H2n model
Wheat	-60	-120	Indicative only	No estimates of yield loss from V&A, assumed low 10%, high 20%
Sugar cane	-150	-300	Indicative only	Lost value of exports; no estimates of yield loss from V&A, assumed low 10%, high 20%
Barley	-10	-38	Fair	Yield losses from V&A: low 10%, high 40%
Sorghum	-6	-13	Indicative only	No estimates of yield loss from V&A, assumed low 10%, high 20%
Fruit	-9.7	-9.7	Indicative only	Based on a fairly weak trend over a short time period

6.4.3 Impacts on plantation forestry

Plantation forests established for commercial purposes, which occupy about 1.1 per cent of South Africa,[36] have an annual turnover of about R1 200 million[37] (1996 Rand), off an asset base valued at about R20 billion.[38] 70 per cent of this value is from export sales. The industrial forestry sector contributes about 1.8 per cent of South Africa's GDP and 8.1 per cent of the output of the manufacturing sector. Plantation forestry accounts for 5 per cent of South Africa's agricultural output and 3.3 per cent of total exports from South Africa.[40] The annual increment in the value of standing stocks is worth some 7 per cent of the total value added by agriculture, forestry and fisheries combined.[41]

An assessment of the physical impacts of climate change on plantation forests was made as part of SACS, based on the HadCM2 model.[42] Although doubled CO_2 concentrations could increase growth rates by 10 to 20 per cent, the potential is limited by available nutrients so that yields will increase only marginally, and only on high-potential sites.[43] Rising temperatures will stimulate forest production in the areas currently cooler than the growth optimum and reduce it in areas where forests are already above their optimum, and increased rainfall will increase tree production. Although the change in CO_2 is fairly certain, the changes in temperature and especially rainfall are very uncertain, as are the magnitude and direction of effects.[44] In modelling range shifts, limits of economic viability were used rather than biological limits.[45] The study indicated a dramatic negative effect of climate change on the forestry potential range and production by 2050.

The GIS outputs of the SACS study were obtained for analysis in this study. The changes in suitable range of species were quantified to determine the percentage change in suitable and optimal growing areas (Table 6.6). *Pinus radiate*, which is grown in the winter rainfall area of the Western Cape, was not considered, since the cultivation of this species is being phased out. There is roughly a 47 per cent and 50 per cent decline in the total area suitable for *Eucalyptus* and *Pinus*, respectively. Since some 80 per cent of these plantations are situated in highly suitable areas,[46] the change in these areas is most pertinent. The predicted reduction in highly suitable areas is about 43 per cent for both *Eucalyptus* and *Pinus*.

For calculation of the economic impact, it should be considered how much of the existing afforested area becomes unsuitable, and hence from which production is lost altogether, and how much of the existing area in highly suitable areas is rendered less productive by climatic changes, but remaining viable. The precision of the data does not allow for such an analysis, but the changes predicted above can be used to estimate the possible magnitude of the impact.

Table 6.6: The percentage change in viable and highly suitable areas for plantations of different species in South Africa

Species	Viable area	Highly suitable area	Overall viable area
Eucalyptus grandis	-34	-35	-35
Eucalyptus nitens	-69	-51	-59
Eucalyptus saligna	-53	-42	-47
Mean for Eucalyptus	-52	-43	-47
Pinus elliottii	-52	-51	-52
Pinus patula	-60	-62	-61
Pinus taeda	-45	-17	-38
Mean for Pinus	-52	-43	-50

Change in productivity that would occur within a suitable afforestation area under the climate change scenario (including CO_2 enrichment) was also modelled. Two possible temperature limits were considered at which *P. patula* might shut down photosynthesis, and a single probable limit was considered for *E. grandis.*[47] The results showed a 49 per cent reduction in the productivity of *E. grandis*, even though temperature effects are somewhat balanced by positive CO_2 fertilisation effects. The effects on *P. patula* could be positive or negative, depending on the upper temperature threshold for the species.

Based on the reduction in highly suitable area for forests by 2050, forestry output could be decreased by as much as 43 per cent, implying a loss of value in the order of R724 million per annum. However, the shortcoming of the model outputs is that they are based on suitable areas, which are considerably larger than the current planted area. Even the highly suitable area is much larger than the planted area. Therefore, a 43 per cent reduction in the highly suitable area may not impact on the currently planted area, if the current plantations are at the core of the area not affected. This problem requires further spatial analysis. However, it is unlikely that the current area will not be impacted by shrinkage of highly suitable areas at all. Furthermore, most plantation areas would be subject to changes in productivity such as those cited above. Although this cannot be predicted for *P. patula* at this stage, half of the current productivity of *E. grandis* could be lost – amounting to a loss of approximately R362 million.

6.5 Health impacts

The changes in temperature and rainfall associated with climate change are predicted to have major impacts on the incidence of diseases such as schistostomiasis and malaria. This will lead to increased illness and associated treatment costs, increased mortality and loss of production by members of society.[48] Alternatively, it would lead to an increase in preventative measures, which, in the case of these diseases, would also be extremely costly. In South Africa, the total costs of treatment plus loss of productivity due to malaria are estimated to reach R277 to R466 million by 2010, and economic impacts of increased mortality are estimated to reach R11 800 to R18 300 million (see Chapter 7).

6.6 Property damage from sea-level rise

Increasing temperatures cause sea-level rise, primarily due to thermal expansion of water and secondarily due to melting ice. The IPCC projects a sea level rise increase of between 9 cm and 88 cm between 1990 and 2100, for the full range of emissions scenarios. These global projections are applicable to South African conditions, considering the estimates conservative compared to other literature.[51] Extreme events such as storm surges would add to the impact of these average increases, but are not included here, owing to their unpredictable timing. In South Africa, a sea level rise of 10 to 15 cm has already occurred over the last century, at a similar rate to global increase.[52]

Four particularly sensitive regions have been identified in South Africa,[53] based on an estimated sea level rise of 1 m: Greater Cape Town (Melkbosstrand to Gordon's Bay); the Cape south coast (Mossel Bay to Nature's Valley); Port Elizabeth; and the KwaZulu-Natal south coast including Durban (Southbroom to Ballitoville). However, no estimates have been made of infrastructure losses.

Detailed case studies of Woodbridge Island, False Bay, Durban and Walvis Bay show that major predicted impacts vary with the type of coastline. Based on property values and expected area of inundation and storm surge, it is estimated that the damages predicted for Woodbridge Island and False Bay would amount to R263 million and R20 million, respectively. However, estimates such as these cannot be extrapolated to a regional scale, and future research is needed to quantify the impacts of sea-level rise at national and regional levels, before valuation can be attempted.

6.7) Counting the costs

The estimates attained in this study are summarised in Table 6.7. The greatest potential impact is on tourism, with a potential loss of up to almost 3 per cent of GDP owing to damages to South Africa's natural heritage; a reliable estimate of this impact was however not possible. Apart from tourism, the greatest impacts can be related to traditionally non-market spheres: the impacts on human health, the existence value of biodiversity and the subsistence use value of natural resources. This is particularly interesting, since most studies concentrate on conventional market-based impacts such as agriculture or forestry. However, this pattern is to be expected for a developing country, and would undoubtedly be even more strongly the case in other African countries.

Placed in the context of South Africa's GDP, these values are significant. Malaria damages would lead to a loss some 1.4 to 2 per cent of GDP, taking the costs of increased mortality into account. The loss of existence value is equivalent to 0.3 per cent of GDP, and the loss of subsistence harvests up to 0.3 per cent of GDP. In comparison, the loss of crop and forest production would probably amount to less than 0.1 per cent of GDP, fisheries losses are more or less the same, and livestock production may increase. The overall losses could be at least 1 to 2 per cent of GDP (depending on whether mortality costs of malaria are included – a controversial issue, but then may be considerably higher, possibly as much as 6 per cent if all impacts are maximal). However, the latter scenario is highly unlikely, especially given that the upper-bound estimate of the tourism impact is considered to be an overestimate. The more conservative estimates as a percentage of GDP are more similar to those for America and Europe, which are around 1.5 to 1.6 per cent of GDP, rather than those for Africa, which are around 6.9 per cent.[54] It could be expected that the overall impacts on the South African economy would be lower than for the rest of Africa because of the country's high productivity in the mining and manufacturing sectors and their relative contribution to economic output. Excluding malaria and tourism impacts, the estimated cost of climate change amounts to some 13 to 23 per cent of the agricultural GDP. These losses can be compared with the 2000 GDP of R873 637 million.[55]

Table 6.7: Summary of preliminary estimates of the unmitigated damage costs of climate change in South Africa made in this study

Source	Activity/Type of value	Estimated impact (R millions per year)
Forest and savanna biomes	Commercial harvests	-4
	Subsistence use of resources	-1 924 to -2 616
Fynbos	Commercial harvests – wildflowers, thatch, etc.	Down to -28
Estuaries	Estuarine recreational and subsistence fisheries	Down to -151
Marine	Inshore commercial, recreational and subsistence fisheries	-441
All rangelands	Livestock production	+292 to +1344
	Cattle herd value	-164
All habitats and biodiversity	Existence value to South Africans	-2 630
All habitats and biodiversity	Tourism value	-4 000 to -26 000

Table continued on next page >>

Source	Activity/Type of value	Estimated impact (R millions per year)
Croplands	Maize	-46 to -681
	Barley	-10 to -38
	Sorghum	- 6 to -13
	Wheat	-60 to -120
	Sugar cane	-150 to -300
Plantation forests	Plantation forests	-362 to -724
Infrastructure	Property damage	> -100
Human health	Malaria	-12 077 to -18 766
TOTAL		**-20 630 to -52 484**
% GDP		**2.4% to 6.0%**

6.8 Conclusion

The estimation of climate change impacts is particularly challenging. Compared to most pollution problems, the analysis of which helped shape the origins of environmental economics, climate change impacts will be wider reaching, both space- and time-wise.[56] The irreversibility of many of these impacts is an issue that defies economic evaluation. The global nature of the problem demands the analysis of impacts on a global level, without neglecting spatial variation. Analyses of regional or national-level impacts could be seriously flawed if they do not take global changes into account. However, the estimation of global level impacts requires detailed estimation impacts at a regional scale, and adjustments can be made at this level. With regard to the temporal scale of the problem, the analysis is particularly difficult because many impacts will not be felt for another 50 years, and will therefore affect a different generation of people. The long time horizon makes any economic assessment highly sensitive to assumptions about the preferences of future generations.

Over time, the relative impact of climate change on the South African GDP is expected to increase as damages increase. One might expect that economic growth and technological and other advances will lead to changes in some of the outputs being valued, independent of climate effects. For example, there may be more development at the coast, genetically modified crops (independent of adaptive measures) may increase production, and greater poverty may exacerbate the increased incidence of malaria. In other words, even without climate change, the country's economic activity might not remain static, and different sectors may change in different ways. Because it is impossible to predict these changes in a study such as this, it is necessary to work under a general (though unrealistic) *ceteris paribus* assumption.

This chapter concentrated on the value of unmitigated damage costs. This is a contentious issue, as adaptive action will undoubtedly take place, even if it is carried out only by the private sector. Nevertheless, the relative magnitude of different impacts presented here places an interesting perspective on the argument of whether to assess unmitigated damage costs or adaptation costs plus residual damages. This arises from the fact that adaptation measures in the case of the highest impacts presented here are difficult, and sometimes impossible. No mitigation of impacts on existence values is possible. Indeed, existence values may even increase as environmental awareness improves, but biodiversity cannot be substituted and therefore there can be little in the way of adaptation to its loss beyond resigned acceptance. Mitigation of the loss of resources which are central to the livelihoods of a majority of South Africans is also not impossible. Adaptation measures would involve the substitution of these resources or the reduction of dependence on natural resources through increasing incomes and cultural changes. Any of the latter measures would prove to be vastly expensive, such that adaptation costs would prove to be even higher than the potential losses indicated in this study. Moreover, they are highly impracticable and may, in some cases, be undesirable.

These findings suggest that, without preventative or mitigatory action, the impacts of climate change will potentially be significant, leading to a reduction in overall societal welfare and thereby potentially offsetting drastically needed efforts to improve it. It is important to note that these impacts will not be evenly distributed over the country. Indeed, many of the most severe impacts are expected to occur in currently underperforming areas of the country. Thus, the impact on poverty in these areas may be more severe than the average would suggest. South Africans should start to take the impacts of climate change seriously. In weighing up the costs of preventative and mitigatory measures against the potential damage costs estimated here, it will be necessary to take a truly far-sighted approach in terms of recognising the irreversibility of biodiversity losses and the long-term impacts on society.

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CHAPTER 7

The cost of climate change: The case of malaria in South Africa

Randall Spalding-Fecher and Shomenthree Moodley

7.1 Introduction

The widespread occurrence of malaria is one of the world's most serious and complex health problems. More than 40 per cent of the world's population is at risk of malaria, with over 270 million cases per year and more than one million deaths.[1] The impacts of malaria, however, go well beyond the immediate effects of the illness, to affect economic growth and development. Controlling for factors such as geography, colonial history and isolation, it was found that countries with severe malaria had income levels in 1995 two thirds less than countries without malaria.[2] Greater investment in prevention, even without climate change, would therefore have very high returns.[3]

Malaria is also one of the diseases identified as most likely to be impacted by climate change, because transmission is sensitive to temperature and rainfall.[4] The burden on Africa, where the vast majority of deaths occur, is likely to be the greatest. Adaptation measures by African governments will be essential to prevent additional loss of economic productivity and also to strengthen the overall health infrastructure available to the poor.

While some analysis is available in South Africa on the increased risk of malaria from climate change and the current illness and adaptation costs of malaria, these two disciplines have not been brought together. Research to date has focused on site-specific case studies of illness costs as well as some modelling of how risks could change with changes in climate. Moreover, no local in-depth studies on the costs of adapting to greater malaria risk are available, although some international research has estimated prevention and control costs for other countries.

The objective of this chapter is to provide an assessment of the economic impacts of increased malaria on South Africa, taking into account both direct health costs and lost economic productivity. Furthermore, comments are provided on how adaptation – through greater preventative measures – could both reduce economic losses and spur local development.

On the impacts side, the goal is to bridge the gap between the climate and malaria risk modelling in the South Africa Climate Change Country Study Vulnerability and Adaptation Assessment and the economic valuation of malaria in South Africa. The focus is on applying the valuation literature to this climate change risk rather than applying new valuation techniques through primary data collection. On the prevention and adaptation side, the possible meanings of other African studies on malaria prevention for South Africa are considered.

The next two sections introduce the relationship between malaria and climate change and the background of malaria in South Africa. Section 7.4 discusses the links between malaria and economic development. Section 7.5 presents an analysis of increased malaria morbidity and mortality and the economic impacts thereof. Section 7.6 looks at adaptation and prevention costs, followed by conclusions.

7.2) Malaria and climate change links

Climate change is predicted to have a dramatic impact on the distribution and severity of disease, particularly in the poorer regions of the world which not only have less health care infrastructure but also already have climates more suitable to vector-borne diseases.[5] World Health Organisation studies also show that malaria is one of the diseases whose incidence is most likely to increase with climate change, and that this will affect more than two billion people (see Table 7.1 below).

Table 7.1: Major tropical vector-borne diseases and the likelihood of change with climate change

Disease	Likelihood of change with climate change	Vector	Present distribution	People at risk (millions)
Malaria	+++	mosquito	tropics/subtropics	2 020
Schistosomiasis (bilharzia)	++	water snail	tropics/subtropics	600
Leishmaniasis	++	phlebotomine sandfly	Asia/southern Europe/Africa/ Americas	350
American trypanosomiasis (Chagas disease)	+	triatomine bug	Central and South America	100
African trypanosomiasis (sleeping sickness)	+	tsetse fly	tropical Africa	55
Lymphatic filariasis	+	mosquito	tropics/subtropics	1 100
Dengue	++	mosquito	All tropical countries	2 500–3 000
Onchocerciasis (river blindness)	+	blackfly	Africa/Latin America	120
Yellow fever	+	mosquito	tropical South America and Africa	–
Dracunculiasis (Guinea worm)	?	crustacean (copepod)	south Asia/Arabian peninsula/ Central-West Africa	100

Source: Kovats, R.S., Menne, B., McMichael, A.J., Corvalan, C., Bertollini, R. 2000. Climate Change and Human Health: Impacts and Adaptation. Geneva: World Health Organisation.

Notes: +++ = highly likely; ++ = very likely; + = likely; ? = unknown.

Malaria risk is governed by a large number of environmental factors, many of which are seasonal, that affect the intensity of transmission and duration of the high risk season. Of all factors, climate is considered the most important limiting factor.[6] Temperature, rainfall and humidity all play a role in determining survival of the vector – the anopheles mosquito – and the parasite itself. Of course, the actual risk of malaria will be affected by adaptation measures, including eradication programmes and public health interventions. Some of these are already in place to combat existing malaria risk. To assess the magnitude of the risk for South Africa a first order estimate of the increased cost of malaria from climate change before additional adaptation has occurred, is made. In other words, the damage costs investigated here are one piece of the opportunity costs of doing nothing to prevent climate change.

Recent modelling of the impact of climate change on malaria distribution suggests that an additional 260 to 320 million people could be at risk by 2080 because of climate change.[7] The areas where this change will be most dramatic are those where malaria transmission is currently marginal because of low temperature or insufficient rainfall, among other factors. This means that while tropical African countries, where malaria risk is already very high, will not see increased risk due to climate change, whereas highland areas in Eastern and Southern Africa, or areas with currently insufficient rainfall, could see significant increases in populations at risk.[8]

7.3 Malaria in South Africa

Malaria was intensely endemic to large areas of South Africa before the 1940s, including major urban areas such as Pretoria and Durban, with more than 22 000 people dying in an epidemic in KwaZulu-Natal in 1932.[9] Systematic control measures in the following decades, including indoor insecticide spraying and active treatment of the disease, reduced the areas of risk for the disease to the north-eastern borders of the country.[10] Current high-risk areas include 24 rural districts in the easternmost parts of the Limpopo Province, Mpumalanga and KwaZulu-Natal.[11] Through the early 1970s, cases had dropped to less than 500 per year with almost no fatalities.

However, this trend has reversed since the 1970s, with exponential growth in incidence of malaria for the last 15 years. The number of cases jumped from 4 693 in 1991 to 27 035 in 1996 to 61 253 in 2000.[12] Malaria experts point out that this increase is not due to changes in climate (for example, excessively warm and wet years), however, but to increasing drug resistance, an influx of migrants from neighbouring countries where malaria is not controlled, and reduced spraying with insecticides such as DDT.[13]

7.4) Economic development issues and malaria

Malaria imposes economic costs in a variety of ways. First, the direct health costs for identifying and treating malaria cases, particularly in remote areas with limited health care facilities, are very high. As important, however, is the lost productivity of those who are ill. This is true even if victims are not in the formal economic sectors, since they may be unable to carry out subsistence activities such as raising food, tending animals, caring for family members or gathering fuel. Even if the victim is a child, it is likely that an economically active adult will have to care for him or her and be unable to perform other tasks for the family and community. These direct and indirect costs, however, do not include the broader social and emotional costs of mortality and morbidity, or the costs of increased susceptibility to other illnesses.

Research by Gallup and Sachs[14] demonstrates the dramatic constraint that malaria places on economic growth in the poorest countries. As is shown in Table 7.2 below, the loss of GDP growth in many malaria-endemic countries from 1980 to 1995 was more than 15 per cent of income. Annual growth rates in countries with severe malaria were found to be 1 per cent to 1.3 per cent lower.[15]

Gallup and Sachs[16] estimate that sub-Saharan Africa's GDP could have been 32 per cent higher if malaria had been eliminated 35 years ago and that economic growth in Africa is annually reduced by 1.35 per cent due to malaria. This would add US$100 billion (five times more than the $20 billion development and aid provided to Africa in 1999) to the current GDP of US$300 billion.[17] A study by the World Bank estimates that an average family of five with an annual income of less

Table 7.2: Loss of economic growth in 31 malaria-endemic African countries, 1980 to 1995

Country	Aggregate loss (millions of PPP-adjusted 1987$)	Per person loss (PPP-adjusted 1987$)	As a fraction of actual 1995 income
Benin	1 172	214	18%
Botswana	503	347	5%
Burkina Faso	1 684	162	18%
Burundi	730	117	18%
Cameroon	4 227	318	18%
Central African Republic	884	270	18%
Chad	995	154	17%
Congo	759	288	18%
Congo, Dem Rep	7 125	162	18%
Cote d'Ivoire	4 107	294	18%
Gabon	1 389	1 290	17%
Gambia	251	226	18%
Ghana	5 355	314	18%
Guinea Bissau	152	142	14%
Kenya	5 272	198	18%
Lesotho	0	0	0%
Madagascar	2 280	167	18%
Malawi	1 072	110	18%
Mali	1 222	125	17%
Mauritania	611	269	15%
Mauritius	0	0	0%
Namibia	832	539	10%
Niger	1 457	161	17%
Nigeria	17 315	156	18%
Rwanda	656	102	18%
Senegal	2 426	286	18%
Sierra Leone	366	87	17%
South Africa	4 056	98	1%
Togo	1 166	285	18%
Zambia	1 359	151	18%
Zimbabwe	4 214	383	18%
Total	73 638	185	10%

Sources: Gallup, J. L., Sachs, J.D. 2001. The Economic Burden of Malaria. Cambridge: Centre for International Development at Harvard. October.

than $800 spends almost 19 per cent of their annual income on malaria prevention and treatment.[18] In a study in Kenya and Nigeria, researchers estimated that GDP losses with current levels of malaria were 2 to 6 per cent and 1 to 5 per cent, respectively, including direct costs of treatment, lost productivity and household level control costs.[19]

On the other hand, effective prevention – or adaptation to increased malarial risk – can both reduce these health costs and potentially increase economic growth. Gallup and Sachs,[20] for example, show that by reducing malaria rates by only 10 per cent, countries could increase their overall economic growth by 0.3 per cent per year. They do not elaborate on the specific cost of this reduction, but argue that the literature shows it would be small in comparison to the benefits.

In the context of climate change, another option other than adaptation is to mitigate climate change – in other words, to prevent the problem from happening in the first place. The Intergovernmental Panel on Climate Change in its *Third Assessment Report* includes an exhaustive list of measures to mitigate climate change, as well as the costs of many of these measures.[21] The challenge, however, is that, because greenhouse gases uniformly mix in the atmosphere, the concentration over South Africa, and resulting damages, depend on emissions from the whole world, not just local emissions. This is another reason why this chapter focuses on the potential damage costs of malaria due to climate change before adaptation and without global mitigation – or the consequences of taking no action to stop or adapt to climate change.

7.5) Cost of increased malaria incidence in South Africa

This section presents a first order estimate of the cost of malaria from climate change, before adaptation has occurred and without mitigation of climate change at a global level. A three-step methodology to estimate the economic impacts of increased malaria due to climate change is developed:

- Estimate the number of excess cases of malaria due to climate change, based on:
  - increased population at risk of contracting malaria because of climate change; and
  - the share of population at risk that is likely to contract malaria (i.e. incidence ratios).
- Estimate the economic cost of malaria morbidity due to climate change, based on:
  - the direct cost of treating the additional cases; and
  - short-term productivity losses from patients or their caregivers being unable to work.
- Estimate the economic cost of malaria mortality due to climate change, based on:
  - lost work years due to premature death from malaria; and
  - willingness to pay for reduced risk of death, adapted from the international literature.

It is important to emphasise at the outset, however, that the uncertainties in each step of this process are quite significant. Even to understand the future population at risk depends on complex models of how climatic conditions impact malaria parasite and mosquito survival, how to translate very coarse global climate model results into higher resolution predictions for rural South Africa, and how population distribution will change as a result of increasing urbanisation. Each of these modelling processes adds another level of complexity and uncertainty. It has been tried where possible, therefore, to express the assumptions and results in terms of ranges and to discuss where uncertainties are the greatest. The second major challenge of this work is how to realistically describe an impact 'before adaptation has occurred' – because, in reality, adaptation to malaria risks has already occurred in South Africa. Given that control programmes are already in place in South Africa, and have reduced the population at risk from much higher historical levels, these controls would still be expected to be present in the future. When it is said, 'before adaptation has occurred', it is meant before additional measures have been put in place, such as dramatically expanding existing programmes.

7.5.1 Impact of climate change on malaria incidence in South Africa

The first step in assessing the economic costs of increased malaria incidence due to climate change is to estimate how many more people will get malaria and how many more will die from it. This is based on both the increased population that is at risk due to future climatic changes in South Africa, as well as the likelihood that people in high risk areas will contract malaria or die from it.

- *Increased population at risk*

  The South African Country Study for Climate Change (SACS) Vulnerability and Adaptation (V&A) Assessment included a chapter on malaria.[22] In this analysis, researchers from the Medical Research Council applied a model that linked temperature (both average and minimum winter) and rainfall to climatic suitability for malaria transmission.[23] This model was checked against historical data for a number of African countries to verify that it gave a reasonable estimate of the area in which malaria is endemic (i.e. stable transmission every year).

  The science of climate change involves the use of sophisticated models of the global atmosphere, oceans and landmasses that link changes in atmospheric concentrations of greenhouse gases. The models at a global scale are called 'global circulation models', and give fairly coarse resolution predictions – in other words, they can only identify the change in rainfall, temperature, etc. for a fairly large unit area. To get consistent results, the various studies within the V&A assessment (for example, health, agriculture, forestry) all used the same future climate scenarios – the Hadley Center global circulation models.[24] In addition, the Hadley models used present two scenarios of future climate – one that includes the effect of sulphates on climate change and one that does not. Contrary to greenhouse gases such as carbon dioxide and methane, sulphates actually exert a local or regional cooling effect on the atmosphere. However, sulphates only stay in the atmosphere for a short time, so in the context of tighter sulphur emissions standards in South Africa,[25] they are unlikely to be an important influence on the climate in coming decades. For this reason, the results from the V&A study that exclude the impact of sulphates is used.[26]

As mentioned before, one difficulty with these global circulation models, however, is that their resolution is quite coarse. Predictions of current average temperature in South Africa from the Hadley models, when compared to more detailed local climate models,[27] for example, vary by two to four degrees Celsius in many areas.[28] As Craig and Sharp[29] note in the V&A study on health impacts, 'the difference between the present [Hadley] models and actual climate are therefore much greater than the difference between the present and future [Hadley] scenarios.' An additional challenge is that the population growth projections for 1996 to 2010 in the V&A Assessment are based on 1990 to 1995 actual growth rates. Most of the current research on demographics in South Africa, however, suggest that deaths due to HIV/AIDS will significantly slow the population growth rate in the coming decades.[30] For example, national population grew at 2.2 per cent per year from 1991 to 1999,[31] but for 2000 to 2010, HIV/AIDS deaths could reduce the projected population growth from 2.3 per cent to 1.5 per cent.[32] The United Nations project population growth rates of under 1 per cent in 2000 to 2005, falling to -0.2 per cent in 2010 to 2015.[33] On the other hand, as the share of the population that are immuno-compromised due to HIV/AIDS increases, so will the susceptibility to contracting illnesses such as malaria. The predicted populations at risk from the Craig and Sharp[34] study should therefore be seen as an upper bound. The projected populations at risk based on the local climate models and the Hadley model with and without climate change are presented in Table 7.3.

All of the climate models, including those based on local data, such as the Hutchinson and Schultze models,[36] over-estimate the current population at risk, because of the adaptation measures already in place, as mentioned earlier. A more detailed assessment suggests that only about three million people live in districts where the malaria cases are more than one per 1 000 people per year.[37] To try to reflect what prevention measures are already in place, the percentage change in population at risk in the climate models is looked at, rather than the absolute numbers.

The Hadley models predict that climate change will increase the population at risk of malaria by 417 per cent in 2010 – primarily because the malaria risk area in the future includes the heavily populated Witwatersrand area. The reason that this

Table 7.3 Estimated populations at risk based on different climate models and climate scenarios from the South African Climate Change Country Study

	Hutchinson	Schultze	Hadley model no sulphates		
	Present climate	Present climate	Present climate	Future climate	Increase
1995	9 101 875	7 854 638	5 049 654		
1996	8 603 783	7 819 266	4 912 228		
2000	10 662 127	9 241 847	5 977 839		
2005	10 622 127	10 966 172	7 174 761	30 637 710	23 462 949
2010	15 133 780	13 211 391	8 703 941	36 300 636	27 596 695

Source: Craig, M.H. and Sharp, B.L. 2000. Health Section. Part 1: Malaria. South African Country Study on Climate Change Vulnerability and Adaptation Assessment. Pretoria: Department of Environmental Affairs and Tourism.
Note: The first two columns – 'Present climate' –are from detailed models of the current SA climate, with growth in population at risk only due to growth in population. 'Hadley model no sulphates' are projections based on the climate outputs (for example, temperature and rainfall) from the Hadley climate models for each year. The 'future climate' column is based on Hadley model projections of climate outputs in the future given continued climate change.

area has higher risk is that not only do average temperatures increase, but so do average rainfall and severe weather events. This is in contrast to the predictions for western South Africa and many other parts of sub-Saharan Africa, where average rainfall is expected to decline.[38] Note that, compared to the Hutchinson and Schultze data, the Hadley model underestimates the *present* population at risk – although the Hadley model estimates are closer to more detailed studies mentioned above.[39] It has been conservatively assumed that there will be almost no net population growth overall between 2000 and 2010,[40] and that the 417 per cent increase to three million, based on the detailed analysis of population at risk in 1999, for a total population at risk in 2010 of 12.6 million. In other words, climate change by 2010 would put an additional 9.6 million people at risk of contracting malaria. While this may appear very large, it is important that this is the potential population at risk due to climatic changes *before* any adaptation measures, and these measures would undoubtedly be implemented in major urban areas, but they would have a cost as well.

) *Increased morbidity and mortality*

) *Methodology*

A wide variety of socio-economic, environmental and health factors influence the share of the population at risk that will actually contract malaria. As many studies of climate change and disease point out, the spread of vector-borne diseases could spur new efforts to control or eradicate these diseases. In this study we have not considered adaptation beyond what is already happening – although this is clearly an important area for future research. For this reason, the best reference point for malaria incidence ratios is to look at current cases of malaria relative to populations at risk. As described in the previous section, however, establishing the size of population at risk is not a simple matter. Based on the detailed estimates by Sharp,[41] three million people were in high risk areas in 1999. Given 51 535 cases of malaria in 1999,[42] this means an incidence ratio of 17.1 per 1 000 persons at risk. Note that this is not a general incidence ratio for South Africa, but only for those relatively small areas with high risk. For comparison, the incidence ratio in high risk areas (defined as areas where climatic suitability is >0.5) in southern Africa is 11 cases per 1 000.[43]

Under the climate scenarios explained earlier, the future change in climate would, in theory, cause some major metropolitan areas in South Africa to become climatically suitable for stable malaria transmission. This is because the climate in eastern South Africa would be both warmer and wetter, in contrast to the western half of the country, which would be substantially drier. In practice, however, the incidence ratios in these areas – even without significant new prevention programmes – will be much lower than in poorer rural areas. To be conservative, a range of incidence ratios, which are 25 per cent to 50 per cent lower than the current incidence in rural areas, is used.

For mortality estimates, the average share of malaria cases resulting in death in the past three years in South Africa, or 0.7 per cent of cases, is used.[44] The southern African average is 1 per cent.[45]

Results

The projected incidence ratio for 2010 is between 8.6 and 12.8 cases per 1 000. Applied to a population at risk of 12.6 million, this means 107 000 to 161 000 cases. Only the cases due to the increased area of climatic suitability, however, can be attributed to climate change. Applying these ratios to the 9.6 million who are at risk due to climate change, therefore, one has 82 000 to 126 000 additional cases of malaria due to climate change. Out of these additional cases, one may expect 600 to 900 deaths per year, given current mortality rates.

7.5.2 Valuation of increased morbidity

To place an economic value on increased morbidity, two tools have been used: the cost of treatment and the opportunity cost of lost work days. The treatment cost is the full cost of treating a particular illness with one or more treatment regimens. Treatment cost is often used as an input to cost effectiveness analysis, where the input costs of two alternative treatment regimens are compared with their health outcomes – in other words, how much it costs to avoid illness, death, or further medical treatment.[46] The opportunity cost of being ill can be measured in terms of lost income from being unable to work. Treatment cost is often called the 'direct' cost of an illness, while lost productivity or opportunity cost is referred to as the 'indirect' cost. What these two methods do not address, however, is the actual physical and emotional pain and suffering that accompanies illness, or the impacts this has on quality of life and society in a broader sense. These measures can therefore only serve as a lower bound for the economic value of morbidity.

- *Treatment costs*
  - *Methodology*

    Being interested in the direct and indirect costs of medical treatment for patients contracting malaria, one must assume that the costs of treating the additional future patients due to climate change will be similar to the cost of treating patients today in real terms.

    Wilkins at the University of Cape Town undertook the most detailed recent study on the costs of treating malaria in clinics and hospitals in South Africa.[47] This study looked at the costs of medical personnel, drugs, and all hospital costs associated with alternative therapies for first line malaria treatment. Building on this work, Tren, of the UK Institute of Economic

Affairs, analysed the costs of malaria treatment in South Africa, including the costs of the Malaria Control Programme.[48] The Malaria Control Programme sends health-care workers into the field to identify, test and treat malaria cases in rural areas and to provide preventive measures such as insecticide spraying. At least part of the costs of this programme should also be included in treatment costs for malaria, since much of the treatment occurs in the field. It was not possible to identify the share of personnel expenditure (the largest item in the programme budget) that was devoted to treatment. Expenditure for insecticides was subtracted, however, since this is clearly a preventive measure.

Results

Table 7.4 shows the cost per patient of treatment in hospital and in the field. The malaria control programme is an order of magnitude greater that hospital costs – but this is to be expected because 42 per cent of cases are diagnosed and treated in the field, while another 32 per cent are treated as outpatients at clinics and hospitals.[49] A more detailed allocation of the Malaria Control Programme costs to treatment versus prevention would improve this estimate.

Table 7.4: Treatment cost per malaria patient (Rands)

	1996	1997	1998
Cost of treating and hospitalising patients	300	276	260
Malaria Control Programme	2 301	2 925	3 016
- less preventive expenditures	190	242	249
Total (current year R)	2 410	2 959	3 026
Total (constant 2000 prices)	3 097	3 502	3 352

Source: Tren, R. 2001. The Economic Costs of Malaria in South Africa: Malaria Control and the DDT Issue. www.anopheles.com/tren.html (accessed 30 November 2001).

The average cost per patient ranges from R3 097 to R3 502. Table 7.5 shows the results for the direct costs of treatment, ranging between R253 and R429 million. Note that this is only the cost of treating the excess cases due to climate change.

Table 7.5: Treatment cost of excess malaria cases due to climate change, 2010

	Low	High
Cost per patient (constant 2000 prices) (R)	3 097	3 502
Number of cases	81 700	122 500
Total cost (constant 2000 prices) (R million)	253	429

- *Lost short-term productivity*
  - *Methodology*

Lost productivity due to illness depends both on wages and days out of work. For wages, Tren analysed the average wage of employed persons in districts in the three provinces with endemic malaria.[50] Weighted average wages for those employed were R193 per day in 1997, which is equivalent to R224 per day in 2000.[51] Only 47 per cent of the population of these districts, however, had formal employment, while a further 12 per cent were employed in the informal sector. As Tren correctly points out, even people who are not formally employed in rural areas would contribute to subsistence agriculture, so it is reasonable to use an agricultural wage (R36 per day adjusted to 2000 wages) for the unemployed and informally employed as a proxy for their lost productivity.

For the 11 per cent of malaria cases that occur in children under five, a caregiver will have to take time off from work during the illness. Even for those in the five to 15 age group (30 per cent of reported cases), it is likely that either a caregiver will have to take time off, or that some of these youngsters would have been involved in supporting subsistence activities. For these reasons, it has been assumed that all malaria cases will result in lost productivity. Days of lost work depend on the severity of the case and treatment regimen, which are also affected by the age of the patient. Children under five, for example, are always hospitalised for four days' treatment, so all of these cases will result in at least four lost productive days, since it has been assumed that the mother or caretaker must stay with the small child. For children aged six to 15, it has been assumed that a caregiver will have to take part of the time off work for an average of two days. For cases aged 16 and up, the days lost depend on severity. Cases identified actively (i.e. through field workers in the Malaria Control Programme) will by definition not be as severe, with only one day lost. For those that report at a clinic or hospital, 55 per cent are assumed to be treated as outpatients with oral medication and 40 per cent will be hospitalised and given oral medication – both of these groups lose four days' productive time. For the 5 per cent of hospital cases that require intravenous quinine, seven days of productive time will be lost.[52] For each of these groups, the share of employed, unemployed, and informally employed has been applied to match wages to days of lost productivity.

Results

Table 7.6 below shows the lost productivity per case, depending on how the case is treated and the employment status or wage of the patient. Using this table and the share of cases falling into the different categories within the matrix, a weighted average productivity loss of R299 per case has been calculated. This implies a total lost productivity of R24 to R37 million from malaria cases due to climate change.

Table 7.6: Lost productivity per case, based on case type and employment status: R (constant 2000 prices)

Types of malaria case	Employed	Unemployed	Informally employed
Age <5 years*		142	
Age 5 to 15 years*	449	71	71
Age >15 years			
- identified by fieldworkers; oral treatment given in the field	224	36	36
- oral treatment as outpatients or in hospital	897	142	142
- intravenous treatment in hospital	1 570	249	249

Note: *this value captures the lost productivity of the person caring for the sick child

7.5.3 Valuation of increased mortality

Valuation of the loss of life is one of the most difficult areas of environmental and health economics. Whether it is appropriate to equate a life, or the prolonging of life, with money, is an important ethical and moral question. The critical issue, however, is that every public decision on spending related to health (or any private expenditure) *does implicitly place* a value on statistical lives – or, more precisely, on the statistical risk of reduced length of life. This is particularly true with decisions on public expenditure to *reduce* health risks: policy makers need some kind of metric to help weigh decisions about what type of investments to make and how their benefits may outweigh their costs.

There are two broad approaches to dealing with valuation of reduced life expectancy. The first is based on assessing the individual's willingness-to-pay to avoid risks, or willingness-to-accept compensation for taking on risks. This is based on basic principles in economics that individual preferences are the most important source of value, and that welfare, as perceived by the individual, is the appropriate metric.[53] If one knows what all individuals in society are willing to pay to avoid a certain risk, one then knows exactly how much society should spend on avoidance investments. The difficulty, however, is how to elicit these preferences accurately. The most direct approach is the contingent valuation method (CVM), where survey respondents are asked hypothetical questions about their willingness-to-pay for reduced risks (or accept compensation for those risks).[54] The practical challenges in designing these studies, and the cost of executing them, have meant that relatively few studies have been conducted in developing countries. This is particularly true because for each specific problem one has a different group of individuals who could be affected and who will be exposed to specific risks that are geographically and temporally defined. The only way to implement this approach in many developing countries, therefore, is to use values from industrialised countries and somehow adjust them for local conditions (discussed in more detail below). This limits one's ability to choose between alternative approaches, such as willingness-to-pay versus willingness-to-accept, or to target particular groups in a society.

The second method is called the 'human capital approach', and equates the value of the lost statistical life with the net present value of lost future contribution to the Gross National Product.[55] In other words, when society loses this person, it loses the value added (for example, wages less personal consumption) that the person would have contributed to the economy for the remainder of his or her natural life. There are obvious problems with this approach, the most important that, from an ethical standpoint, there is no reason that an individual's value (to themselves or to others) should be related to their economic output.[56] The possibility that the life of a pensioner or someone who is disabled could be zero (or negative) goes against other social values – although if one uses average GDP per capita for the whole population, one can avoid this problem in a given country. Worse yet, the GDP is not necessarily an appropriate measure of social welfare in any case.[57] At best, the human capital approach should only provide an absolute minimum estimate of economic costs.[58] Despite these serious theoretical drawbacks, the practical reality facing researchers and policy makers in developing countries is the sheer lack in willingness-to-pay for such studies. The human capital approach is relatively simple to implement, and so it is still used in many developing countries.[59] Moreover, it avoids some of the serious problems with transferring willingness-to-pay values across countries (discussed in more detail below).

Because of the ethical issues related to this type of analysis, many health economists use measures such as 'Disability Adjusted Life Years' (DALYs) lost. This is a standard health care analytical tool that combines years of life lost and years of life disabled, measured relative to incidence of the illness. Although the economic analysis is presented below to illustrate how to use the two major types of valuation tools, it has been decided to limit the final results to DALYs lost because of the ethical issues surrounding mortality valuation.

- *Human capital: Lost productive years of life*
  - *Methodology*

    Two approaches to estimating human capital have been used. The first is to estimate the average years of life lost in South Africa and the contribution to economic output that the average individual would have made over those years based on GDP per capita. This gives a direct estimate of years of productive life lost. The second possibility is to use the measure of DALYs lost per case and GDP per capita to then place a value on those DALYs. While there are no DALY values for malaria in South Africa, the Global Burden of Disease study estimates that, for sub-Saharan Africa, DALYs for malaria are 0.145 per incidence of illness.[60] This takes into account the age at death, years lost, and a discount rate of 3 per cent for future years lost.

Results

For lost work years, age at death is based on Tren's reporting of deaths from malaria in Mpumalanga in 1997 and 1998, where the average age at death was 22.9 years.[61] According to the UNDP's Human Development Report, life expectancy in South Africa is 54.7 years,[62] so this means a loss of 32 years of economically active life. If the mortality rate for malaria is 0.7 per cent, then the DALYs lost per incidence of malaria for South Africa is 0.149 (using a 3 per cent discount rate for future years as in Murray and Lopez[64]). This is very close to the sub-Saharan average reported previously. The difference could relate in part to the fact that malaria is not severe enough in South Africa for the population to acquire partial immunity, as is the case in some other parts of sub-Saharan Africa.

Because the impacts of deaths in 2010 are evaluated, one should use per capita GDP in 2010, which is estimated as R22 360[65] (in 2000 Rands). Table 7.7 summarises the range of DALYs lost per incidence of malaria, and the economic valuation, using GDP per capita.

Table 7.7: DALYs lost and economic valuation for malaria mortality using GDP per capita, 2010

	Low	High
DALYs lost per case	0.145	0.149
Total DALYs lost	11 800	18 300
Lost economic output (in constant 2000 Prices) (R millions)	265	408

observed consumer behaviour. Questions are, for example, how much additional wages people are willing to *accept* to compensate for more dangerous work and how much consumers will spend on purchases like smoke detectors, homes in areas with better air quality, or choices they make about driving speed and use of seat-belts. Values from the wage risk studies may exceed $1 million, and different studies often differ by several orders of magnitude. Values from consumer behaviour studies tend to range from $300 000 to $900 000 per statistical life.[71]

One can conclude that given the lack of research in South Africa (or Africa) on these issues and the uncertainties about how comparable the overseas studies are, it is difficult to apply these results to the present analysis. For illustration purposes, one could assume a range of $300 000 to $1 million. When adjusted for 2000 exchange rates[72] and relative GDP per capita between the US and South Africa,[73] this means a total valuation of mortality from malaria due to climate change of R360 to R1 700 million.

7.5.4 Summary of economic cost

Table 7.8 below summarises the direct and indirect economic cost of increased risk of malaria due to climate change, but only provides a valuation for morbidity. Based on the assumptions and analysis described in this study, the opportunity cost of increased morbidity from malaria would be between R277 and R466 million in 2010. Because market values have been used for both morbidity and mortality – in other words, direct opportunity cost of lost time, treatment cost, and lost future productivity – and have not included a monetary measure of the increased mortality, these figures should be seen as an absolute minimum estimate of damages. The irony of current national accounts practice is that all of the treatment cost will show up as a positive impact on GDP, even though they represent a decrease in the quality of life for South Africans (see Chapter 2).

These results are consistent with the earlier study by Tren,[74] which estimated that current damage costs (i.e. roughly one quarter of what would be expected from future climate change) were 70 to 82 million Rand, excluding mortality costs. The losses as a percentage of GDP are much less than 1 per cent (for example, current

Willingness-to-pay and benefits transfer

Methodology

As was discussed above, the use of contingent valuation to determine willingness-to-pay (WTP) relies on large-scale surveys on individuals to ask them to evaluate what they would pay to avoid a certain additional risk, or what they would accept as compensation for that risk. This methodology is controversial, for the reasons outlined in the previous section, but is also widely used in the literature as a proxy for individual preferences. Where primary research is not available in a given country, as is the case for many developing countries, one can adapt these values using the concept of 'benefits transfer'. With benefits transfer, one uses the relative GDP per capita of the two countries to adjust the valuations. In other words, if one wants to apply a WTP value to a country with one tenth the per capita income, then one should divide the WTP value by 10. The problem with this approach is that, if one uses it to place a value on the mortality risk, it appears that one is again setting people's value equal to their economic output. This would mean that people in poor countries are worth less than those in rich countries.[66] This was particularly problematic in global valuation exercises such as those assessing the potential damages of climate change.[67] While economists have proposed ways to address this problem,[68] it was found unnecessary to tackle the international dimension of the problem in this study because it looks only at domestic health impacts. The results are shown below for illustrative purposes only.

Results

A survey of economic valuations of health risks found that the value of a statistical life can vary greatly, in part because 'considerable risk reductions of about 1:103 do not call forth a substantially larger willingness to pay than reductions of around 1:105 to 1:106'.[69] For studies that looked at higher risks (1:103), values for two studies were between 120 000 and 300 000 US dollars (2000 dollars).[70] This is much lower than in studies for lower risks, where values of $1 million or more were common. In the case of malaria, however, the risk of dying is of the order of 1:105 in endemic areas. The survey mentioned first also looked at valuation studies based on

Table 7.8: Summary of opportunity cost of increased malaria due to climate change in 2010 (constant 2000 prices)

Category	Damages	
	Low	High
Opportunity cost of excess morbidity		
Cost of treatment (R million)	253	429
Productivity losses (R million)	24	37
Total (R million)	277	466
Mortality impact		
Disability adjusted life years lost (DALYs)	11 800	18 300

GDP is 873 billion Rand[75]), but this is understandable, given the lower rate of incidence in South Africa compared to other countries in Africa and the relatively effective control strategies already in place. It also reflects the fact that no mortality costs have been included, which form a substantial portion of other estimates of total damage costs. Does treatment cost higher than lost productivity mean that South Africa is already offering too much treatment, since productivity losses are small? This is not the case, for several reasons. First, the cost of treatment is not avoidable – in fact it prevents much higher mortality rates and consequent economic and social losses; second, the productivity losses are only those associated with morbidity, not the much larger losses associated with mortality; and third, productivity losses do not capture the wider social cost of illness, including pain and suffering, and social disruption.

7.6 Adaptation strategies and development

A wide range of strategies is required to effectively reduce the risk of increased disease burden from malaria due to climate change. These include cross-sectoral strategies that cut across health, education, water, energy, tourism, and other development issues. Improving basic infrastructure, economic development, and baseline health will all make it easier for communities to adapt to higher malaria risk and prevent increased transmission. Table 7.9 illustrates the different actors involved, as well as broad strategies. It is important to note that the reason why adaptation is so difficult, and vulnerability high, is mainly because of the high levels of poverty in the South (see Chapter 5). As was discussed in Section 7.4, research suggests that endemic malaria is a contributor to continued poverty – and on the other hand, poverty and lack of social and economic infrastructure exacerbate vulnerability and impede adaptation.

Table 7.9: Types of adaptive strategies using malaria as an example

Level	Vector control	Vaccine development	Access to anti-malarial drugs	Preventive measures such as bed nets, housing design	Epidemic fore-casting	Environ-mental manage-ment
International	++	++	+++	+	-	-
Regional or federal	++	-	++	+	-	-
National or state	+++	-	+++	+	+++	+
Local or community	-	+	++	++	+++	
Individual	+++	-	+	+++	+	++

Source: Kovats. R.S., Menne, B., McMichael, A.J., Corvalan, C., Bertollini, R. 2000. Climate Change and Human Health: Impacts and Adaptation. Geneva: World Health Organisation.

Notes: +++ = very important strategy; + = Not so important; - = No strategy

One of the greatest challenges with malaria control is the controversy that surrounds spraying DDT in homes. Vector control was a key part of the strategy that largely eradicated malaria from the eastern and northern regions of South Africa. In more recent years, however, concern over human health impacts, growing concern among environmental pressure groups over DDT, and concern over the impact of DDT spraying on tourism has led to a marked decline in the use of home spraying as a strategy.[76] While alternatives to DDT have been investigated, they tend to be more expensive, and it is not clear whether they are equally effective.[77] Less stringent vector control programmes, and increased resistance to DDT substitutes, are in part behind the increase in malaria cases in recent years in South Africa.[78]

Estimating the cost of a more active prevention programme that would include household spraying and treated bed nets is challenging, because of the wide range of activities involved. In terms of insecticide costs alone, average costs per household are roughly R3 for DDT and R5 for DDT alternatives.[79] If one applies this to the 2.5 million households at risk for malaria transmission under the 2010 climate change scenarios, the cost of prevention would be R9 to R13 million per year. Even if this only reduces incidence by 10 per cent, it is an order of magnitude lower than the health costs from malaria. The fully-fledged prevention programme would, of course, comprise more than just increased spraying, but this is one of the major costs involved.

Note that these programmes would be used to address all malaria cases, not only those due to climate change. The baseline cases (i.e. cases without climate change) in 2010, however, are only approximately one quarter of the total. World Health Organisation (WHO) estimates of the cost of malaria control programmes using DDT in 1992 were from $0.50 to $5.00 per capita per year,[80] which would be R5 to R50 per capita. Similarly, Mills[81] estimates prevention programme costs, including mosquito coils, sprays, treated bed nets and repellents, to be from $0.60 to $25.00 in a range of sub-Saharan African countries. The WHO values would mean a prevention cost of R60 to R650 million. While no precise estimate of the effectiveness of these strategies in southern Africa is presented, the experience in the Lubombo Spatial Development Initiative, on the borders of South Africa, Mozambique and Swaziland, has shown dramatic declines in vector presence due to an effective control programme.[82] In addition to reducing the economic impacts of malaria, effective prevention and control programmes can stimulate economic growth by strengthening local health infrastructure, creating rural employment and increasing the tourism potential.

7.7 Conclusion

Increased incidence of malaria because of climate change poses major health and economic challenges for South Africa. The direct health costs of treatment and loss of economic productivity are likely to be significant, and this does not capture the broader social and economic impact of malaria becoming endemic to areas where it has not occurred in decades. The valuation analysis presented here is one example of how one can apply environmental economics tools to assess the impacts of major environmental and health risks.

The same tools should be applied to prevention measures for malaria. One of the most important conclusions from this study, however, is the need to understand both the costs and effectiveness of prevention measures – as a subcategory of what are referred to in the climate change literature as adaptation measures. As Craig and Sharp point out,[83] for malaria to become endemic in Pretoria again would require an almost complete breakdown of the public health system and malaria control measures. There will clearly be some adaptation and increased need for preventive measures. On the other hand, the exponential growth of malaria cases in the last decade clearly indicates the challenge facing the health policy makers even in the absence of climate change. An adaptation costing study that clearly identifies the potential effectiveness of increased malaria control measures over larger parts of the country, as well as their cost, is an important next step to understand the full economic implications of managing malaria risks.

Valuation of the potential impacts of malaria and the costs of prevention, however, still does not complete the picture of how malaria, climate change and economic welfare interact. Mitigation of climate change – preventing it from occurring in the first place – not only reduces the impacts but also the need to spend money on adaptation. As was discussed above, however, analysing the mitigation options and costs for one country is not sufficient to decide whether it is better to mitigate or to adapt. The policy challenge with climate change is that all countries must take actions to change the global emissions trajectory. The IPCC, for example, estimated that to stabilise the concentration of CO_2 at its present level could only be achieved through an immediate reduction in its emissions of 50 to 70 per cent and further reduction thereafter.[84] The scenarios upon which the climate model results are based assume a doubling of CO_2 concentrations in the atmosphere from pre-industrial levels by 2050, which is typical of a range of the most recent IPCC emissions scenarios *without* action to mitigate climate change.[85] Obviously, the current international agreements under the Kyoto Protocol, which require only an average of 5.2 per cent reduction from

1990 levels by industrialised countries by 2008 to 2012 and even this has been rejected by the US and Australia, do not come close to mitigating the potential damages. Substantial literature suggests, however, that the Kyoto Protocol cuts, and even deeper ones, could be made at a net economic benefit to countries, even without considering the avoided climate change damages.[86] A combination of cost-effective mitigation and adaptation measures would form part of an overall strategy of linking climate change policy with sustainable development.[87] Working from this policy framework can provide important benefits for poverty relief and development, since development-focused mitigation measures can also strengthen the economic and social resilience of poorer households to adapt to the impacts of climate change.

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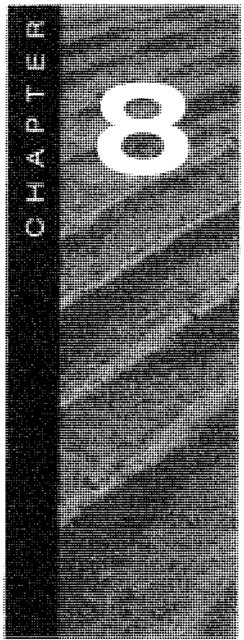


Economic guidance on prioritising invasive alien clearing to achieve the preferred public land use in South Africa

Stephen Hosking

8.1) Introduction

Land is a very special natural resource – providing space for people to live, travel and play, providing spiritual well-being for owners, and last, but by no means least, providing materials and a place to grow food. Given its importance, it is not surprising that land issues are at the heart of many development and political problems South Africa is facing. The issues are many, for instance private versus community ownership, the race and gender of the owners, loss of capital value through climate changes, poor agricultural practices or contamination, and the external impacts of land use. In this chapter, one aspect of the development problem with respect to the external impacts of land use through changes in naturally sown vegetation coverage of the land is dealt with, while considering what guidance economics can offer in this respect.

It has been recognised for some time that alien tree plantations and the infestation of alien species are reducing the water yield of river catchments through flow reduction.[1] During the past decade this concern has intensified because the area covered by these trees was steadily increasing by natural means.[2] The invasive alien species sowed themselves on land adjacent to where they were planted, and, lacking natural indigenous enemies, there was no check on their rate of spread. Deliberate planting of these trees for profit was one matter, but spontaneous growth in other areas was entirely another. In the latter case, no profit[3] was to be realised, but there certainly were losses – in the form of water yield and biodiversity.

These losses are very serious in some areas as they add pressure to an already water-stressed situation, and have led natural scientists to call for the institution of measures to contain the spread of the trees. However, there is a problem – this containment is costly and the question arises as to when these costs are justified. Economics requires that the benefits outweigh the costs – and some light will be shed on this issue. The containment programme pursued in South Africa is described and selected cost-benefit analyses carried out with respect to it is outlined.

8.2) The Working-for-Water programme

All of South Africa's total area of 1 221 040 km^2 is potentially subject to alien plant invasions,[4] but that most threatening to river flow falls in river catchments. Of South Africa's total river catchment area about 8 per cent was considered invaded in 1998.[5]

Against this background, natural scientists persuaded the government that some form of market failure was occurring and that intervention was necessary. Perhaps because this initiative was led by natural scientists, they chose not to treat the source of the problem, but the symptom. For instance, no attempt was made to internalise the costs of spread of invasives to original planters or to adjust private incentives to generate spontaneous clearing on privately or communally held land, as economists would argue should have been done. Instead, in 1995 the government opted for direct intervention by commissioning an agency to contain this invasion of largely dormant land – that sustaining limited commercial agricultural activity, or that which was publicly owned. This agency was called the National Working-for-Water (WfW) programme. In the year 2003, the programme enjoyed a government-funded budget of R442 million to carry out its tasks.[7] To a large extent this money is drawn from funds set aside for poverty alleviation (81 per cent during 2002).[8] Government views the WfW programme as a public works programme which benefits the environment as such, while at the same time creating environmental services and jobs.[9]

The agency explores techniques for containment, prioritises areas for control, and manages the containment programme. It has enjoyed considerable success up to now.[10] The National WfW programme has made rapid progress in the understanding of the nature of the problem and in developing effective techniques for containing it. A wide range of techniques is employed, from highly cost-effective biological control[11] to more expensive chemical treatment and labour-intensive manual clearing methods. With respect to the development of principles by which to prioritise areas for containment, progress also appears to have been made, but perhaps less dramatic.[12] There is still a lack of clarity about the particular sites to clear, and whether clearing should commence at these sites in areas heavily invaded or lightly invaded.[13]

Economics has much to offer in providing guidance on both of these issues – how clearing should be done and where it should be done. For some containment tasks there may be only one technique feasible, for example, manual clearing for complete eradication in a given area. In these cases economics is, of course, not necessary, but where in most cases there are many techniques to choose from, there is a need for guidance on which is efficient. To determine this, it is necessary to determine the real cost of different inputs. In this way it will become possible to compare the scientist-intensive and unskilled labour intensive alternatives. By real cost is meant the product of the unit shadow price of the input and the number of units. There are many issues in this connection; two crucial ones being the discount rate and the shadow price of labour. The discount rate that should be applied is the one most appropriate with respect to the type of decision that should be informed. In some cases the cost of raising capital is appropriate, while in others it is society's time preference rate in consumption. The shadow price of labour applicable is the opportunity cost of the labour employed. It is crucial that this cost be determined in cost-benefit analyses relating to decisions on the technique of clearing as well as prioritisation of areas for clearing (discussed below).

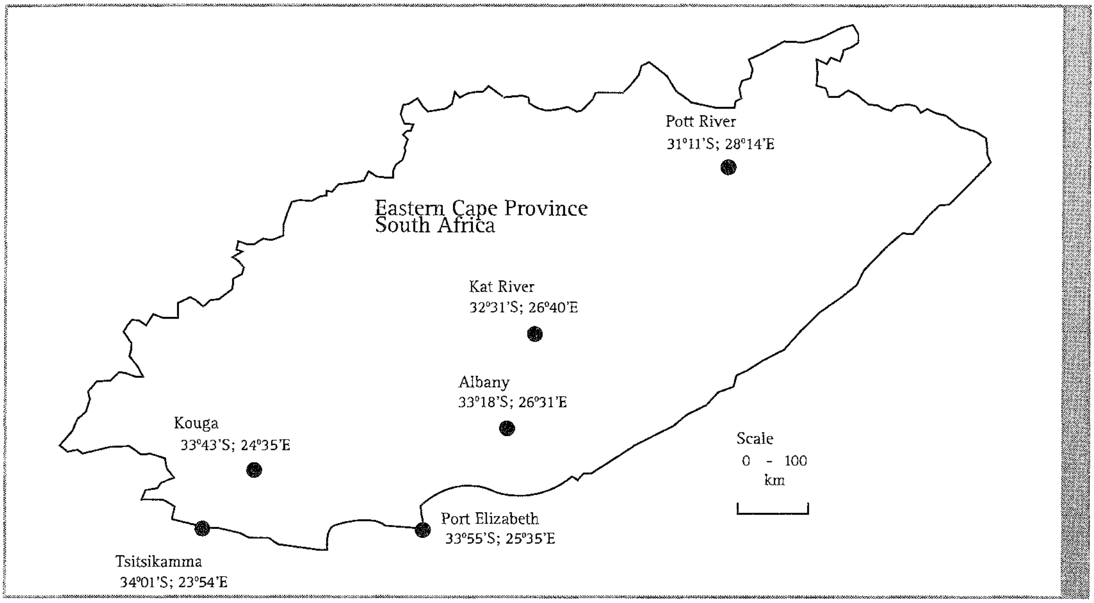
With respect to providing guidance on prioritisation of areas in which to implement containment techniques, economics can play, and is playing, a role in identifying the best options. This is done by way of individual site cost-benefit analyses. The rest of this chapter is devoted to a discussion of these contributions.

8.3) Cost-benefit analyses of the WfW programme

8.3.1 Method

Cost-benefit analysis (CBA) is the standard economic method for comparing the social costs and benefits of alternative projects or investments. Costs and benefits are measured and weighed up against each other to generate criteria for decision-making. Typically one or more of three decision criteria is used: net present value (NPV), internal rate of return (IRR) and benefit-cost ratio (BCR). A project is deemed acceptable if the NPV is positive, or the IRR exceeds the applicable discount rate, or the BCR exceeds unity.

A considerable number of cost-benefit analyses have already been carried out for the WfW programme.[14] In all of these cases it was concluded that the programme was effective. Van Wilgen *et al.* and Marais considered projects in the Western Cape, while Gillham and Haynes considered a project in KwaZulu-Natal. Two cost-benefit analyses were done in the Eastern Cape, one by Hosking and du Preez,[15] followed by a more comprehensive study by Hosking *et al.* covering six sites in the Eastern and Southern Cape Provinces, namely Tsitsikamma, Kouga, Port Elizabeth Driftsands, Albany, Kat River and Pott River[16] (see Figure 8.1).



Source: Hosking, S.G., du Preez, M., Campbell, E.E., Wooldridge, T.H. and du Plessis, L.L. 2002. Evaluating the Environmental Use of Water – Selected Case Studies in the Eastern and Southern Cape. Pretoria: Water Research Commission, p. 17.

Figure 8.1: Location of Working-for-Water programme projects: Eastern and Southern Cape

8.3.2 Scope of the study

Three cost-benefit analyses were carried out per site:

- one incorporating a water yield benefit as well as a livestock benefit;
- another incorporating a water yield benefit, an expanded agricultural benefit and a fire benefit; and
- a speculative one which not only included the water yield benefit, the expanded agricultural benefit and the fire benefit, but also a possible biodiversity benefit.

The cost estimates were held unchanged for all three analyses, with the only variation the expansion of the benefit streams.

There are four basic elements to CBA, namely time considerations, the social discount rate,[17] costs and benefits. All of these are discussed below with respect to the WfW programme. A project time horizon for these projects was set at 100 years, divided up in one-year periods. The social discount rate was determined by reference to the sources of funding for the WfW programme during the period 1996 to 2000 (10.1 per cent per annum) and only primary costs and benefits were incorporated.[18] The primary costs (fixed and variable) were estimated from key performance indicator (KPI) reports, the projections of the respective project managers and specialist advice.[19] All values were adjusted to 2001 price levels.

The main variable cost was labour. As one of the declared aims of the programme was (and still is) to uplift marginalised communities in areas where high unemployment exists, the question arose as to how labour should be valued. Three options were considered:

- the normal market wage for unskilled labour;
- the wage paid by the WfW programme; and
- the shadow price of unskilled labour.[20]

Given the extent of unemployment at the selected sites, it was deduced that the shadow price would be applicable, i.e. the subsistence wage or the minimum required to induce the workers into employment. It was further deduced that the subsistence wage would be below the market wage. However, it was not clear that this wage would be below the wage actually paid by the WfW programme, as this is also well below the market wage. This lack of discernable difference led to the decision to equate the Working-for-Water wage with the shadow wage rate and use this to calculate the labour cost in the CBA.[21] No significant secondary costs were identified other than the use of the timber as a source of firewood (an opportunity cost).

In addition to the socio-economic benefits of the WfW programme, the perceived primary ecological benefits are:

- increased water yield (m^3/ha/year);
- conservation and maintenance of biodiversity nurseries;
- improvement in water quality;
- reduction of flood and fire damage (and soil erosion); and
- gain in potentially productive land.

The WfW programme has argued on occasions that an important secondary benefit is wood industry stimulation.[22] However, this 'benefit' fails the 'with and without' test (the so-called additionality test) for inclusion in the project, because this industry can exist with or without the WfW programme.

) *Water yield*

The estimates of the increased water yield in m^3/ha were calculated taking grassland and fynbos fire cycles into account and by applying a model that generated estimates of streamflow on an annual basis for a simulation of 10 years, for situations where alien trees and plants are present and where they are absent. In this model, streamflow reduction with invasives was estimated using Versveld *et al.*,[23] with the addition of a 'rate of spread' component of Le Maitre *et al.*[24] Stream flow reduction without invasives was estimated using Chapman *et al.*[25] The water yielded at the six Working-for-Water projects in the Eastern and Southern Cape was priced in terms of relative scarcity according to the pricing methodology described by Hosking *et al.*[26] Two pricing methods were employed, namely marginal cost pricing (where water saved through the WfW programme is to be used to satisfy urban demand) and a willingness-to-pay approach (where additional water is generated for agriculture). The value selected was the highest of the two for the particular site (the best option).

) *Productive land*

The gain in potentially productive land was estimated by subtracting the agricultural potential with infestation from that without infestation. The net livestock benefit was estimated by subtracting livestock farming profit potential with infestation from the profit potential without infestation. The respective profit potentials were calculated, using the Department of Agriculture's Enterprise Budget for 2001[27] and the land that would be made available for grazing through alien tree removal. Along with the expanded agricultural benefit, all current farming practices were traced, as well as other suitable land uses and their contribution to the overall productive capacity of the area. The current ownership of cleared land played a role in the determination of future possible land uses. Publicly owned land is usually earmarked for conservation, while privately owned land has the potential for agricultural use. The agricultural practices considered were livestock, horticulture, agronomy, wild flower and honeybush harvesting and commercial afforestation.

On the negative side, clearing areas for increased agricultural activity undermines the water benefit and in some cases the biodiversity benefit. For this reason the increased agricultural activity benefit is a two-edged sword: on the one hand, it is a reason in itself for clearing, but on the other it reduces other benefits of the WfW programme. In this study, additional water use of each potentially productive land activity was subtracted and a revised water benefit profile generated. The Department of Agriculture and Water Supply's Estimated Irrigation Requirements of Crops in South Africa[28] and the computer program *Sapwat* were used to determine water requirements of crops. The Döhne Agricultural Institute's[29] estimates were used for the water requirement of livestock.

› *Fire benefit*

For the estimation of the fire benefit, the question was explored whether unplanned fires in invasive alien vegetation translated into higher fire management costs during and after such fires. The direct fire-fighting costs at the six sites were assessed using a 'with and without' invasive alien vegetation scenario. The costs of fighting fires in the pristine indigenous vegetation present at the six sites – grassland and fynbos – were compared with fire fighting costs in areas where a 50 to 100 per cent infestation level was present. The difference in these costs was deemed to constitute a benefit of the WfW programme. It could not be determined whether there was any change in the frequency at which fires occurred because of alien plant invasion.

Fire-fighting costs were generated by reference to expert opinions. These connected the cost of fires with the alien infestation level. The average infestation levels at the relevant WfW programme sites are much lower than the 50 to 100 per cent stated in the survey. They vary between 1 per cent and 20 per cent. However, within these areas there are patches that have dense infestation levels. The fire benefit was calculated for those areas.

Fire managers in both fynbos and grassland vegetation were asked what resources they would use to extinguish a wildfire in pristine indigenous vegetation under high fuel loads, with adjacent agricultural lands and under high risk conditions (climatic conditions with temperatures above 28 centigrade, medium humidity and a wind speed above 28 km/h from a prevailing south-easterly direction). Resources employed in fire fighting were divided into two categories, equipment and the number of person hours spent in fighting fires. The latter costs consisted of a Rand per hour component for normal work hours and an overtime component for the hours between 5 pm and 8 pm. Special overtime was provided for people working from 8 pm through the night and equipment used during and after the fire. The fire managers were asked how their use of the amount of resources would change with a wildfire in areas with a 50 to 100 per cent infestation under similar conditions. Only the cost of additional equipment hired and used in the fighting of pristine indigenous vegetation and invasive alien vegetation was regarded as a cost of fighting fires in infested land.

In the determination of the net fire benefit for grassland, a fire size of 50 hectares was used, which fire managers considered an average for fire in grassland. For wildfires in fynbos, it was assumed that the fire would start at less than 50 ha, but would spread to approximately 500 ha, which the fire managers agreed was typical of such fires.

The fire managers involved in the surveys agreed that there would be very little difference in the cost of physically fighting wildfires in pristine fynbos and fynbos 50 to 100 per cent infested with alien vegetation, even though the fire behaviour and damage would be different. Some argued that damage costs may be reduced because invasive clusters reduce the speed at which fires spread. Others argued that direct fire-fighting costs were higher because of injuries to workers through falling burning branches. The majority were of the opinion that the main differences in direct cost of fire management with and without alien infestation were those of post-fire-care costs (mop-up costs) and the probability of flare-ups. It was estimated that post-fire cost of wildfires in alien-infested fynbos would be more than twice that of vegetation in the pristine condition, necessitating double the number of working hours because the roots of some dead aliens smoulder for days below the ground surface. The chances of fires flaring up in alien-infested areas and starting runaway fires also was estimated to increase by about 75 per cent.

› *Biodiversity benefit*
Ecological damage such as loss in biodiversity, dam silting and erosion is an indirect cost associated with fires in alien-infested fynbos,[30] but an economic valuation of these costs can only be made once further research on the nature of the fire impact in different vegetation zones has been completed. Fire managers offered conflicting views on the potential cost of soil movement – pointing out that trees also can anchor the soil and that much of the heat generated in this burning occurs well above the immediate ground level. In grassland, differences in fire fighting costs only become apparent at infestation levels at and above 70 per cent. Pristine grassland fires spread very fast and the existence of invasive species, especially live wattle, will sometimes slow down the rate of spread of the fires and so reduce damage costs. The biodiversity loss due to fires occurs because fires stimulate alien seed germination.[31]

The idea that biodiversity can be valued is a contentious one – both because there is uncertainty over its quantifying at an ecological level and because the economic methods of valuation have almost unknown margins of error. It was deduced here that the aspect of biodiversity (or ecological processes) most amenable to valuation at the six project sites was a preference for indigenous vegetation over alien invasive vegetation and that the most appropriate method to value this was the contingent valuation method (CVM) (for a discussion on CVM, see Chapter 4).

CVM has two main advantages as a method for valuing biodiversity at the sites. Biodiversity is known for its substantial non-use component and non-use values can be captured through the CVM. Furthermore, CVM can be made very specific, much more so than, for instance, the hedonic pricing (HPM) or travel cost methods (TCM). CVM also has numerous weaknesses, not the least of which is the adequacy, consistency and impartiality of the information exchanges involved. From the outset it was realised that a full contingent valuation would not be feasible within the time frame and financial resources available. For these reasons only pilot studies were undertaken. The target population identified was users and non-users of biodiversity in the immediate area adjacent to the six sites. These groups were subdivided into tourists and local residents at the time the survey was conducted. Only household heads were sampled. A total of 219 questionnaires were administered: 30 at Tsitsikamma, 30 at Kouga, 60 at PE Driftsands, 33 at Albany, 34 at Kat River and 32 at Pott River. These samples constituted less than 1 per cent of the estimated sample population at all of the sites. The sample size was considered too small to draw conclusions about the population, but big enough to speculate about possible population characteristics.

The WfW programme's contribution towards biodiversity relates to its facilitation of indigenous tree growth and improved ecosystem functioning through the eradication of invasive alien plant species. Respondents were asked what amount of money they would be willing to pay as a municipal levy (residents) or a tourist levy (tourists) in order to facilitate WfW programme activities. On the basis of these responses a possible value of the biodiversity benefit was determined. The possible biodiversity benefit of the WfW programme was substantially higher than the fire and agricultural benefits at five of the six sites. It is deduced that non-market preference values may well be a very important component of the benefit of the WfW programme.

In addition to the small sample size problem, there were two other serious problems with this valuation exercise. First, the surveyors expressed concern about possible part-whole bias problems, despite attempts to sensitise the respondents to it and, second, some of the project managers felt that further (restoration) costs would have to be incurred, in addition to clearing, for the full return of indigenous vegetation to take place.

8.3.3 Study results

The results of selected CBAs are shown in Table 8.1 below.

Table 8.1: The CBA results

C B A	CBA used	CBA criteria	Sites: PE Driftsands	Albany	Kat River	Poti River	Kruga	Tsitsikamma
1	Water yield and livestock benefit	NPV (R)	-14 674 240	-15 232 753	-1 031 609	-1 446 624	-33 854 196	-31 757 404
		IRR** (%)	0	1.13	3.60	-3.14	7.25	5
		BCR	0	0.21	0.43	0.03	0.75	0.54
2	Revised decision criteria including expanded agricultural & fire benefits	NPV (R)	-15 407 671	-9 058 614	-1 109 142	-1 034 188	-35 950 176	-32 765 901
		IRR** (%)	Undefined*	4	4	1	7	5
		BCR	0.01	0.56	0.42	0.21	0.74	0.55
3	Revised decision criteria including agricultural, fire & biodiversity benefit	NPV (R)	67 721 069	-3 046 798	16 767 386	16 137 316	-18 244 864	-26 875 031
		IRR** (%)	202	8	Undefined*	Undefined*	9	6
		BCR	5.37	0.85	9.82	13.3	0.74	0.63

Source: Hosking, S.G., du Preez, M. and du Plessis, L.L. 2003. A cost-benefit analysis of the Working-for-Water Programme on selected sites in South Africa. Paper delivered at National Working-for-Water Biennial Research Symposium, Cape Town, 19–21 August.

Notes: * An undefined value indicates that no sign change occurs during the whole benefit cost stream. In these cases there are only benefits and no costs (positive values)
** The estimated social discount rate of 10.1 per cent was used

For CBA 1, which comprises the water and livestock benefits only and is based upon a 10.1 per cent discount rate, the NPVs were less than zero, the BCRs less than one and the IRRs less than the social discount rate. Based on these factors, the WfW project is an inefficient use of public money if the socio-economic benefit of increased employment is not internalised and if the WfW programme is considered to be equivalent to any other project bidding for scarce funds. However, the results and conclusions change as more factors are taken into account and different assumptions are made with respect to the discount rate.

When the fire benefits are added to those of agriculture (CBA 2), the NPVs are still negative, the IRR values are still less than the social discount rate and the BCRs are all less than one. When all the projects are combined into a regional cost-benefit profile, the NPV is -R95.3 million and the BCR is 0.62. It was deduced that the CBA does not change significantly when the agricultural and fire benefits are incorporated.

When the possible value of the preference for indigenous vegetation as a non-water benefit was added to the cost-benefit profile (CBA 3), the picture changed significantly. With the inclusion of this benefit, the PE Driftsands, Pott River and Kat River sites became efficient. If the project was redefined in terms of the sum of all the subprojects, the NPV comes to R52.5 million and the BCR comes to 1.14. A sensitivity analysis of CBA 3 was undertaken to establish the worth of the programme under lower social discount rates of 8.1 per cent and 5.1 per cent respectively. With a lower discount rate of 8.1 per cent, the Kouga site also becomes efficient. When the discount rate was reduced to 5.1 per cent (which allows effectively for more future benefits), all the sites became attractive economic propositions. These results are particularly interesting since they indicate that local communities have a considerable appreciation for biodiversity and indigenous vegetation. The WfW programme therefore offers much more than just water and employment; it also contributes to the sense of place and aesthetic non-use value of a specific area. Providing environmental goods and services is therefore perhaps more than just acceptable, but could even be preferred, and lends more justification for the provider-gets principle discussed in Chapter 5.

8.4 Conclusion

Economics has much to contribute with respect to providing guidance on land use in river catchments in South Africa, especially in those that are subject to invasive alien species. Cost-benefit analyses of the initiatives aimed at the containment of this invasion, known as the WfW programme, are showing that on some sites it is efficient (for example, in the Western Cape and KwaZulu-Natal[32]), but based on very restrictive assumptions, on other sites it is not, as is indicated by this study.

It is clear from this study that the results are sensitive to what is included and what is left out of the analysis, and as indicated through sensitivity analyses, which showed that the results change significantly under different assumptions about labour costs, discount rate levels and the value of the biodiversity benefit. The cost-benefit reported here on the activities of the WfW programme at the six sites in the Eastern Cape provides only qualified economic support for the programme, when focusing on water only. If the biodiversity preference benefit is excluded, the WfW programme is inefficient on all the sites mentioned above, based on strict assumptions. The inclusion of a possible biodiversity benefit, however, does significantly change the results, indicating that local people appreciate indigenous vegetation and are prepared to value these resources highly.

Important management decisions have to be made with respect to the prioritisation and continuance of various WfW programme projects. The above CBAs provide a basis for making these decisions. Subject to the substantiation of the scale of the biodiversity benefit by a more comprehensive contingent valuation and the adoption of a low discount rate, the CBAs reported in this chapter show that there is considerable merit in the projects assessed.

Acknowledgements

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3 See for example: De Wit, M., Crookes, D. and Van Wilgen, B.W. 2001. Conflicts of interest in environmental managements: Estimating the cost and benefits of a tree invasion. *Biological Invasions*, 3:167-78.

4 Versveld, D.B., Le Maitre, D.C. and Chapman, R.A. 1998. *Alien Invading Plants and Water Resources in South Africa: A Preliminary Assessment.* Stellenbosch: CSIR Division of Water, Environment and Forestry Technology, p. 1.

5 Versveld, D.B., Le Maitre, D.C. and Chapman, R.A. 1998. Alien Invading Plants and Water Resources in South Africa: A Preliminary Assessment. Stellenbosch: CSIR Division of Water, Environment and Forestry Technology, p. 35.

6 The overall goal of the Working-for-Water Programme is: By the year 2020 the Working-for-Water Programme will have contributed to a South Africa in which invasive alien species are sustainably controlled, in order to contribute to economic empowerment, social equity and ecological integrity.

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9 Working-for-Water Programme Biennial Research Report 2001/02-2002/03:1. Cape Town: Working-for-Water.

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11 Van Wilgen, B.W. In press. The costs and benefits of biological control: Studies from South Africa. *South African Journal of Science.*

12 McDonald, I. 2003. In press. Overview and the way forward. *South African Journal of Science.*

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14 De Wit, M., Crookes, D. and van Wilgen, B.W. 2001. Conflicts of interest in environmental managements: Estimating the cost and benefits of a tree invasion. *Biological Invasions,* 3:167-78; Gillham, S. and Haynes, M. 2001. Evaluating a riparian clearing programme as a water management strategy. *Unpublished paper presented at the tenth South African National Hydrology Symposium,* Kirstenbosch, Cape Town, 26-28 September; Marais, C. 1998. *An Economic Evaluation of Invasive Alien Plant Control Programmes in the Mountain Catchment Areas of the Western Cape Province, South Africa.* Unpublished Doctoral Thesis, University of Stellenbosch, Stellenbosch; Marais, C., Turpie, J., Mullins, D., Conradie, B., Khan, A., Golding, J., van Zyl, H., Grobbelaar, E., Vink, N. and Ndzinge, V. 2001. *A Cost-Benefit Framework for the Working-for-Water Programme.* Cape Town: Working-for-Water; Van Wilgen, B.W., Little, P.R., Chapman, R.A., Görgens, A.H.M., Willems, T. and Marais, C. 1997. The sustainable development of water resources: History, financial costs, and benefits of alien plant control programmes. *South African Journal of Science,* 93:404-11.

15 Hosking, S.G. and du Preez, M. 1999. A cost-benefit analysis of removing alien trees in the Tsitsikamma mountain catchment. *South African Journal of Science,* 95:442-8.

16 Hosking, S.G., du Preez, M., Campbell, E.E., Wooldridge, T.H. and du Plessis, L.L. 2002. *Evaluating the Environmental Use of Water – Selected Case Studies in the Eastern and Southern Cape.* Pretoria: Water Research Commission.

17 The social discount rate is defined in the context it is used. As a guide to the allocation of capital it is the social opportunity cost rate of capital. As a guide to when to consume it is society's time preference rate in consumption.

18 Hosking, S.G., du Preez, M., Campbell, E.E., Wooldridge, T.H. and du Plessis, L.L. 2002. *Evaluating the Environmental Use of Water – Selected Case Studies in the Eastern and Southern Cape.* Pretoria: Water Research Commission. Having a discount rate of 10.1 per cent, implies that all values after approximately 30 years approach zero. This further implies that the future benefits resulting from current expenditure are discounted. This yields a cost-bias in the calculations.

19 Buckle, J. 2002. *Personal communication.* Technical advisor for the Working-for-Water programme in the Eastern Cape.

20 Shadow prices are opportunity costs, where the latter differ from market prices due to some distortion.

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22 Marais, C. 2003. *Personal communication.* Chief Scientific Officer: Working-for-Water programme.

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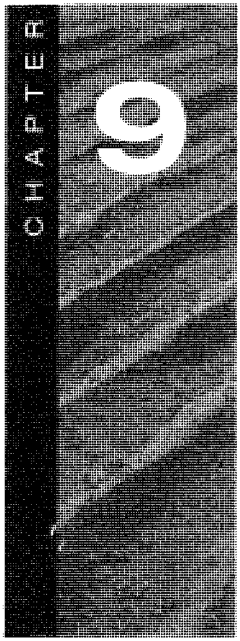


The economic value of water in South Africa

Nicola King

9.1 Introduction

Water is recognised worldwide as the most indispensable of all natural resources, and neither the maintenance of biological diversity, nor the promotion of social and economic development, is possible in its absence.[1] Today, countries have to face the growing challenge of meeting rapidly rising demands for water that are driven by increasing population numbers coupled with growing urbanisation, industrialisation and mechanisation, in the face of dwindling water supplies due to resource depletion and pollution.[2] The situation is particularly acute in the more arid regions of the world, such as Africa and in particular northern and south-western Africa, where water scarcity and associated increases in water pollution hinder social and economic development and are linked closely to the prevalence of poverty, hunger and disease.[3]

Throughout Africa, the distribution of water resources is spatially and temporally unequal, resulting in seasonal variability and unpredictable supply; furthermore, though as yet unverified, evidence suggests that projected trends in global climate change could worsen this situation and exacerbate local and regional water shortages.[4] Recent estimates suggest that almost half of the countries in Africa (24 out of 53) will exceed the limits of their economically usable, land-based water resources before the year 2025.[5] These disturbing statistics emphasise the urgent need to find sustainable solutions to the problem of securing adequate access to water supplies in Africa, highlighting the fact that the manner in which water resources are used and managed is an increasingly controversial and urgent reality.[6]

Historically, water resource managers in South Africa met rising water demands through the establishment of a complex system of engineering supply-side solutions.[7] However, due to their increasingly high associated marginal costs and limited exploitable potential, these supply-side solutions are becoming less viable, and water managers are turning to the attractive solutions offered by demand-side management.[8] Further pressures are now also being acknowledged by the establishment of ecological flow requirements for all types of water bodies as set out by South Africa's latest National Water Act (Act No. 36 of 1998, hereafter referred to as the National Water Act), placing additional constraints on the availability of water for many off-channel users. South Africa may possibly face the harrowing prospect of chronic water scarcity within two to three decades.[9]

This has obvious adverse implications, both for the national economy and the vulnerable poor communities. Social welfare and livelihoods can only be sustained through a policy environment that reduces vulnerability to resource scarcity threats. This requires technical and food security interventions. It also needs interventions that offset market and institutional failures[10] while aimed at facilitating decision-making around water resource allocation and use for all South Africans. Intrinsic to this process is the need to understand the true economic value of water resources beyond pricing measures that serve merely to cover marginal costs in the absence of market prices and associated resource value. A poor understanding of the value of water resources will continue to encourage resource overuse and degradation, poor internalisation of the associated costs and benefits of water use and sub-optimal allocation among competing users, thus further compounding threats to development. Section 9.2

provides an overview of the availability of water resources, policy goals and pricing in South Africa. The concept of value is introduced in Section 9.3, with examples of its application and use in South Africa. Section 9.4 relates value to decision-making, and the chapter concludes with recommendations and future challenges.

9.2) Water availability in South Africa

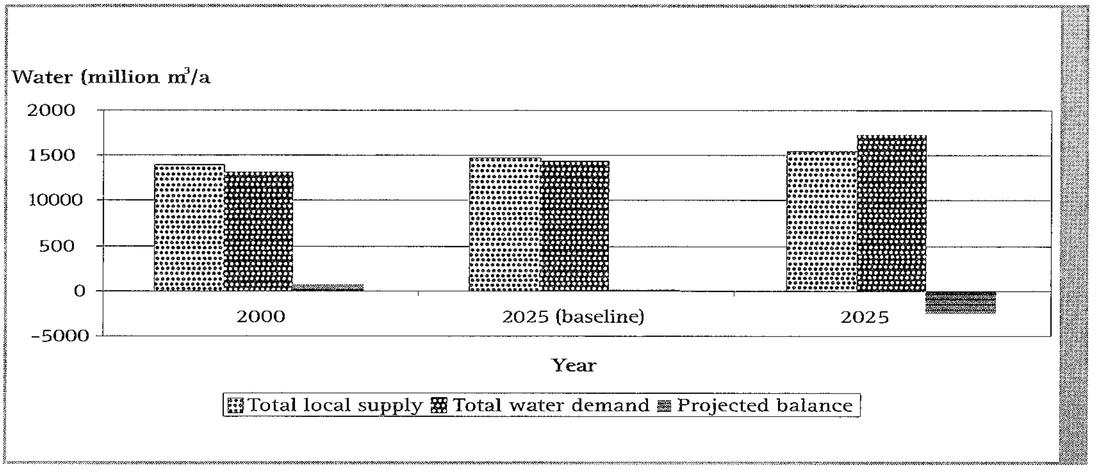
9.2.1 Water stresses and scarcity

Urgent pressures to address inequities in water use and inaccessibility among population groups, compounded by the variability in water resources, throughout the country, potentially threaten the future reliability and availability of water resources leading to water stresses and scarcity in the absence of appropriate intervention.[11] Precipitation in the country's interior is highly sporadic and unevenly distributed. The mean annual precipitation (MAP) is 500 mm/a, which is a bit more than half the world average of 860 mm per year, but in many areas of the country it is further pressured by high rates of evaporation. Only 20 per cent of the surface area yields 60 per cent of the mean annual runoff (MAR), estimated to be 49 200 million m^3. Restricting this to runoff attributable directly to South African land territory, the estimation reduces to 43 700 million m^3.[12]

With water being regarded as one of the most valuable resources towards the functioning of the South African economy, its scarcity may prove to be the limiting factor to economic growth and social development, while inducing water-related health problems and environmental degradation,[13] or, as the FAO states:[14]

> The availability of water of acceptable quality is predicted to be the single greatest and most urgent development constraint facing South Africa. Virtually all the surface waters are already committed for use, and water is imported from neighbouring countries. Groundwater resources are quite limited; maintaining their quality and using them sustainably is a key issue.

Scarcity here extends beyond the limits of some variant condition of the hydrological cycle and includes the boundaries reflected in the gap between the quantities of water supplied and demanded within the economy.[15] The degree of potential water scarcity for South Africa is depicted in Figure 9.1, which shows the total local water yield for 2000 and 2025, including baseline and high scenarios against the total local water requirements for the same period. Supply, estimated to remain relatively constant with minor adjustments for storage under construction in 2000, as reflected in the 2025 scenarios, ranges from 13 911 million m^3/a (2000) to 14 681 million m^3/a (2025b) and 15 460 million m^3/a (2025h) respectively. Demand is expected to increase from 13 280 million m3/a to 14 486 million m^3/a and 17 248 million m^3/a respectively, potentially reducing the available surplus from 631 million m^3/a to a deficit of 1 788 million m^3/a.



Source: Adapted from statistics in Department of Water Affairs and Forestry (DWAF). 2002. National Water Resource Strategy: proposed first edition. August. Pretoria: DWAF.

Figure 9.1: Demand and Supply balances for water (over time) in South Africa, excluding transfers

Regional growth in water demand is often also indicative of sectoral growth. Table 9.1 shows the disaggregated demand for water by sector per water management area for 2000. Irrigation and urban use are shown to be the largest water using sectors for 2000, followed by mining, rural demand, afforestation and ultimately power generation. The Crocodile West and Marico, the Upper Vaal and the Inkomati Water Management Areas are currently experiencing the highest demand and are projected to approach water stress and scarcity first if demand continues to grow in these areas. Based on the currently observable trends of urbanisation and economic growth, it is expected that future water requirements will increase in the urban areas, with a growth in demand for mining use in the northern parts of the country.[16]

Table 9.1: Current water requirements per sector and water management area in South Africa: million m^3

Water Management Areas	Irrigation	Urban	Rural	Mining and Bulk Industrial	Power Generation	Afforestation	Total Local Requirements	Total Local Yield	Deficit or Surplus
Limpopo	238	37	28	14	7	1	325	282	-43
Luvuvhu/Letaba	248	11	31	1	0	43	334	310	-24
Crocodile West and Marico	445	691	38	127	27	0	1 328	693	-635
Olifants	557	92	44	94	181	3	971	611	-360
Inkomati	737	65	24	24	0	198	1 048	943	-105
Usutu to Mhlatuze	404	54	40	91	0	104	693	1 010	317
Thukela	204	56	31	46	1	0	338	738	400
Upper Vaal	114	795	42	173	80	0	1 204	1 723	519
Middle Vaal	159	112	32	86	0	0	389	201	-188
Lower Vaal	525	78	44	6	0	0	653	50	-603
Mvoti to Umzimkulu	207	438	44	74	0	65	828	527	-301
Mzimvubu to Keiskamma	190	100	39	0	0	46	375	855	480
Upper Orange	777	129	60	2	0	0	968	4 557	3 589
Lower Orange	780	28	17	9	0	0	834	-1 007	-1 841
Fish to Tsitsikamma	763	116	16	0	0	7	902	437	-465
Gouritz	254	57	11	6	0	14	342	277	-65
Olifants/Doring	356	7	6	3	0	1	373	335	-38
Breede	577	43	11	0	0	6	637	868	231
Berg	301	423	14	0	0	0	738	501	-237
Total for country	7 836	3 332	572	756	296	488	13 280	13 911	631

Source: Adapted from statistics in Department of Water Affairs and Forestry (DWAF). 2002. National Water Resource Strategy: proposed first edition. August. Pretoria: DWAF.

Furthermore, water supply and demand imbalances are expected to widen where supply yields are unable to meet the demands of economic development and quality of life improvements, with critical threats evident in the Lower Orange, the Lower Vaal, and the Crocodile West and Marico Management Areas. This heightened awareness of the scarcity value of water resources and its impending consequences has encouraged water managers and ultimately users to recognise that the value generated by, or dependent on, water for the provision of goods and services, recreation, life support and ecosystem functioning must be determined and understood.[17]

9.2.2 Policy responses and implications to the threats of water scarcity

With a structured government policy focused on food production and national growth, irrigation agriculture formed the biggest user profile for water in the twentieth century, as it still does. Consequently, large investments were made in agricultural infrastructure and laws were introduced to protect the water rights of riparian farmers. However, rapid industrial growth proved to be a significant competitor to the agricultural sector, and the 1956 Water Act was passed to encourage efficient inter-sectoral allocations. Droughts in 1966 only served to highlight the impacts of certain activities, such as afforestation on the flow of rivers and their impact on downstream users. Decision-making attitudes that had perceived water as an abundant resource began to change. The need for conservation measures increased, encouraging a re-evaluation of the existing water legislation. Today a new and highly sophisticated Water Act exists with a clear focus that includes the role of the environment and water demand management strategies.[18]

The National Water Act[19] specifies that the Government is the trustee and custodian of the nation's water resources and in turn must ensure that water is protected, used, developed, conserved, managed and controlled in an equitable and sustainable manner for the benefit of all people. It further states that the necessary measures must be taken by the government to ensure that its citizens have access to a healthy environment that will be sustained into the future. The provision of reliable, clean water is implicit to the establishment of an enabling environment that supports well-being, health and environmental sustainability.

Consequently, the focus of the National Water Act is directed at the development of a comprehensive framework for water resources management that reflects the social, economic and environmental objectives of the nation. It stipulates that the allocation of water among users after the reserve requirements have been met be *guided by social equity and economic efficiency goals.*[20] The 'reserve' refers to the quantity and quality of water necessary to satisfy the basic human water needs and to protect aquatic ecosystems. This is guaranteed as a societal right, after which water use for all other purposes will be determined according to administrative authorisations.[21] Another important aspect of the Act is the provision made for water demand management and the use of economic incentives for water management. The Act states that 'the Minister may establish a pricing strategy for charges for any water use (Section 56)', and that such a strategy for raw water user charges may employ economic mechanisms such as the imposition of economic charges, water licence auctioning and the establishment of water markets as possibilities for ensuring allocative efficiency among users.[22]

The Act further provides recommendations on the following:

- forecasting water demand;
- strategies for service provision;
- policies on water rights, cost recovery, pricing investment, private sector roles, environmental protection and restoration;
- river basin activity and relationships;
- interrelations between water sources; and
- integrated basin and watershed management.

The implementation framework for the National Water Act is addressed in the National Water Resource Strategy (NWRS). The NWRS has four objectives, namely:

- to establish the national framework for managing water resources;
- to establish the framework for catchment management strategies. A catchment management strategy is the framework of water resource management in a water management area;
- to provide information; and
- to identify development opportunities and constraints.[23]

Historically, water management was administered by offices of the national department at a regional level. According to Principle (23) of the White Paper on Water Management,[24] *the responsibility for the development, apportionment and management of available water resources is to be delegated to a catchment or regional level in such a manner as to enable interested parties to participate.* This in turn requires investment in technical and managerial expertise at these levels of decentralisation, so that the national objectives of a more responsive and effective water management process may be achieved. Support from the national department in the form of capacity building and effective monitoring is expected to facilitate the process of decentralisation, ensuring that equity and corrective action goals are strengthened. The successful implementation of the Water Act and consequential effective water resources management will also depend on cooperative governance across all spheres, including environmental and development policies.

9.2.3 Water pricing and tariffs for South Africa

The appropriateness of a fitting water pricing system underpins demand-side management strategies. This is based on the notion that cheap water will be wasted and that the correct pricing of water will instead lead to it being treated as a precious resource and an efficiently used commodity. Numerous approaches to this question of efficient pricing have been addressed, including delivery cost pricing, electricity and pumping cost-based pricing (for groundwater exploitation), marginal cost pricing, opportunity cost pricing, scarcity value, marginal value pricing and value added. Each approach has its shortcomings, and South Africa now not only has to find a way of measuring consumption and valuing its water resources, but also has to address the welfare pressures of a large population living without basic domestic supplies and sanitation facilities.

Underpinning the argument for any pricing strategy is the distinction between a tariff and a price for water. A water price relates to the broader market for water resources and includes the aggregated tariffs for all user demands. Water tariffs, on the other hand, refer specifically to a monetary charge that each user pays for withdrawing water from the bulk water supply (in the case of direct abstractors) or for water services (such as municipalities, industry or households). These tariffs include payment for accessibility to the resource, operation and maintenance costs and a user fee discussed later in this chapter. The structure of water tariffs is also further complicated by the nature of the resource, as in some cases water is re-used or re-cycled and the associated tariffs may include direct extraction charges coupled with pollution charges and rebates for efficient water use. The nature of pricing discussed here refers to pricing of water based on water service charges and not the pricing of water rights, a separate issue.

In order to capture the associated costs of water provision, service and use, tariff structures are set up in a manner that aims to address the goals of a particular pricing strategy. Three types of pricing strategies are widely recognised, although the first is the more commonly adopted. They are financial pricing, economic pricing and environmental pricing. Financial pricing strategies focus on the recovery of operation, maintenance, servicing and capital investment costs for water delivery, and are reflected by average costs (the cost of delivery divided by the number of users). Economic pricing strategies aim to reflect and capture the opportunity cost of water provision (the gains and losses of allocating water to one use over another and in one time period versus a later one), they tend to reflect opportunity and marginal costs associated with long-term investment planning and inter-generational water demands. By doing so, the scarcity value of water is often reflected as the opportunity costs of use today may lead to declining future development as resource demands increase and the available resource becomes relatively scarcer. Alternatively, environmental pricing strategies recognise that there are environmental costs associated with water use that in turn impact, the potential for resource use by other users. Known as externalities, these strategies aim to reflect and internalise these costs into the water management and decision-making process. Questions arise as to whether users should be expected to pay for investment costs as well as maintenance and operation costs, and the debate extends to the burden of costs associated with environmental externalities.

Intrinsic to the development of any pricing strategy and its underlying tariff structures is an understanding of the associated developmental goals (nationally, regionally, and locally) such as economic efficiency and equity goals, the availability of investment information, and the constraints imposed by administrative and transaction costs for implementation. The reason being that some of these goals may go against optimal pricing strategies where users are unable to pay for costs of provision let alone the associated opportunity and environmental costs. Water pricing may also appear to be inappropriate when used in direct opposition to developmental goals such as sectoral growth for agriculture requiring subsidisation of water-intensive agricultural inputs or where the resource is superabundant.[25] Water pricing does however give some indication of a baseline level of 'willingness-to-pay' by users for access to and use of water resources.

Market prices for water may diverge significantly from their shadow prices (economic opportunity cost), due to the existence of distortions such as monopoly practices, external economies and diseconomies, taxes and subsidies. Furthermore, the practice of shadow pricing allows the water sector to address social and political goals across sectors and within the water sector itself that are overlooked by strict efficiency goals.[26] In South Africa, numerous criteria and requirements for the setting of water tariffs exist, the most fundamental being that:[27]

- Water pricing policies must promote *equity*, such that the reserve requirements for basic needs are met first while addressing inadequate access and income-inequality constraints. This may require the use of subsidies for poor consumers.
- *Ecological sustainability* must be supported, with the aim of internalising external environmental costs into the water price.
- *Financial sustainability* is imperative, implying that all consumers must face at least some positive marginal price for water, while a water tax base is encouraged to cover both capital and operational costs.
- Pricing policies are to account for *efficiency* goals recognising the economic and social nature of water.

Table 9.2: Illustrative disaggregation of the various pricing tiers for the Umgeni, Mnyamvubu, Mvoti, and Vaal river WMAs***

RAW WATER CHARGES – TIER 1ª									
WMA	Government Water Scheme / Irrigation district	Charges for irrigation purposes					Charges for domesti		
		m³ quota per ha**	R per ha i.r.o. water made available from total quota or portion thereof: Operation and maintenance	Depreciation	Total tariff R/ha unless indicated otherwise	Payment dates	Operation and maintenance	Return on asset	D c
11	UMGENI RIVER (MIDMAR, ALBERT FALLS & INANDA DAMS)								
11	MNYAMVUBU RIVER								
	(a) Farmers	7 600	307.73	45.80	353.53	31/07			
11	MDLOTI RIVER								
	(a) Irrigation use sector	4 600	250.91	46.00	296.91	31/07			
	(b) Domestic & industrial								
8	UPPER VAAL RIVER SYSTEM (Excl. Sterkfontein dam) In excess of servitude water quantities						0.093	0.122	(
10	VAAL RIVER (VAALHARTS & LOWER VAAL) (a) From Vaalharts canal system					31/07			
	(i) Vaalharts Water User Association and D&I users	9 140.00	639.71	29.38	669.09	31/01			
	(ii) Taung & Ganspan emerging farmers		118.56	Nil	118.56				
	(b) Bloemhof Dam to Vaalharts Weir		0.24 c/m³	0.27 c/m³	0.51 c/m³				
	(c) Vaalharts Weir to Schmidtsdrift	9 140.00	21.94	24.68	46.62	31/07			

Four tiers of pricing that address the above policy goals are evident in the country. First-tier pricing reflects raw (or bulk) water prices and encompasses what water extractors, whether individuals, water boards, municipalities or water user associations, pay the Department of Water Affairs and Forestry supply schemes for water. This tier includes a resource management charge, recently included for catchment management. Second-tier pricing relates mainly to the water boards selling water at a wholesale or bulk level. The third tier captures the retail price of water, charged by municipalities to end-users. The fourth tier is the waste discharge charge system addressed in Chapter 11. An example of these pricing tiers is given in Table 9.2.

It is evident that, based on these prices, the true economic value of the water resource itself is not explicitly captured by water managers and users in decision-making. To ensure that the economic costs or benefits foregone in one particular use of water over another are internalised in decision-making it is necessary to understand what the actual value of water is, especially where monetary values cannot easily be assigned to the worth of non-consumptive functions such as maintenance of human life and ecosystem sustainability.

...ral use: R/m³	WATER MANAGEMENT CHARGE[b]: Tier 1 extension: R/m³			WHOLESALE: TIER 2[c] (R/m³)				RETAIL – TIER 3[d]							
								R/m³				R/m³			
								Domestic				Industrial and Commercial			
Total tariff	Domestic & Industrial	Agriculture: Irrigation	Forestry	Raw water	Bulk water	Reticulation	Waste water	0kl-6kl	6kl-30kl	30kl+	fixed charge	0kl-6kl	6kl-30kl	30kl+	fixed charge
0.1564	0.86	0.83	0.81	1.12	2.14	5.61	4.23	0.95	0.92	1.27	2.44	2.43	2.88	2.88	20.52
	0.86	0.83	0.81	1.12	2.14	3.61	4.23	0.95	0.92	1.27	2.44	2.43	2.88	2.88	20.52
	0.86	0.83	0.81	1.12	2.14	5.61	4.23	0.95	0.92	1.27	2.44	2.43	2.88	2.88	20.52
0.399*															
	0.75	0.62	0.62	1.20	2.60	N/A	N/A	0.00	2.43	4.13	7.05	N/A	N/A	N/A	N/A
1.295*															
	0.49	0.48	N/A	1.20	2.60	N/A	N/A	0.00	2.43	4.13	7.05	N/A	N/A	N/A	N/A
1.295*															
1.295*															
1.295*															

Source: DWAF. 2003. Based on information supplied by the Deputy Director: Water Pricing. Pretoria: DWAF.

Notes:
a: Charges levied on water extractors by DWAF for those using DWAF water supply schemes. b: Charges paid to DWAF, eventually to the CMA's; c: Charges levied by water boards on municipalities and other end users; d: Charges levied by municipalities on end users
* The amount paid by the water board for industrial and domestic use disaggregated by the components to the left of this figure; ** Indicates the maximum amount that an irrigator can extract from a river; *** No single user will pay all these charges at all levels, the charge will depend on where in the system the user is sitting. All these charges are for illustrative purposes only, though they are based on actual 2003 data
WMA: Water Management Area

9.3 The economic value of water in South Africa

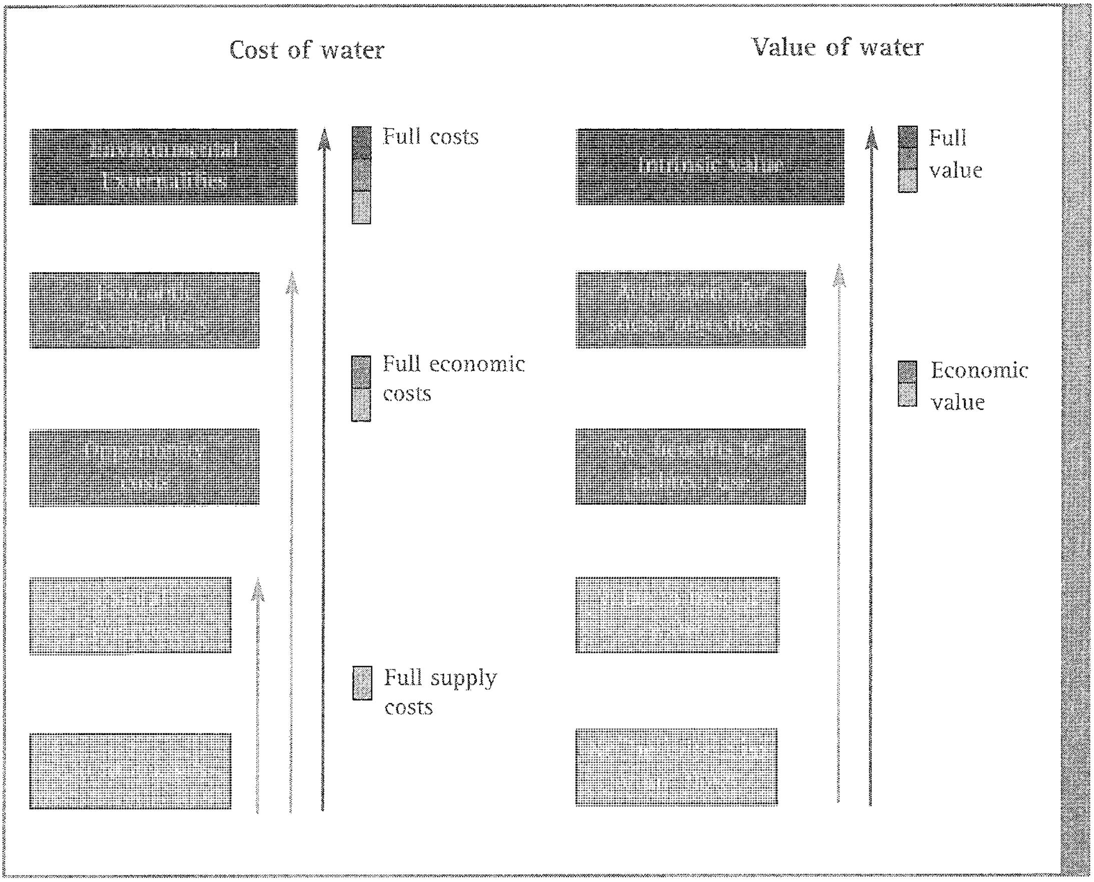
9.3.1 Economic value versus price of water

Both the 1992 Dublin Water Principles and the World Summit on Sustainable Development (WSSD) 2002 Water Principles support the notion that 'water is an economic good' and should be managed accordingly, to promote the policy goals of equity, efficiency and sustainability in the water sector. Intrinsic to this process is the use of pricing, conceptually simple to develop, but politically sensitive to implement.[28] Ultimately, pricing policies aim to understand the full cost of water supply and the full value of water in-use, including the implications of different tariff structures for different user groups. Unfortunately, water literature at times tends to create ambiguity around the fundamental concepts of full-cost pricing, water value-in-use and water tariff or price.

Figure 9.2 depicts these complexities in the levels of water pricing and highlights the difficulties faced by water managers when striving to price water so that the full costs and benefits of use are internalised. The figure on the left-hand-side focuses on five levels of costs of water supply including operation and maintenance costs, capital costs, opportunity costs, economic externalities and environmental externalities. Commonly water tariffs tend to under-price the resource as they relate specifically to the basic costs of water supply focusing on operation and maintenance costs – the costs associated with maintaining water infrastructure and capital charges. To overcome this shortfall, the full economic cost of water should be incorporated into tariffs by adjusting for the opportunity costs of water and the costs of economic externalities. Environmental economic theory has developed this thinking further by recognising the impacts on the environment of water use beyond the social and economic capital impacts, proposing that the costs of environmental externalities (positive or negative) be included in tariff structures as well. This would mean that for the 'true' full cost of water supply to be reflected, all five levels of costs need to be captured in pricing strategies and tariff structures.

However, pricing based on supply costs, albeit 'full-cost' supply costs, does not reflect the economic value of the resource. The full economic value of water incorporates many of the less tangible benefits of losses associated with water use as outlined on the right-hand side of Figure 9.2, including: benefits to users, benefits from returned flows, indirect benefits and intrinsic values. In brief, it captures the use-value of water rather than the cost of supply and allocation, and incorporates re-use and recycling aspects. The economic value of water includes the value of water in use by different users, and the net benefits from return flows as well as benefits derived from indirect use such as the protection of ecological functioning and adjustments for societal objectives. Intrinsic or existence values, as reflected by anthropocentric demands, are then added to the economic value for water to obtain the full value for water resources.

Water pricing and tariff determination (amount set by the governing body, social or political system to ensure cost recovery, equity and sustainability; may or may not include subsidies) are implemented as tools to achieve water policy goals. Prices or tariffs do not necessarily reflect the full cost or use-value of water resources within an economy, but in South Africa the raw water charges tend to be equal to the cost of operation and maintenance, depreciation and a capital component. South African water-pricing strategies have reflected this approach to pricing in the country's long history of water resource subsidisation across various sectors. This, however, is being addressed as the economic value of water is being recognised.



Source: Adapted from Rogers, P., de Silva, R., Bhatia, R. 2001. Water as an economic good: How to use prices to promote equity, efficiency, and sustainability. Water Policy. December.

Figure 9.2: Underlying principles for the cost and value of water

To evaluate the efficacy of pricing policies and allocation decisions, it is necessary to understand the value-in-use for water resources and, also important, the marginal value at which consumers trade preferences. A better understanding of this anthropocentric behaviour directing choice and the demand-supply dichotomy facilitates the potential internalisation of externalities into decision-making around water resources, while at the same time driving water availability to its highest competing users and most efficacious application.

9.3.3 Applications of the economic value of water in South Africa

A number of studies have been conducted to determine (and to get a better understanding of) the value of water resources in the country and the associated implications for economic development and social welfare changes. The majority of these studies focus on irrigation agriculture and the contribution of water to this sector,[32] but an increasing number of studies are concentrating on municipal and domestic demand,[33] with emerging studies looking at industrial demand.[34] Using the information provided by a number of these studies, some insight can be gleaned into some of the results and complexities associated with determining values for water in South Africa, many of which are congruent with international findings. Practical applications of environmental economics to the estimation of water values for South Africa are included, ranging from municipal or domestic water use, industrial and agricultural water use, to water values for ecological functioning.

- *Municipal/domestic water values*

  Municipal and domestic demand functions for numerous countries in the developed and developing world have been estimated.[35] Only a few studies on demand estimation and elasticity derivation have however been undertaken for developing countries. In South Africa, empirical analyses were used to determine price elasticities of demand for domestic water users in the former Witwatersrand region, the Tshwane Metropolitan area, the Eastern Cape and Alberton/Thokoza respectively, while water values were only determined for Tshwane and the Eastern Cape.[36] The contingent valuation approach has also been widely used to determine the value of water service provision.[37] Generally, the price elasticity of municipal demand is expected to be low, with marginal water values being higher than corresponding irrigation values. The results of the abovementioned studies are outlined in Table 9.3.

  Typically, water use among low-income users is restricted to water for basic needs such as drinking, cooking and basic sanitation, categories of demand that are considered to be inelastic. By implication this means that users in his category will be less responsive to price changes, but will be more likely to incur the associated costs as a proportionately larger share of the household budget. Furthermore, this user category often expresses a higher

9.3.2 Approaches to determining the value of water

The willingness by consumers to make trade-offs is what determines value, in particular the marginal value for a specific good or service. For marketed goods, this willingness refers to the willingness-to-pay a specified monetary price for a good; for water resources it is the maximum amount a user would be willing to pay for the resource.[29] Where market transactions are observed, market-clearing prices will represent the value of the respective resource and where markets do not exist, market-like transactions can indicate the amount that consumers are willing to pay for a particular resource and thereby provide a measure of at least a lower bound value. For water resources, pure markets (markets that are free of transaction costs and imperfect information, with well defined property rights) rarely exist; hence alternative approaches to determining value have to be considered. Three approaches provide more complete demand information, namely the formal demand curve, the production function and the financial budget.[30] Demand information may be obtained through the traditional measures of the consumption and production functions or their associated duals, through non-econometric approaches such as the direct measure of willingness-to-pay through contingent valuation or indirect approaches of hedonic property valuation, travel costs methods and varying parameter demands, or through normative approaches such as linear programming (see also Chapter 4 in this regard). The choice of approach will depend on the nature of the results required and the availability of information.

Valuing water use is also dependent on the definition of use, as it has a number of dimensions, namely quantity, quality, timing and location. Use values have to be adjusted for in-stream and off-stream users to reflect the location and the implied costs of transportation. Quality aspects have to be accounted for along with the nature of the quantity used, as water can be withdrawn but not consumed. Hence, the trade-offs between competition and complementarity of users arise. Furthermore, the different measures of value produce different results of value, which are not always directly comparable. Average and marginal values differ widely as do long-run and short-run values. Where constant returns to scale are exhibited, however, these differences may be equated, and then usually reflect long-run values.[31]

Table 9.3: Comparative municipal and domestic water use studies for South Africa

Study	Region	Year	Pricing policies	Price elasticities	Water values
Döckel & Groenewald	Witwatersrand, RSA Cross-sectional data, macro-econometric model	1973	Flat rate & increasing block rate tariffs	D: -0.63 to -0.84	None
Goldblatt settlements,	Informal urban Witwatersrand, RSA Contingent valuation	1999	Flat rate & increasing block rate tariffs		Recurrent cost recovery
Veck & Bill	Thokoza, RSA Contingent valuation, Econometirc approach	2000	Related tariffs for levels of service as stated in the study, & increasing block rates	D: -0.12 to -0.14 S: -0.19 to -0.47 Average: -0.14 to -0.18	
King	Tshwane Municipality, RSA Time-series & cross-sectional data, econometric model	2002	Increasing block rate tariffs	D: -0.09 to -0.32	R2.61 to R15.36 (per m^3)
Mavis	Rural Limpopo Province, RSA Contingent valuation	2002	Related tariffs for levels of service		R18.25 to R23.48 (per type of service)
Conradie	Fish-Sundays Scheme, Eastern Cape, RSA Econometric model	2002	Flat rate & increasing block rate tariffs	M: -0.27 to -0.70	R2.40 per m^3

Source: Own compilation

Notes:

D refers to domestic water use; S refers to sprinkling water use; M refers to municipal water use

The studies referred to are listed in endnote 38

willingness-to-pay for water and water services, as these services form an intrinsic component of their daily survival, but are often unable to do so. High-income residential water users also reflect inelastic demand characteristics, as their water use tends to form a small portion of their household budgets and may extend beyond the demand for water for mere basic needs provision. These users are often less willing to pay for changes in water or water provision services, as they are already benefiting from good levels of service. Despite these complexities, in order to address the policy problem of whether supply pricing mechanisms can be used to encourage a reduction in the quantity of water demand for various user categories, it is necessary to know the level of demand for different user categories and the responsiveness of users to price changes. The following text box gives a brief review of one method available for determining domestic water value.

Box 9.1

An example of domestic demand estimation using econometrics

Residential water demand based on utility theory using time-series data for different cross-sections of the Tshwane Municipality is estimated below. The pragmatic approach is followed and seemingly relevant variables were included in the estimation, such as rainfall and temperature. Income and price elasticities are determined from the estimations and the former is used to determine value. The generic model is as follows:

quantity water demanded =

$$f\left(\begin{array}{l}\text{average price, marginal price, number of users, rainfall, maximum temperature,}\\ \text{household income, population, seasons}\end{array}\right)$$

with specifications for two levels of users, namely domestic use and agricultural small-holding use as follows:

$$Q_{wd} = f(P_{wd}, Other) \quad (1\text{-}1)$$

$$Q_{wa} = f(P_{wa}, Other) \quad (1\text{-}2)$$

Where,

Q_w = the quantity of water per capita per annum (cubic meters)

P_{wd} = the price of water (per cubic meter) for domestic use

p_{wa} = the price of water (per cubic meter) for agricultural small holdings

from which the derivative of a log function yielded the price elasticity's of demand for water as follows:

$$\frac{\partial Q}{\partial P} < 0, \quad \textit{for each sector} \quad (1.3)$$

The results were then fitted to a consumer surplus equation in order to determine the marginal value for water as follows:

$$\textit{Marginal value water} = \left[\frac{\frac{P^* Q_2^x}{1-x}\left(\frac{Q_2}{Q_2^x} - \frac{Q_1}{Q_1^x}\right)}{(Q_2 - Q_1)}\right] - P \quad \text{where } x = \frac{1}{|\varepsilon|} \quad (1\text{-}4)$$

Source: King, N.A. 2002. Valuing a City's Water: The Case of Tshwane. MCom thesis. University of Pretoria, Pretoria.

Once price data and elasticities have been obtained it may be possible to determine marginal values for water. Marginal values are useful, in their being able to influence policy efficacy and to determine levels of implementation. An example of how water values may differ across user groups and for different levels of water availability is given in Table 9.4. Water values are determined for three user categories, namely agricultural smallholdings demand, residential demand at high-income and residential demand at low-income levels.

Table 9.4: Willingness-to-pay for increments in water availability by three user groups in Tshwane

Users	Time	Reductions in water availability from current levels*				
		Current Price**	1% Value	10% Value	25% Value	50% Value
Agricultural smallholdings	SR	3.42	3.44	3.65	4.09	5.21
	LR	3.42	3.44	3.96	5.14	9.35
Domestic high income	SR	2.53	2.57	2.67	2.94	3.59
	LR	2.53	2.57	2.99	4.01	8.01
Domestic low income	SR	2.55	2.58	2.89	3.60	5.93
	LR	2.55	2.61	2.61	5.10	15.36

Source: King, N.A. 2002. Valuing a City's Water: The Case of Tshwane. MCom thesis. University of Pretoria, Pretoria.

Notes:
*Water reductions from the original / current level of consumption in kilolitres
**Price is recorded in South African Rands per kilolitre
SR = Short run; LR = Long run

It is interesting to note that the average price for residential water use in Tshwane ranged from R1.81/kl for old age homes to R3.42/kl for agricultural smallholdings. Mamelodi, Attridgeville and Pretoria faced similar charges for household water use, ranging from R1.22/kl at the lower consumption levels to R2.55/kl on average and R3.15/kl at the highest consumer class. However, the resultant marginal values for water in Tshwane based on the current level of use, a 1 per cent, a 10 per cent, a 25 per cent and a 50 per cent level of reduction from the current levels of water demanded indicated that consumers are actually willing to pay substantially more for water, especially when faced with increasing scarcity. The results indicate that agricultural smallholding users are willing to pay R5.21/kl for a 50 per cent increase in the availability of water in the short run, an increase of 52 per cent from the price currently being paid, and R9.35/kl in the long run, an increase of 173 per cent. Residential users at the high-income level are willing to pay R3.59/kl for a 50 per cent increase in availability in the short run and R8.01 in the long run, while low-income users indicate a willingness-to-pay for water at R15.36/kl in the long run when facing the threat of a fifty per cent reduction in the resource. This may be attributed to the fact that much of this water is used for essential basic needs such as drinking and washing.[39]

Water managers in South Africa are also interested in the willingness to pay by consumers for access to various levels of service for domestic water provision. The contingent valuation approach is often used to estimate these values.[40] However, there are discrepancies in this approach that arise through survey design biases and respondent biases but these are universal and have been dealt with in the international literature. Interestingly, indications in South Africa show that residents in informal settlements and rural areas do not necessarily perceive water to be a free good but are actually willing to pay significant amounts for improved levels of service. However, many of these households are constrained by their low income levels and their proposed payments are often practically unable to cover the capital costs of improved service delivery to free-standing individual plots or homes. Hence the levels of willingness-to-pay revealed are often only enough to cover recurrent costs at low levels of water consumption. The following text box gives an example of a contingent valuation survey done for rural water service provision. The results indicated that respondents were willing to pay on average R18.50 for connection to yard taps and R23.48 for household reticulation.

Box 9.2

Using contingent valuation to estimate willingness to pay for water service provision in the rural Limpopo Province

It is recognised in the country that for water planning and policy to be effective it has to take into account not only the necessity of supplying water to the rural areas but also the ability and preparedness of rural water users to pay for the resource, including decisions for infrastructure development and the design of appropriate tariff structures. Fundamentally, water managers have to know whether users in the rural areas are unwilling or unable to pay for water: Do objections arise around the notion that water must be paid for because it is a natural resource or because

continued on next page >>

historically it has not been paid for from the household budget, or is there just a general dissatisfaction with the level of service provided?

Ordinary Least Squares is used here to estimate the following model based on contingent valuation theory:

$$\ln WTP = C_0 + C_1 \ln QU + C_2 ATS + C_3 SLS + C_4 ELH + C_5 TAS + C_6 RCS + C_7 HHI + E$$

Where:

ln *WTP*: the log of the maximum WTP for a household per month for water such that,

$$\forall_1 > 0; \forall_2 < 0; \forall_3 > 0; \forall_4 > 0; \forall_5 > 0; \forall_6 > 0; \forall_7 > 0$$

QU: the number of litres used by the household per day. A negative or positive relationship is expected between litres used per day and willingness to pay for an improved water supply service. It will depend on whether households place more value on the opportunity cost of obtaining more water or on the price involved in paying for more water used

ATS: dummy variable for the existence of an alternative water source, 1 represents a borehole and zero otherwise

SLS: measures the respondents' satisfaction with the current level of services, i.e. street taps. If respondents are satisfied with the street taps, we expect them to be more willing to pay for the service. Therefore a positive relationship is expected between willingness to pay and SLS

ELH: dummy variable that measures the educational level of the household head

TAS: time accessing service, as theory suggest households are more willing to pay for improved water supply services when the opportunity costs in terms of time (for travel and queuing) or distance to an existing source are high

RCS : Reliability of water source is very crucial to household's WTP

HHI : Household income

E : Error term

Source: Mavis, M.N. 2002. Willingness to pay for water in rural South Africa: a case study of the Kutama/Sinthumule. Paper presented at the Second World Congress of Environmental and Resource Economists, Monterey, California, 23-27 June.

) *Environmental use values for water*

Fundamental to the National Water Act is the prioritisation of the protection and sustainable management of the country's water resources. This raises the question of what is the value of water retained in river systems to maintain the provision of environmental services and ecosystem functions. As these services tend to be intangible and have intergenerational impacts, with often non-consumptive use values (but may also exhibit non-use existence value), it is not easy to capture their value. One of the more commonly used approaches is that of contingent valuation which attempts to give some indication of a market price for the resource. Environmental use values for water include:

- protection of aquatic ecosystems;
- primary and secondary contact recreation;
- visual amenity;
- maintenance of water supplies for other users such as irrigation or industry;
- streamflow regulation;
- sedimentation control;
- flood control;
- water quality control; and
- maintenance of ecosystem functions and environmental services.

The text box below gives an example of an approach used in South Africa to obtain environmental use values for the Keurboom Estuary.

Box 9.3

Determining water values for environmental use

To achieve a better understanding of the value of freshwater inflows that maintain environmental services in the Keurboom Estuary, a contingent valuation study was conducted. Respondents were asked how much they were willing to pay (WTP) to prevent the loss of these services, understanding that a reduction to the inflow from the Tsitsikamma catchment could potentially lead to the closure of the estuary mouth. It was recognised that the reductions to instream flow resulted from an increase in the number of water-consuming alien species in the area, the removal of which was being targeted by the Working-for-Water Programme under the Department of Water Affairs and Forestry. The identified respondents were all users of the estuary and included anglers, baiters, swimmers, water frontage/access, birdwatchers, bathers and scenic benefit. From the sample of 150, the WTP for prevention of reduced freshwater inflow into the Keurboom Estuary was estimated at R274 per user and the total recreation value of water to the Estuary was estimated at R3 626 128 or 4.6c/m^3/a. The environmental value of water was estimated at about 5c/m^3/a. These estimates did not include upstream benefits or benefits from fire control and biodiversity preservation.

Source: Hosking, S.G., du Preez, M., Campbell, E.E., Wooldridge, T.H. and du Plessis, L.L. 2002. Evaluating the Environmental Use of Water – Selected Case Studies in the Eastern and Southern Cape. Pretoria: Water Research Commission.

Another central component to water management strategies in the country is the removal of invasive alien plant species that are highly water dependent, to improve streamflow. The invasions by alien species are perceived, at least in the ecological community, to be one of the largest threats to ecosystems in the world.[41] The United Nations Environment Programme (UNEP) noted that invasive alien species are considered second only to habitat loss as the major threat to native biodiversity and the integrity of natural communities (see also Chapter 8).[42] The largest impacts are experienced in the reduction of streamflow, loss in biodiversity, changes in productive capacity of land and a loss of grazing potential, increase in fire hazard, increase in erosion and the destabilisation of river banks and a loss of recreational activities.[43] An overview of some of the water values obtained through projects aimed at the removal of these species is given in Table 9.5. These values are based on the conservation value of water approximated by its agricultural and urban use value (best alternative use value).

Table 9.5: Water values for the removal of invasive alien vegetation in the Eastern Cape Province (2000)

Site	Value of water (c/m^3)	Valuation Method
Tsitsikamma	12.5	willingness-to-pay
Port Elizabeth Driftsands	0.0	potential user response
Albany	0.0	user response
Kat River	15.7	willingness-to-pay
Pott River	0.0	Non-scarce resource

Source: Hosking, S.G., du Preez, M., Campbell, E.E., Wooldridge, T.H. and du Plessis, L.L. 2002. Evaluating the Environmental Use of water – Selected Case Studies in the Eastern and Southern Cape. Pretoria: Water Research Commission.

) *Industrial water values*

Surprisingly, there is relatively little literature concerning industrial water demands. A few studies are evident, tending to focus on a cost approach to econometric estimation,[44] although some have attempted to value water by using the marginal product approach.[45] Reasons for this situation may be explained by the historically low pricing structures that industry faced and the widely held perception that industrial water use is better suited to engineering than to economic analysis. In South Africa, the industrial sector is one of the fastest growing sectors, relying, to varying degrees, on water resources as an input to many production processes. Marginal values for primary industry water use in the Tshwane Metropolitan area are shown in Table 9.6. Derived from the pragmatic approach outlined in the first text box, above, the results indicate that industry in this area operates at the margin for profitability and would be willing to pay relatively small incremental amounts for water when threatened with rising scarcity. This may also allude to the possibility that the industry reviewed uses water as a marginal input to the production process.[46]

Table 9.6: Willingness-to-pay for increments in water availability by a primary industrial user

		Reductions in water availability from current levels*				
Users	Time	Current	1%	10%	25%	50%
		Price**	Value	Value	Value	Value
Industry	SR	3.01	3.02	3.09	3.52	3.52
	LR	3.01	3.02	3.10	3.59	3.59

Source: King, N.A. 2002. Valuing a City's Water: The Case of Tshwane. MCom thesis. University of Pretoria, Pretoria.

Notes: *Water reductions from the original/current level of consumption in kilolitres

**Price is recorded in South African Rand per kilolitre

SR = Short run; LR = Long run

) *Agricultural water values*

Agriculture is regarded as the most important consumer of water in South Africa, consuming approximately 54 per cent of total use. As a result numerous studies have been conducted on the value of water to agricultural production in a number of regions in the country, including the Fish-Sundays Scheme in the Eastern Cape Province,[47] the Berg River,[48] the Crocodile River Catchment,[49] the Lower Orange River[50] and various others in the Eastern and Southern Cape Provinces.[51]

Agricultural water tends to be highly subsidised in the country, under-reflecting its 'true' economic value as a contributor to employment and income generation. It is estimated that 30 per cent of South Africa's agriculture income is produced under irrigation. Table 9.7 gives a breakdown of the value of commercial irrigation agriculture in the country.[52]

Table 9.7: Estimated contribution of irrigation to commercial crop production in South Africa

Crop	Area irrigated		Production	
	x1 000 ha to crop	% of total area planted	R million	% of national production
Maize	110	3	626	10
Wheat	170	12	739	30
Other small grains	52	3	16	6
Potatoes	39	70	1 373	80
Vegetables	108	66	2 296	90
Table grapes	103	90	1 504	90
Citrus	35	85	1 462	90
Other fruit	95	80	4 148	90
Oilseeds	54	10	199	15
Sugar cane	60	15	779	25
Cotton (Lint)	18	17	92	42
Tobacco	12	85	559	90
Lucerne	203	70	657	80
Other pastures & forages	104	15	250	25
Total			**14 700**	

Sources: Backeberg, G.R. and Odendaal, P.E.1998. Water for Agriculture: A future perspective. Proceedings of the 39th General Meeting of the Fertilizer Society of South Africa. 24 April. Sun City; Nieuwoudt, W.L., Backeberg, G.R. and du Plessis, M. 2003. The value of water in the South African economy - a review. Presented at a workshop on the 19 March 2003, Water Research Commission, Pretoria.

Market values

The National Water Act provides a policy framework for water markets in the country as a means to address issues of water allocation and demand. However, it remains unclear regarding the legal transfers of water use licences, relying on a fairly regulated approach to markets that is expected in turn to increase transaction costs. Trade is also dependent on the premise that allocations come from the same source, particularly for the purposes of cross-sectoral trade,[53] and that allocations are value driven.

Water trading in irrigation agriculture in South Africa exists at an informal level in the north-eastern part of the country, the prices at which water is traded being negotiated by individual farmers and varying accordingly. Discussions have been ongoing with the Department of Water Affairs on the establishment of water markets under their demand management strategy. Water use along the Orange River has been evidenced by water transfers since the 1980s and indicates transaction costs varying between R2 000 and R6 000 per farm of 30 hectares, with an allocation of 15 000 m^3/ha, excluding the cost of electricity, irrigation infrastructure and brokers' fees.[54] Surveys further indicate that farmers along the Berg River also participated in water trading and paid about 6c/m^3 of water for permanent water transfers. Temporary water transfers were, however, carried out frequently on a goodwill agreement basis and did not have transaction costs associated.[55] These transfers all serve to give some indication of a market value for water in the respective regions, as indicated in Table 9.8 below.

Table 9.8: Market values for water trades in South Africa

General Trade Information	Permanent	Temporary	Region	Source
Trade price (capital value of water c/m^3)	18.75c/m^3	No price available	Crocodile River catchment	Bate *et al.* 1999
Trade price (capital value of water c/m^3)	22.75c/m^3	No price available	Crocodile River catchment	Bate *et al.* 1999
Average price per ha	R3 407.21/ha	No price available	Lower Orange River	Armitage 1999
Average price of trade	6c/m^3	3 cents/m^3	Berg River	Louw and Van Schalkwyk 2000

Sources: King, N.A. 2002. Valuing a City's Water: The Case of Tshwane. MCom thesis. University of Pretoria, Pretoria; Nieuwoudt, W.L., Backeberg, G.R. and du Plessis, M. 2003. The value of water in the South African economy – a review. Presented at a workshop on the 19 March 2003, Water Research Commission, Pretoria.

9.3.4 The economic value for water and development

Water resources are intrinsic to welfare creation as the costs and benefits associated with the use and changes in the nature of this resource have impacts on social well-being. An understanding of the associated economic impacts is therefore necessary for efficient and sustainable development. In Figure 9.2, the cost of water as defined in the diagram on the left-hand side, shows that traditional approaches to capturing the costs of water use focus on the direct costs and that this excludes those welfare changes that may be less tangible, indirect or intrinsic. Where water is priced incorrectly it is likely to be overused or underused. As the resource is generally under-priced, there is a pattern towards overuse and misuse, contributing towards environmental degradation, impacting future income-generating streams, or towards arrested development, impacting current opportunities for welfare improvement. The economic value of water is needed across all sectors to reflect these true costs to development, sectorally, nationally and inter-temporally. This in turn will lead to the internalisation of the true costs of resource use for sustainability as well as for future generations, encouraging the most efficacious water management behaviour.

9.4 The impact of water values on decision-making

Decision makers need to take into account the value of water in order to ensure that the following contributions are internalised:

- the importance of water in supporting income;
- the importance of water in supporting job creation; and
- that if valued correctly, water will be:
  - used at the most efficient level; and
  - allocated to the highest value user.

Policy recommendations should take cognisance of various factors, such as:

- the level of service provision across sectors;
- the method of payment across sectors;
- water vendors and other suppliers and sources;
- reliability of the water supply service;
- income across sectors and user groups;
- willingness-to-pay for water by different user groups, including ability to pay;
- highest competing valued users; and
- the efficient and beneficial use of water.

Further environmental management instruments, such as taxes or subsidies, pricing policies and water sector development and returns, will be better informed where water pricing reflects the true economic value of the resource. The value of water (including the opportunity costs of water use) also plays a role in the efficient allocation of water and in the appropriate expenditure on water conservation and water resource development measures, including determining allocations of water between users and between catchments as well as determining the scale and timing of new water resource developments. Policy makers will also be better equipped to price the resource appropriately when they understand the willingness-to-pay for water at the residential, agricultural and industrial level.

9.5 Conclusion

The impending urgency to address the rapidly expanding constraints to economic development and quality of life through access to dwindling supplies of water resources is currently driving research institutions, academia and water management institutes such as water boards and the relevant government departments to find innovative and effective solutions.

Supply management is no longer the only mechanism for achieving water security. Demand management is becoming an increasingly more viable option for wise water resource allocations. The use of pricing as one of the tools available under the umbrella of water demand management options is recognised in conjunction with water awareness programmes where reductions in water use are to be promoted.

Despite the fact that water is increasingly being recognised as a scarce resource in South Africa and that a progressive policy framework exists to address many of the associated issues, water prices fail to reflect, or respond to, user values. This apparent gap in the pricing-value debate encourages market failure, resulting in the wrong pricing and allocation signals for the resource, thus impacting on economic development. The value of applying resource economics to the decision-making process lies in the possibility of identifying the gap between current pricing levels and the true economic value of water resources, and therefore the potential loss or gain to human welfare in changes to the resource. It encourages decision-making that recognises the existence of limits to growth and that development in one area of low returns may be highly detrimental for the future sustainability of the resource itself, the economy of the country, and ultimately the development potential of the next generation.

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CHAPTER 10

A small-sample approach to hedonic valuation of the environment: A case study at Zandvlei, Cape Town

Tony Leiman and Hugo van Zyl

10.1 Introduction

The valuation of environmental externalities is often regarded as an adjunct to environmental impact assessment (see Chapter 16). In this context, valuation is part of a process that informs decision makers ahead of major capital expenditures regarding the magnitude of the impact of expected environmental externalities. Valuation can, however, also be used at a broader strategic level, to inform policy development. In an urban context, valuation studies can be useful as an aid to decision makers debating the maintenance of existing facilities, viz. in justifying ongoing expenditures. The urban environment has a powerful effect on the quality of life of most city dwellers. It is obvious that certain areas in cities are more desirable to live in than others. It is not always clear what drives this desirability or how city councils should respond in the course of decision-making.

Traditionally, Cape Town's planners saw open spaces and green belts as civic amenities for recreational use by the residents of an area, i.e. generating utility. More recently, however, they have become aware of other benefits not normally capitalised in the value of properties, such as biodiversity in particular. The growing concern with these open spaces is easy to explain: land lost to the green belt tends to stay lost in perpetuity, and irreversibility lends weight to debate. City planners are faced with a number of issues, such as: how to reconcile the growing demand for land; its limited supply; and the apparent utility and biodiversity costs of rezoning and wetland reclamation. This chapter is the product of a research effort intended to inform city decision makers of the sources of utility generated by open space and to value them using a cheap and credible technique.

10.2) Hedonic pricing method: A review

Hedonic analysis is a technique that offers relatively cheap and credible information about the management of urban open spaces. The technique reveals preferences and therefore looks more convincing than contingent valuation. The potential for bias is less, although there are still problems for the unwary. Its real advantage, however, is that housing data do not have to be collected. Records of all property transactions are available and the characteristics of all properties sold by estate agents are generally recorded. One can thus find details of the number of rooms, bathrooms, garages, whether a house is north facing or not, its stand and roof size, plot number, etc. In the face of all the data being so readily accessible, hedonic analysis has immediate appeal.

Typically, hedonic studies make use of the entire set of property sales in a city. Both the internal and external characteristics of each property are identified, the latter being studied particularly regarding their sales prices. Finally those characteristics of the buyers (income, age, levels of education, etc.) that will influence their choice of location are identified. A regression is conducted with house prices as the dependent variable and the characteristics of the houses, the neighbourhood and the environment as independent variables. The resulting coefficients appear as partial derivatives of the parameters and, if only cash value is sought, the results obtained are valid. This would be the hedonic method selected, for instance, if a municipality is seeking a consistent method for revaluation of the rateable values of properties.

A problem does arise, however, if the researcher wants to comment on utilities rather than mere pecuniary valuations. The coefficient of an environmental variable in such a model is not likely to be its marginal utility function. The utility function is indirect, in other words, a consumer's utility is driven simultaneously by the characteristics of the product and by that consumer's characteristics (typically income). One cannot merely extrapolate from the regression parameter of the environmental feature concerned, since this presumes that incomes, etc. (and indeed utility functions) are constant across consumers, when in fact they probably vary significantly across the suburbs of a city. This is a long-standing identification problem. It means that, although the regression coefficient is the revealed marginal willingness-to-pay for an extra unit of that characteristic, it is *not* ordinarily the slope of the consumers' bid function, i.e. not the slope of their willingness-to-pay function (the Hicks compensated demand curve).

If a researcher wants to use a city-wide sample, the non-homogeneity of consumers presents a problem. Its solution ordinarily requires a further step to the analysis, typically a Box-Cox transformation.[1] A weakness of this is that the end result is driven, to some extent, by the form of the transformation, giving the analyst some power over the findings. For simplicity, neutrality and cheapness one would like to by-pass this step. Fortunately one can sometimes do so: *If buyers are identical, but sellers differ ... single cross-sectional observations trace out compensated demand functions.*[2] In other words, if one can legitimately make two assumptions, namely that incomes and utility functions are identical across households, *then* the regression coefficient of the environmental variable will give that variable's bid function and hence show its marginal utility.[3] The aim in conducting this research was to perform hedonic analyses in areas with open spaces, and where these two assumptions could be realistically made. This is one advantage of a small-sample approach.

In the effort to save the time, trouble and expense of the two-step approach, the first issue was to establish whether there were indeed such sets of relatively homogeneous households. To do this, interviews were held with estate agents in the suburbs selected. They largely contended that areas (though not necessarily suburbs) tend to be relatively homogeneous. Newly married couples might live in one area, middle-aged professionals in another and affluent retirees in a third. This homogeneity is more a feature of some areas (especially newly built suburbs that were advertised, designed and targeted at specific market segments) than others, but it did provide a starting point. It meant that a simpler and cheaper single-step hedonic approach was justifiable to a degree.

There is a cost to this shortcut. The results appear as a series of independent regressions of data from small, local areas, each with a homogeneous population. Although these results are expressed in monetary terms, they should not be put to use to effect comparisons of utility between suburbs, or even aggregation of the figures, to give a total utility equivalent: the marginal utility of money varies between the affluent and the poorer suburbs. An open space generating a premium of R100 000 in suburb A does not necessarily offer twice the utility of an open space that generates a premium of R50 000 to a similar house in suburb B, where the population have totally different incomes and preferences.[4]

It was clear that estate agents had considerably more relevant information to offer. They speak to buyers and sellers of property in a specific area on a daily basis. Many of them have specialised in one area for years and may live there themselves. They actually constitute a repository of the kind of information normally sought with open-ended contingent surveys. The variables that actually drive people to buy (or not) and induce families to sell are generally well known to estate agents in an area. They can provide quick and low-cost information about the factors driving house prices, and in particular the role of open land. For this reason it was decided to approach estate agents, obtain their estimates, and then check these through applying a conventional, regression-based hedonic approach.

Might it have been worthwhile to use the aggregate data, and do the second step, using suburb/zone-based *average* details, for example, household incomes and other characteristics obtained from census data? In retrospect it would have been possible, but the interview process gave insights that a purely statistical analysis could not have yielded. In particular, it indicated the powerful role of externalities in driving the demand for open space. The most common observation, therefore, was that the utilities (or disutilities) engendered by open spaces are largely a function of their implications for home security. It was also mentioned that the same area (but with a picnic spot located to one side) can possibly add a premium to properties on the one side, and impose a discount on properties on the other. Once again, the apparent valuation of the open space is based on a derived demand – that for quietness. The open space does provide it on one hand, and removes it on the other. For an aggregate hedonic study to show that an open space can act both as a good (adding a premium) and as a bad (creating a discount) factor, an enormous amount of extra information would have had to be captured. It has to be mentioned, however, that although the design of such a study would be difficult, it has been done elsewhere.[5]

10.3 Data and method

A problem commonly encountered when making use of the hedonic approach is that of data shortage. This may seem absurd, given the large number of houses that change hands weekly, but if one lacks information about the incomes and preferences of home buyers, then theory does not allow the use of large sales data sets in hedonic analysis. The estimates of utility (willingness-to-pay) would be under-identified. The best one can do is to rely on the relative homogeneity of buyers in particular areas.[6] In addition, a specific environmental amenity or disamenity may only affect a few properties directly. Collecting a reasonable data set may then mean making use of sales figures collected over a long period of time. Unfortunately, detrending property prices is difficult in a country like South Africa, where the trends tend to vary with the income levels of the buyers. Here the city-wide trend may differ substantially from that in a given suburb, and price movements in housing at the top end of the market may differ from those at the bottom end. Many of Cape Town's suburbs show conspicuous variation in home quality and resident income. Factors such as devaluation of the South African Rand, which makes the top end of the property market particularly attractive to overseas buyers, and hence raises prices, may have the opposite effect at the bottom end. These reasons contributed to the small sample sizes from which the study suffered, despite an apparent abundance of data.

For the purposes of the study, fairly detailed investigations, which included the estimation of values, were conducted for Zandvlei, Zeekoevlei and parts of Kuils River. As the data and analyses were most complete for Zandvlei, only those findings are reported here.

The open-space valuation process commenced with a series of interviews, used in a structured questionnaire, with 12 estate agents operating in the study areas. They provided opinions on the effects of open spaces on property prices, but, more important, helped to identify the key variables that drive property prices in specific areas. Issues such as the proximity to schools and noisy roads and pubs could be significant (and easily overlooked) local factors. Estate agent interviews also provide an understanding of these and other exogenous issues.

Previous experience had shown significant colinearity between house characteristics (number of bedrooms, servants' quarters, number of garages, pool, stand size, roof size, etc.). The explanatory power of any regression ($\bar{R}^2$) could be enhanced by simply using roof area as a proxy for all other house characteristics (after controlling for double-storey houses, duplexes and flats). This was especially important where a low number of relevant property transactions in an area would otherwise leave inadequate degrees of freedom.

It was initially hoped that the estate agents would have already-evolved rough valuation formulae available, as they have in certain of the city's other suburbs. The variables in these could then be tested and used for further statistical valuation exercises. Unfortunately, only a few agents in the areas involved took such an approach to the valuation process. Most of them based their valuations on experience and intuition; when asked to explain further, these emerged as a combination of previous prices achieved for the house in question, those achieved for houses nearby, and a judgement of the state of the property market.[7] In discussion it emerged that a property's price is a function of a vector of characteristics: both its own and those of the neighbourhood, and the prices of similar houses in the area, or of its own historic sale prices and the relative 'state of the market'. This approach is fairly standard in the literature, although the functional forms applied vary widely.[8]

The analysis made use of property sales over the four-year period from January 1997 to December 2000, utilising the more detailed data available from Cape Property Services (CPS). The CPS records indicate the final selling price as well as the asking price, and the time taken to sell the property. The first of these was used as a dependent variable, but clearly the potential exists for a more sophisticated model that will take cognisance for all of the three price aspects. Among the property characteristics are the nature of the development (house, flat, duplex, double storey, etc.), the zoning characteristics (residential, commercial 1, commercial 2, etc.) and the erf (stand) number. Also included are: the house and stand sizes, the condition of the house, number of garages, number and types of rooms (bed, living and bath), and special features such as roof (thatch, tile, iron), pool, north facing, servants' quarters, etc. A number of these were only entered as dummies, as their presence would limit the options. This provided a further reason to simplify the vector of intrinsic characteristics of the properties.

Proximity to open space was included as an independent variable. The distance of each house from the relevant open spaces was measured by using maps with erf numbers and street addresses sourced from the municipality. The sales prices were detrended to correct for house price inflation in the area over the four years for which data were used; however, the caveat already mentioned should be borne in mind: detrending is sometimes a far trickier and far more suspect operation than it initially appears.

The pure theory of valuation requires that one runs a regression, the parameters of which provide partial derivatives; hence the regression parameter of distance from the open space should reflect its marginal value. Note, however, that this is not the value of an incremental square metre of open space, but rather the disamenity of moving an incremental distance further from the existing open space. It is therefore the marginal price of a unit of distance away from the open space. Once one has an idea of the limits to this effect, however, one can measure the impacts of open spaces on surrounding property prices. Typically, the further away an open space from a house, the less its influence on the property's price.

Estate agent interviews led us to expect that the impacts of an open space on property prices fall to zero within three rows of housing from the space itself, i.e. they would approach zero once one reached the fourth row of properties from the open site. One can follow a number of paths at this point. For example, the reciprocal of the distance from the open area has been used as the relevant independent variable. This sounds reasonable, but the resulting asymptotic decline (if one assumes that open space generates a price premium) as one moves away, does not accord with the opinions of the estate agents. An intuitive response might be to use dummies – using the suggestion that impacts are exhausted once the fourth row of houses from the open space has been reached, and simply ascribe a row number to each property. Those facing the vacant land would be ascribed a value of 3, those in the second row a value of 2, in the third row a value of 1, and all others a value of 0. This looks neat and simple, but presents some problems. Firstly, the choice of dummy values is arbitrary, and secondly the physical distance of the second and subsequent rows of houses from the edge of an open site will be affected by the width of the intervening stands. Stand sizes clearly vary as one moves from high-income to low-income suburbs.

In the end a simpler dummy variable approach (borders open space/doesn't border open space) was used. In addition a simple distance scale was used, with the premium or discount in the prices of intervening houses as the difference between their actual sale price and the calculated sale price if the house had been located in the sixth row from the open space. There is a substantial 'fudge factor' in these approaches, which should be addressed in future.

It should be stressed again that the resulting discount (or premium) is not a welfare measure, merely an indicator of impacts on market prices. Given Rosen's argument, however, it can be used as one within any area with homogeneous residents. However, this requires two strong assumptions, namely that both the income and utility functions are identical over all households in the data set. If one is unable to justify these assumptions, then one should proceed to one of the second steps recommended by Rosen himself,[9] and by Nelson[10] and Freeman.[11]

As was mentioned earlier, the small, localised impacts observed in appraising the effects of open spaces, and the relative homogeneity of communities in the areas involved, provided some justification for using a one-step approach. The trade-off was to confine the study to relatively small data sets.

The approach only allowed for an estimation of the relative (i.e. localised) effects of open spaces on properties in close proximity to open spaces. It did not capture the full influence of open spaces on property prices at a larger (suburb level) scale. To capture the full effect (rather than the relative impact on local properties), comparisons between suburbs similar in all respects apart from the number of open spaces would have been necessary. Because of the potential pitfalls, in particular the development of indices of open space quantity and quality, such an approach was dismissed. In retrospect, however, this may have been an avenue worth exploring. The travel-cost study undertaken as part of the general research effort did add some useful information, though. This will be discussed shortly.

Initially it was hoped that statistical analysis could be applied to at least one major open space with ecological and recreational significance in each study area. The possibility of applying statistical analysis to Zandvlei was investigated first. Fortunately, adequate house sales data existed to make it feasible. The next possibility investigated was the area along the Kuils River. Unfortunately too few recent sales had been recorded in this area. Detrending would have been tricky, due to a recent major upgrading of a section of the river. The possibility of analysing a public park in the area shared the same problem, as did Zeekoevlei. The study therefore concentrated on Zandvlei and allocated more resources to estate agent interviews in the other areas. The analysis was performed using *Statistica*.

10.4 Results

10.4.1 The study area

Zandvlei is a natural lake utilised for recreational canoeing, sailing and windsurfing. Its western shores are lawned parkland, equipped in places with barbeque and picnic spots and also a boating clubhouse. It is surrounded by four residential areas: Lakeside/Muizenberg North to the west, Muizenberg to the south, Marina Da Gama to the east and Sheraton Park and Frogmore Estate to the north. The portion of Lakeside/Muizenberg North between the vlei[12] and the railway line that runs approximately 300 metres to the west resembles the portion of Muizenberg that borders on the vlei to the south. Residential housing in both these areas offers easy access to the vlei and, in some cases, a vlei view. Marina Da Gama on the eastern shores also offers these benefits, but is distinct in having been designed as an enclosed (and therefore secure) marina. Sheraton Park, on the other hand, borders on reed beds and is fenced off from the vlei, thus offering neither access nor views.

10.4.2 Comments of estate agents

- *Lakeside*

  Estate agents would speak confidently about the influence of the vlei only on property values in the portion of Lakeside between the vlei and the railway line. In this area, it was felt that proximity to the vlei yielded a positive premium. The premium for the first row of houses facing the landscaped areas on the vlei's shores was estimated at between 7 per cent and 12 per cent. This premium captures the view and sense of open space as well as recreational access. The interviewees provided insights that conventional hedonic studies would have missed. In particular they argued that the premium would not be constant along the first row of housing. Some agents felt that the houses south of the yacht club, overlooking the barbeque facilities, enjoyed no premium and might even sell at a discount due to the disturbance created in this area over weekends. Some recreational uses of the vlei by day-trippers clash with values that could be derived by residents. For approximately five rows of houses from the second row back towards the railway line, recreational access was estimated to add no more than a 3 per cent premium to values. Beyond that point, estate agents were not sure of any premium. This implies that the view and sense of open space enjoyed by those whose properties actually face the water add a 4 per cent to 9 per cent premium.[13]

The area between Main Road and Boyes Drive not only offers relatively easy access to the vlei, but also a view of the vlei that should add value. It also lies on the slopes of Muizenberg Mountain, however, and without extensive interviewing of residents it would be impossible to separate the value specifically added by the view of the vlei from that added by the view in general and by proximity to the mountain.

Estate agents identified security as one of the most important considerations for buyers. An example given was the difficulty of selling houses near the un-landscaped northern section of the vlei, being an area of dense reed-beds. Potential buyers were deterred by a belief that criminals could gain easy access via the vlei. By contrast, houses facing the Westlake golf course (which is fenced and offers no access to potential criminals) command higher prices than similar houses close by that border on unmanaged open space (to which they have access): the golf course, to which access is strictly controlled, is seen to lower residents' security risks while the nearby open space is seen to raise them.

- *Muizenberg*

  Muizenberg borders on the southern and south-eastern parts of the vlei. Interviews with estate agents revealed that the vlei's property price effects in this area are similar to those found in Lakeside (i.e. 7 per cent to 12 per cent for the row of houses bordering on the vlei and 3 per cent from the second to the fifth row for recreational access). This is not surprising, as the two neighbourhoods border on landscaped park areas that offer similar views and recreational opportunities.

- *Marina Da Gama*

  The Marina Da Gama complex was designed with Zandvlei (and the views and recreational options associated with water frontage) as its main selling point. Consequently, the position in relation to the water is a primary determinant of prices. Estate agents argued that having water frontage was the key, while a house without water frontage would lose value markedly, whether situated two rows or five rows from the water. An average house in the marina without water frontage or views sells for approximately R400 000. Interviewees argued that the same house with water frontage, south facing would sell for approximately R500 000 (a 25 per cent premium), while the price would rise to R600 000 if the house were north facing (a premium of 50 per cent).

Most, if not all, of the abovementioned south and north facing houses have a view across an arm of water on the house on the opposite side of the canal. While this is pleasant enough, the largest premia are achieved by the few houses that face westward and have uninterrupted views over the vlei only, and not on someone else's property. Westward facing houses can further be divided into two groups with differing premia. The first group are the prime properties in the marina looking out over Park Island – an attractive island covered in well-maintained indigenous vegetation, with good bird life and that offers low-key recreation only in the form of walking trails. Estimating premiums for these houses is difficult as they are the largest in the marina and there are no similar houses with which to effect comparisons. Premia for this group are, however, likely to exceed the 50 per cent achieved by the north facing houses. The second group, with a less attractive view over the peninsula, lie in the south of the vlei. This is a grassed public park area utilised for high intensity recreation and picnics. Not only is the view less attractive; there is less privacy and the possibility of irritation caused by recreational users. Estimating premiums for these houses is also difficult, as some of the negative influences on house prices have recently been mitigated and there is as yet no indication of how the market will adjust. Positive improvements include stricter control for recreational access, only allowing access until seven in the evening, and limiting noise levels. Premiums for this group, however, seem likely to fall between 25 per cent and 50 per cent.

Sheraton Park and Frogmore Estate

Sheraton Park and Frogmore Estate border on reed beds and are fenced off from the northern part of the vlei, offering neither access nor views. Estate agents were of the opinion that proximity to the vlei did not add to property values and, due to security concerns, could even mean some reduction. The extension of Steenberg Road along the northern boundary of the vlei to link up with Prince George Drive has been mooted for many years. This has curtailed expenditure on management measures to upgrade the open space (as it has been earmarked for potential road works), further discouraging buyers. Separating out these expectations-based effects again proved difficult.

The information from estate agents outlined above was used to estimate premiums for each area as indicated in Table 10.1.

Table 10.1: Property price premiums associated with proximity to Zandvlei

	Lakeside	Muizenberg	Marina Da Gama	Total area
Number of houses affected	124	282	923	1 329
Total premium	R1.05 million	R3.32 million	R87.45 million	R91.8 million

10.4.3 Hedonic analysis

Using the approach described in Section 10.2, house sales data for the last four years were collected, corrected for inflation, and then analysed for the hedonic model. The detrending was relatively straightforward, as neither the vlei nor the surrounding suburbs underwent any major structural changes in the past four years.

An analysis that uses a small sample and many variables can easily run into 'degrees of freedom' problems. Fortunately, such conventional hedonic variables as proximity to shops and major roads, pollution sources, etc. could be eliminated as inapplicable to the sample. This left only house characteristics and proximity to open space driving differences in property prices.

Preliminary regressions were performed for each of the three distinct areas surrounding the vlei to determine whether statistically significant relationships existed between distance from open space, house characteristics and house price. Significant relationships were found for Marina Da Gama but not for Lakeside and Muizenberg. This was not surprising, given the very small sample sizes for these areas (14 and 16 observations respectively).

A step-wise regression was then performed on the Marina Da Gama data (80 observations) to ensure that only statistically significant independent variables were included. Using a dummy to indicate whether a house had water frontage or not generated results with only marginally better explanatory power than using the distance away from the vlei in metres (Adjusted $\bar{R}^2$ = 0.66 vs. Adjusted $\bar{R}^2$ = 0.63). The choice of the dummy approach was informed by this result and the fact that it conformed better to the views expressed by estate agents. The results of the regressions are shown in Table 10.2.

Table 10.2: Zandvlei property price hedonic regression results

Area	Independent variables used	Measures of property price premium
Marina Da Gama	House size, house condition, number of garages, water frontage dummy	Calculated average premium of R131 000 on houses with water frontage

These results were then used to estimate the premia for each area, as is shown in Table 10.3.

Table 10.3: Property price premiums associated with proximity to Zandvlei (hedonic analysis)

Area	Marina Da Gama
Number of houses affected	923
Total premium	R76.7 million

The hedonic analysis of property sales in Marina Da Gama yielded results similar to those derived from estate agent interviews (R76.7 million using statistical analysis versus R87.5 million using estate agent interviews). Although there was insufficient data for the statistical analysis of property prices in Muizenberg and Lakeside to reveal a relationship between house price and proximity to open space, this does not challenge the view of estate agents that such a relationship does indeed exist.

10.5 Applicability of findings to other suburbs

The property price premiums or discounts associated with open spaces were found to be highly case specific. For example, a park evaluated in Kuils River created a premium while one in Claremont generated a property price discount. It is clear that extrapolation of premiums or discounts is inadvisable without site-specific investigations. However, the following trends appeared at Zandvlei and the other areas investigated:

- Most of the open spaces lead to premia or discounts of less than 10 per cent. However, areas surrounding major environmental attractions such as Zandvlei and Zeekoevlei can attract substantial premia often above 10 per cent or even 20 per cent. This is particularly true of areas that have been purpose built to make the most of the environment. It is also interesting to note that the areas that showed the highest premia included water as a major component of the open space.
- Security is a key determinant of property prices. A perception exists that open space allows easier access for criminals unless specific security-linked provisions have been made.
- The value of an open space depends on the quality of its management. 'Well managed' typically means well manicured, secured, and free of vagrants and other users who generate disamenity to residents.
- The preservation of botanical diversity and indigenous flora is problematic. Trimmed lawns are preferred to dense growths of fynbos (which are seen as increasing fire and security risks).
- Vacant land discounts may be influenced by expectations of future developments and uncertainty over the strictness with which zoning and building regulations will be enforced.

10.6 Critical appraisal of methods

One of the main strengths of the property price approach is that it derives values from actual market transactions and known trends. This gives ease of understanding and credibility in the eyes of the public and policy makers. However, effective hedonic analysis using property price effects presupposes adequate data (both household and transaction). Data can prove inadequate for a number of reasons, most of which were encountered during the course of this study:

- If an open space as a whole is to be appraised, independent of individual sites, then details of the purchasing households are needed. Income, race, education, tribal or language group, in particular, seem likely to be influential factors. The conventional approach, which only treats income as a key 'indirect' variable, seems inadequate given the complexities of a third-world city. In reality neither this, nor any of the other 'indirect' variables mentioned, is recorded when property transactions take place. This means one has to work on a zonal basis, relying on local buyer homogeneity.

- In any local area the number of houses traded may be low. This limits conventional hedonic analysis to larger open spaces bordered by large numbers of homes.
- The formal property market in the suburbs analysed must have been sufficiently active to generate the sales data required.
- Sales data for areas where the property market is not well developed tend to be scarce. This is a particular problem in high-density suburbs. Effectively, the implications of open space for low-income black city dwellers are not adequately evaluated.

The method requires less assumptions and complex analysis when analysing localised property price effects. It seems reasonable that a feature of desirable suburbs is that they are well provided with trees and have substantial areas of open space. Unfortunately, the property price approach is not suited to such broad scale analysis. Even with the use of dummy variables, one runs the risk of capturing the influences of town planners of the past rather than the utilities of current residents.

Some of the problems mentioned can be avoided by making use of estate agent interviews. However, a caveat is necessary: it soon became clear that some agents were more aware than others of issues and factors driving prices and their movements. Care should be exercised when interpreting such inputs.

The opportunity cost evaluation based on land development values can be fairly rough when applied to the extensive areas of open space; it nevertheless gives a reasonable market-based indication of the total opportunity cost. As with the other methods, it can be used to produce more accurate results when applied to defined parcels of land.

10.7 Conclusion

The key finding of the study was that open land does not have an identifiable external value *per se*. It generates flows of services and disservices that impact on the welfare of local residents and are captured in local property prices. Indeed, the external values captured were in large measure driven by the activities of the city council in maintaining and regulating greenbelt areas and in establishing clearly defined, stable and policed zoning regulations.

The results of the evaluation indicate that property values can be enhanced by well-managed, secure open spaces free of frequent public disturbances. Effectively it was found that the value was not so much determined by the open space itself (or its ecological integrity), as by the quality of its management and the public's perception of management's role in social issues such as crime. There is no reason to believe that this finding would change for other areas. This was not an anticipated conclusion.

Property price evaluation based on estate agent interviews proved a reasonably fast way of getting information for all types of open space, while data constraints meant that hedonic analysis had to be more selectively applied. As performed here, hedonic analysis captures only local effects of open spaces on properties nearest to them. It does not capture the full influence of open spaces on property prices at a larger scale, such as at suburb level. Most important, it does not reflect the very real possibility that the property premium which Cape Town commands over other cities in South Africa may be a consequence of the city's extensive open spaces.

Endnotes and References

1 A further stage dealing with endogenous prices and identification issues can also be added.

2 Rosen, S. 1990. Hedonic prices and implicit markets: Product differentiation in pure competition. *Journal of Political Economy*, 82(1):24-55.

3 It is tempting to argue that irrespective, the city council is not concerned with utility but with monetary valuations since these drive the city's rates base. If so, the distribution of income and the variations in utility that this generates would be irrelevant to them and the regression parameter would suffice. If, on the other hand, civic policy does imply some process of interpersonal utility comparison, then, it is an issue of practical rather than theoretical concern.

4 We have serious reservations about valuations which purport to aggregate utilities across an entire population. Monetary values don't worry us, mention of utility in this way does!

5 One approach to a similar problem is provided by D.R. Bowes (2001) who introduced a security variable into his regression. Introducing a variable such as 'number of break-ins per annum' might enable the separation of security issues (and their attendant disutility) from the utility generated by open space. See Bowes, D.R. and Ihlanfeldt, K.R. 2001. Identifying the impacts of rail transit stations on residential property values. *Journal of Urban Economics*, 50(1):1-25.

6 Ideally one would want to stratify the sample so that each set is made of individuals whose utility functions are weakly separable, though Freeman has stated that 'the conventional approach does not add buyer characteristics' (Freeman, personal communication).

7 Price records over the preceding seven years for the house in question and for nearby properties can be sourced from the South African Property Transfer Guide database.

8 Contrast this with the conventional hedonic approach which uses the same vector of characteristics, but then adds the characteristics of the buyer.

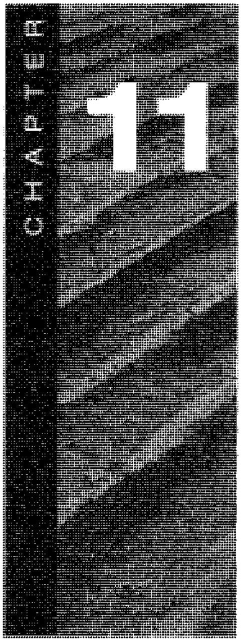
9 Rosen, S. 1990. Hedonic prices and implicit markets: Product differentiation in pure competition. *Journal of Political Economy*, 82(1):34-55.

10 Nelson, J.P. 1978. Residential choice, hedonic prices, and the demand for urban air quality. *Journal of Urban Economics*, 5(3):357-68.

11 Freeman, A.M. 1979. *The Benefits of Environmental Improvement: Theory and Practice*. Baltimore: Johns Hopkins University Press; Freeman, A.M. 1994. *The Measurement of Environmental and Resource Values: Theory and Methods*. Washington, DC: Resources for the Future (RFF); Some texts simply argue for weak separability in the utility function. In this study, weak separability means that one's preference for open space is not affected by the other features of the house one lives in (independence) and are not locally satiated

12 A vlei refers to a wetland area.

13 7 per cent–3 per cent and 12 per cent–3 per cent seeing that the view and recreational access combined add a premium of between 7 per cent and 12 per cent.



Towards internalising the cost of water pollution

Martin Grosskopf

11.1 Introduction

In 1998, the Department of Water Affairs and Forestry (DWAF) proposed a Waste Discharge Charge System (WDCS)[1] for South Africa to comply with the stipulations of the National Water Act. The WDCS involved introducing charges for various water uses, including waste discharges into water resources. The aim was to ensure that the costs of waste discharges are internalised in accordance with the user-pays and polluter-pays principles.[2] The main argument in favour of such a WDCS is that internalisation of costs can best be achieved by means of economic instruments rather than through so-called command-and-control regulations, namely the waste authorisation system currently in place. Following the decision to introduce the WDCS, a series of studies were commissioned to determine the most appropriate way to introduce the system.[3] These studies endeavoured, amongst others, to determine both the appropriate charge and the economic impact of such a charge on the South African economy, using the analytical framework of environmental and resource economics. This chapter provides an overview of the theoretical framework used and the results of the initial quantitative analysis.

11.2 Water pollution in South Africa

11.2.1 Characterisation

As a waste sink, South Africa's water resources are limited due to low rainfall and high evaporation rates (see Chapters 9 and 15). Yet, they are currently expected to carry large amounts of domestic, industrial, mining and agricultural waste. An effort to reduce water pollution is therefore not only an issue of improving water quality but also of ensuring adequate usable quantities, as there are seldom sufficient alternative sources from which to draw if a water resource becomes polluted. See Appendix 11.1 for an indication of water quality levels across various quaternary river catchments.

Total dissolved salts (TDS), causing salinity, is considered to be one of the most important pollutant categories in semi-arid regions such as the western United States, Australia and also South Africa. Common sources of salinity are mining waste, industrial and sewage effluent, and irrigation return flows. Salts are discharged from many mines, and particularly high concentrations are decanted due to groundwater build-up in disused mines. Salts are also leached from agricultural land. Being conservative pollutants, salinity loads persist in the environment and build up due to evaporative concentration in dams and irrigated land and to evapotranspiration from riparian vegetation. In agriculture, salinity causes soil infertility and crop losses. In mining, industry and utilities, salinity causes, amongst other things, scaling of boilers and corrosion of pipes. In households, higher salinity requires increased use of soaps and detergents and causes more rapid scaling of kettles, washing machines, steam irons and geysers. The direct costs of salinity have been estimated in 2001 at R507 million per year.[4]

Plant nutrients are another important category of pollutants. The primary nutrients are phosphate, nitrate and ammonia. Nutrients originating from domestic waste are normally taken care of by municipal sewage treatment works, but large quantities are often discharged from informal settlements where the sanitation facilities are inadequate. Eutrophication (nutrient overload) results in algal blooms, accelerated growth of cyanobacteria as well as higher plants such as water hyacinth and duckweed. This accelerated growth is accompanied by rapid decomposition.[5] When large masses of algae die, fall to the bottom of rivers and dams and are decomposed by aerobic bacteria, the dissolved oxygen in the water is taken up, causing fish and other organisms requiring oxygen to die as well. The self-purification function of aquatic ecosystems is impaired, and water becomes unfit for human use and consumption. Nutrients are often discharged along with pathogens when their source is sewage water. High levels of nutrients are therefore often accompanied by a high risk of disease to humans. This impedes economic development in a more subtle way than physical damage to property, but should be accounted for as part of the downstream costs.

In addition, there are many other pollutants that enter the country's water resources, such as heavy metals, radionuclides and oxygen-demanding substances.

11.2.2 Analysis of cost within the environmental economic framework

Water pollution costs can be considered to consist of those with a direct economic impact to people who utilise the water and those that are usually termed *environmental costs*. The latter are often neglected, as such costs are considered far more difficult to quantify, and most of the time it is thought that there is no economic impact from the pollution that results in these costs. In recent years, however, a greater understanding of the interconnections between physical and biological cycles in the environment, including those in human habitats, has led to the realisation that almost any damage done to natural processes will ultimately have consequences for the economy.[6]

Many waste streams, especially those in gas form, such as carbon dioxide, have not had as immediate or direct an impact on the economy and human health as has been the case with water pollution. Water pollution has an impact time lag which is often only as long as it takes the water to flow from where the waste is discharged to where the water is utilised. These impacts include water-borne diseases and the corrosion of equipment. There has therefore been greater pressure to combat the pollution and to account for the cost at a fairly early stage in the case of water pollution as opposed to other forms of pollution.

Because the quality of water has a direct use value for those who utilise water resources, the determination of the costs of water pollution in South Africa was historically based on relatively straightforward methods, rather than those which are the special focus of environmental economics. These latter methods focus on the determination of indirect use values and non-use values of resources.

Traditionally, the costs of water pollution in South Africa were largely estimated by calculating the difference between the operating cost when using polluted water and the cost when using unpolluted water. These can be regarded as *replacement* and *response* costs. Valuation exercises for water were mainly carried out for the purpose of water pricing, and this was based on the cost of providing water, not primarily on its use value.

Determining the cost of pollution only in terms of replacement and response costs as a result of the direct use of water means that the full costs have not been accounted for to date. For example, the costs arising from the loss of biodiversity in aquatic ecosystems and riparian habitats have not yet been accounted for in the downstream cost in the case study either, leading to an underestimation of the cost of water pollution.

11.3 Theoretical basis and methodology followed for the proposed Waste Discharge Charge System

11.3.1 Marginal costs and benefits

The economic impact assessment of the DWAF WDCS study was based on a Pigouvian analysis.[7] Such an analysis shows that there is a gain in efficiency if externalities are internalised. In the case of an external cost caused by pollution, such an analysis would be aimed at determining the marginal damage resulting from pollution so that it can be added to the private cost of the discharger. This addition can be levied by the authorities and is known as a Pigouvian tax. A Pigouvian tax is one of the many ways of ensuring that such external costs are internalised. In response, the discharger can then follow either of two strategies:

- if the abatement cost is lower than the charge, engage in abatement to avoid the charge; or
- if the abatement cost is higher than the charge, pay the charge and continue to discharge.

In practice, both the charge and the abatement cost could vary with the level of discharge in such a way that the one is not consistently higher than the other across the range, so the discharger might also engage in partial abatement. But, whether the discharger pays the charge or avoids it by treating the waste, pollution is likely to be reduced, since the additional cost to the discharger will most likely cause the discharger to re-optimise the level of production to the point where the marginal cost is equal to the marginal revenue, in order to maximise profits. Therefore, even if the discharger just pays the charge, the resulting decrease in the level of production will be associated with a lower level of discharges.

An analysis of marginal values is useful because it allows one to focus only on the changes resulting from a change in the level of production. When working within the constraints considered in neo-classical economics, it is also easy to determine an optimum level of production. This is the level at which marginal cost is equal to marginal benefit, as both fewer and more units of production would yield less revenue. It should be noted that, because the technique of marginal analysis is part and parcel of neo-classical economics, it does not make any provision for an ecological threshold and would therefore only be applicable under conditions where effluent levels have not yet led to permanent ecological damage or will not do so. Should such ecological thresholds be exceeded, other than neo-classical solutions should be sought. Providing that such ecological thresholds will not be exceeded, the following marginal cost equation is relevant:

MSC = *MPC* + *MD*

where:

MSC is the marginal social cost of production, with inclusion of environmental externalities

MPC is the marginal private cost of production

MD is the marginal damage (for instance, downstream cost)

In addition:

MB is the marginal benefit derived from production.

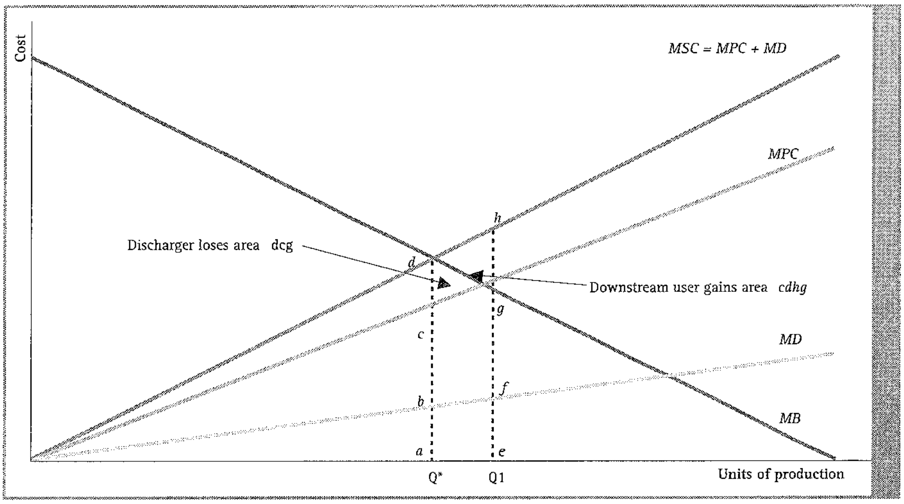


Figure 11.1: Gains and losses from moving to a more efficient level of production[8]

Without internalisation of the externality, profits are maximised where *MPC* = *MB*,[9] or at a production output of Q1 (see Figure 11.1). The total revenue is equal to *MB* X Q1 and the total private cost is equal to *MPC* X Q1. For the economy as a whole, the most efficient level of production is found where *MB* = *MSC*, or at a production output of Q*. If the discharger were forced to reduce pollution by reducing the level of output to Q* without being levied a pollution charge, the resulting loss of profits to the discharger would be less than the gain to downstream activities. The polluter loses profits for each unit of production when reducing output from Q1 to Q*, equal to the difference between marginal benefit and marginal private cost. In the diagram, this is shown as area *dcg*. However, the downstream user gains the reduction in marginal damage, or area *abfe*. The area *abfe* is equal to the area *cdhg*, as is defined by the equations. This means that the increased benefit to society is the difference between the areas *cdhg* and *dcg*, i.e. the area *dhg*. This is an overall gain, which means that the introduction of the charge leads to greater efficiency.

If a charge equal to the marginal damage is levied to induce the discharger to move to Q*, the discharger will lose profits greater than the downstream benefit (*dcg* + (*cd* X Q*)), but the revenue from the charge (*cd* X Q*), or firm funds to that value if the firm chooses to avoid the charge, are still available for pollution abatement. The net benefit to society is still the same (*dhg*).

11.3.2 An 'optimal' charge

The issue of optimality with respect to an environmental charge is subject to several additional considerations. If an economic instrument is introduced which leaves some economic players worse off, this does not meet one of the Pareto conditions for optimality, namely fairness, and this is one reason why tradable permits are preferred to charges by some policy makers. However, externalities can be considered to be a form of existing unfairness which needs to be corrected.

Within the neo-classical paradigm, the question as to which level of waste discharges leads to an optimal situation can be analysed by counterbalancing total abatement costs and downstream costs against each other. This optimum bears reference only to costs, and possible resource constraints are ignored. However, adding the two costs together, the 'optimal' solution is found where the total costs are minimised. This is illustrated in Figure 11.2. The downstream cost increases with increasing waste discharges. At the same time, to obtain a lower waste load, abatement costs will be high, and vice versa, hence the shape of the abatement cost curve. Excessive waste discharges usually occur when there is no incentive to reduce them, as at level Q1. The overall costs to society are C1. There is room for reducing the overall costs to society by reducing waste discharges to level Q2. An optimal discharge level (Q2) can be found at which the total of the abatement and downstream costs is at a minimum (C2).

The analysis in Figure 11.2 shows an optimal level of waste discharges and that the maximum reduction of waste is not necessarily optimal and may impose a greater cost to society than is borne at present. However, it is easy to overstate the benefits and understate the costs if only humans, affected at present, are considered. As has already been pointed out, the short- and long-term costs to natural systems and non-human species have not been fully accounted for in the study, nor the indirect or long-term impacts of these on humans.

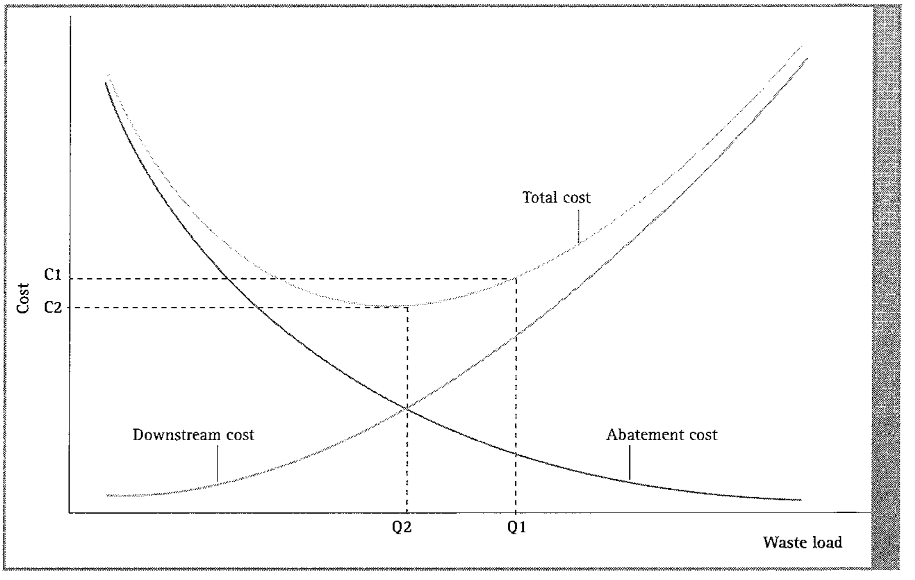


Figure 11.2: Optimal level of resource utilisation

In addition, the optimal level of discharges is not static. The introduction of the charge will set in motion processes that occur over a period of time:

- structural economic change due to a shift towards non-polluting production processes; and
- increased abatement activities, resulting in economies of scale that reduce the unit cost of abatement.

These changes will cause the abatement cost curve shown in Figure 11.2 to move downwards. The optimal level of waste discharges should then be found at a lower level than Q2.

11.3.3 Formulating charge scenarios

When formulating the charge scenarios of the WDCS, it was initially proposed that the charge should consist of a basic component to be paid to cover water quality management costs, such as administrative and monitoring costs. It was also proposed that for pollutant concentrations that exceeded the authorised amount, dischargers would pay an additional deterrent charge, which would increase more than proportionally to an increase in concentration. The charge structure proposed is as follows:

Tier 1: Basic charge, based on volume of water discharged, irrespective of waste load. This covers the water quality management costs of the water management area.

Tier 2: Dischargers exceeding the target concentration for the relevant water resource will be required to pay a charge directly proportional to the waste load discharged. The revenue from this charge can be used for regional or collective pollution mitigation facilities.

Tier 3: When a discharger exceeds the authorised waste pollutant concentration, a supplemental charge is levied. This supplemental charge must be an incentive to rather treat the waste than discharge untreated or partially treated waste into a water resource.

Tier 4: When a discharger exceeds the inhibitory/toxic pollutant levels, a substantial additional charge is levied. This must serve as a strong disincentive to discharge untreated or partially treated waste, which threatens natural aquatic ecosystems and public health.

The Tiers 3 and 4 charges would be designed to increase more than proportionally to an increase in waste load. The basis of the charge should reflect at least the equivalent pollutant treatment cost as well as a charge which is in proportion to the potential downstream damage. Any additional revenue from this charge would be used for remediation of historically accumulated pollution, targeted studies on areas where there are water quality problems and national water quality-related priorities.

Tier 3 has been amended since, but the economic impact determined in the study was part of the above proposal. It was subsequently proposed that the threshold for paying the Tier 3 charge is the maximum allowable resource-directed value (MARDV), which is part of a new classification system for water resources[10] that was still being finalised at the time of writing. The MARDV is not necessarily linked to the authorisation, as a discharger may be authorised to discharge more, and if so, will pay a progressive charge if he or she does. It was also proposed that the discharger receive a rebate for discharging better quality water than that abstracted, but this was not modelled.

Although the progressive charges would always be used for water quality-related purposes, it could exceed the amount that can be considered to be a user charge, and can therefore be considered to be a tax,[11] which is not currently supported by the National Water Act. If it is approved in the form of a money bill, it can be justified as a shift of taxes away from income taxation to resource-based taxation.

To account for the possibility that the payment of a charge equal to the costs of a level of abatement which produces cleaner water than that which society could benefit from, the Tiers 2 to 4 charges were multiplied by a coefficient which would be a proportion less than 1. This coefficient (P) was randomly set at 0.4 and 0.2 for two alternative charge scenarios, labelled Scenario 1 and 2 respectively. These were merely experimental values, and do not bear any relation to knowledge about the optimal charge. Optimising is far more complex than Figure 11.2 suggests.

A further scenario where the waste treatment costs exceeded the abatement costs by a small margin (P = 1.05), but which had no Tiers 3 and 4 (progressive) charges, was set as Scenario 3. According to such a scenario, a large-scale discharger would always have an incentive to treat waste water in-house rather than to discharge and pay the charge if the target concentration was exceeded. According to Scenarios 1 and 2, this would only happen if the discharger exceeded the *authorised* concentration by a relatively large margin, namely where its progressive nature causes the charge to exceed abatement costs.

11.4 Modelling the costs and benefits of a waste discharge charge

11.4.1 Preliminary modelling

The model component developed for the economic impact assessment was supported by a component to determine the waste-load reduction required to meet downstream water quality targets[12] and also a component to determine the cost of the water treatment required to reduce the load by that amount.[13] These latter two components form the basis of the set of charge scenarios of which the economic impact was to be tested.

The waste-load reduction required was confined to the assessment of salinity and the nutrients consisting of phosphorous and nitrogen compounds. This was done after an assessment of pollutant groups, which could feasibly and usefully be included in the analysis. The pollutant concentrations for a selection of catchments[14] were modelled for river reaches, taking into consideration the hydrological and other factors that would cause this concentration to vary as pollutants flowed down the river. Such factors include seasonal rainfall patterns, natural drainage into rivers, transfers, evaporation, bed loss, attenuation, and so forth.

For treatment cost, the costs of standard treatment technologies for plants of different scales were determined.[15] As far as pollution abatement through other means aimed at prevention were concerned, such as a switch to less-polluting industrial processes, the costs could not be determined, as these would vary from situation to situation, and would usually take longer to implement than end-of-pipe treatment.

To determine the economic impacts of the respective charge scenarios, the additional cost incurred due to the waste discharge charge had to be subtracted from the benefits. The benefits were considered to be equal to the reduction in downstream cost, which could be attributed to the introduction of the charge. A reduction in downstream cost had to be referenced against the current downstream cost.

As far as the downstream costs of salinity are concerned, a study was completed in 1996 to determine the costs for the various sectors of the economy.[16] This study was relatively comprehensive in determining direct costs, but did not address costs incurred because of diminished indirect or non-use values. It did determine indirect costs by means of input-output analysis, the term 'indirect' referring to the multiplier effects through the economy as a whole, which is not to be confused with the costs related to the indirect use value of water as providing environmental goods and services.

As far as the nutrients are concerned, it was decided that the damage costs were to be considered equal to the cost of treatment. This is because nutrients have an impact mainly on aquatic ecosystems, which impairs the self-purification function of the system, making water unfit for human consumption, and this necessitates treatment in any case.

11.4.2 Modelling the economic impact

) *Data*

In practice, the marginal analysis discussed above has proven difficult to use as a basis for determining charge levels and impacts. This can mainly be ascribed to inadequate information. The study obtained information by means of a sample survey to determine marginal private costs, marginal costs of abatement of dischargers and marginal damage to downstream activities. The sample size was 200, and included dischargers, downstream activities and abatement activities. The response rate overall was 17 per cent. Downstream activities generally did not know the marginal damage costs, nor did dischargers know their marginal abatement costs. Data from a previous survey in each of the DWAF regions,[17] as well as from annual company financial statements, were used to supplement the data from the sample. For marginal damage costs, data from previous studies on salinity[18] could be used.

In total, data of varying degrees of completeness were obtained for 225 economic activities, and were entered into the model. Apart from the marginal private costs, the data obtained from the sample were generally inconclusive. In many cases marginal benefit schedules had to be estimated from the demand characteristics of the commodity produced, and if perfect competition could be assumed or if prices were set on commodity markets, the marginal benefit curve could be assumed to be horizontal. A horizontal marginal benefit curve would result in the charge having its maximum effect, and if information is not available, assuming a horizontal curve would therefore not result in an underestimation of the impact.

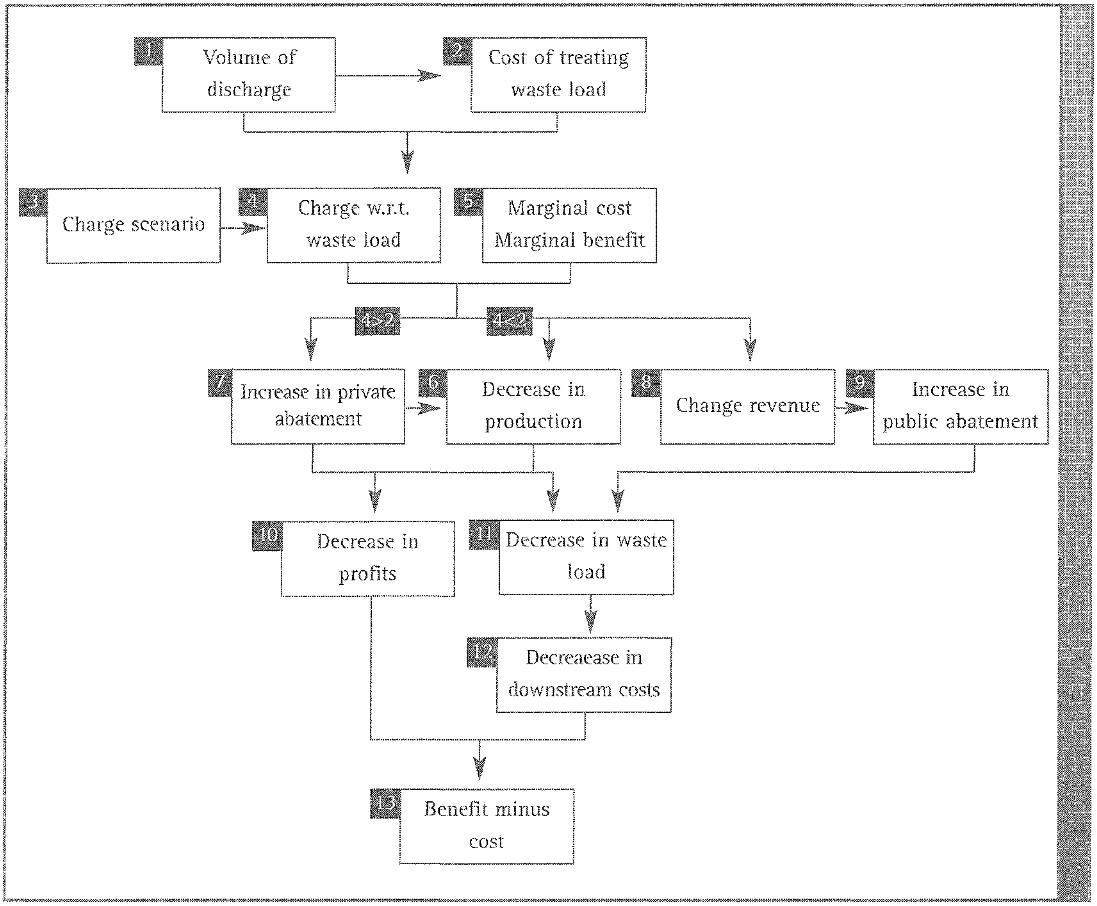
- *Simulation*

  The economic impact assessment component of the model was designed to simulate the economic impact of the following:
  - increases in production costs resulting from discharge charges;
  - increases in production costs arising from engaging in abatement;
  - decreases in direct downstream costs;
  - decreases in the unit costs of abatement due to an increase in scale; and
  - disinvestment/reinvestment due to changes in profitability.

There could be decreases in production costs as a result of the charge if it spurs activities to invest in alternative technologies that prevent pollution and result in lower unit costs at the same time, but this would vary from situation to situation and was therefore not modelled. Figure 11.3 illustrates the main causal relationships in the model.

When combining the cost and benefit curves with the charge curves, the impact on the firm's costs and production levels could be determined, while the impact on the economy could be estimated in turn. Generalisations of the different combinations of cost and benefit curves can be described to assist in the analysis. There are two dimensions along which these can differ that must be considered first:

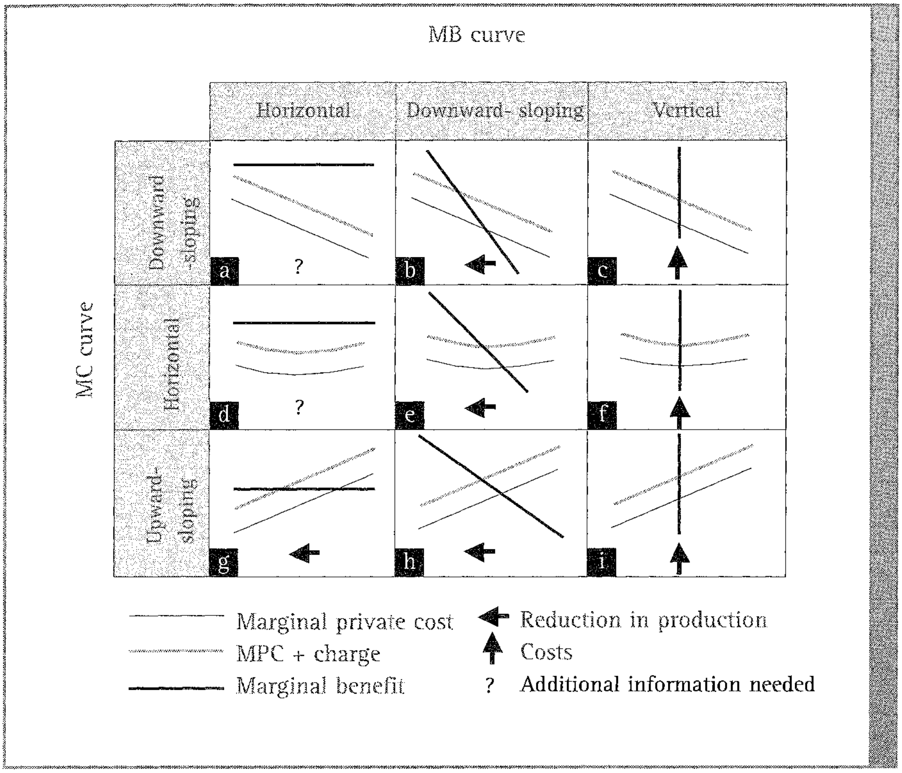
- slope of the marginal cost curve; and
- slope of the marginal benefit curve.



Note: In the case of activities whose core function it is to treat waste (for example, municipal treatment facilities) there will not be a decrease in production (box 6)

Figure 11.3: The main causal relationships in the economic impact model component

The respective slopes determine whether a firm's level of production will be altered by the introduction of the charge, and whether it is able to pass on the additional cost to the consumer or not. Figure 11.4 shows all of the possibilities.



Source: Department of Water Affairs and Forestry (DWAF). 2001. WDCS Economic Impact Assessment. Pretoria: DWAF, p. 32.

Figure 11.4: Different combinations of marginal cost and benefit curves

The firm's response to the charge can also differ, depending on the following aspects:

- whether it is a public or private concern;
- the scale of the plant;
- whether its main business is pollution abatement, or not; and
- the extent to which shares are offered to the public.

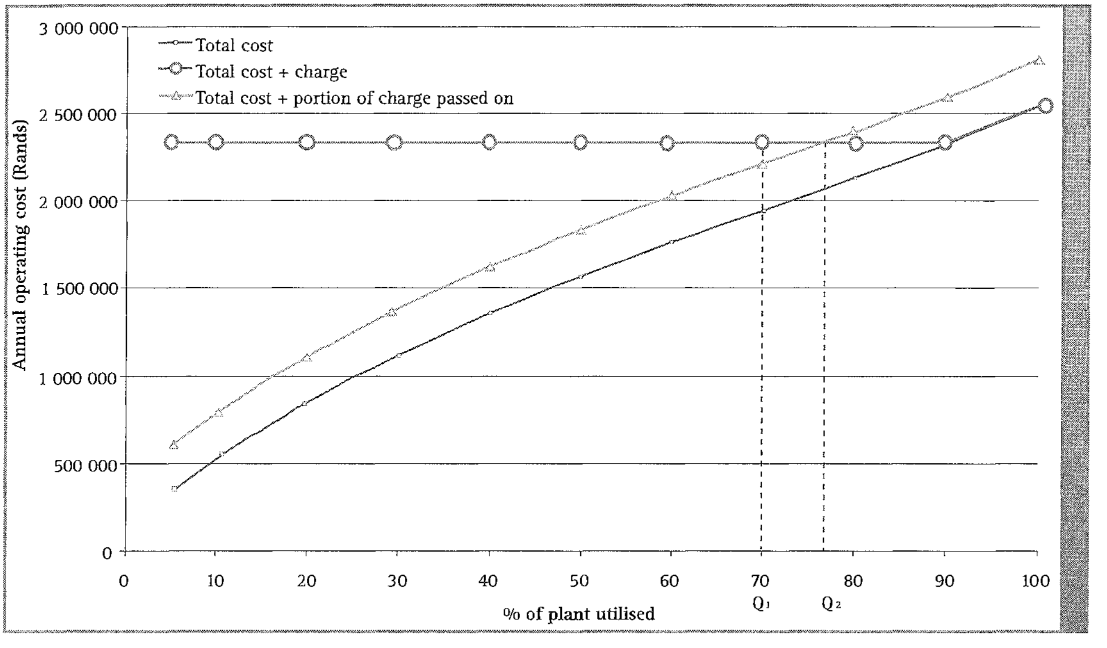
These aspects will have an influence on the firm's decision whether to engage in abatement or pay the charge. They are especially important considerations if the marginal cost and benefit analysis do not indicate whether the production level is reduced or increased as result of the introduction of a charge.

- *Public sector organisations*

  Public concerns often provide a service for which there is no full cost recovery, because they provide public goods from which consumers cannot be excluded based on the non-payment. This is the so-called free-rider problem. The provision of sanitation services is such a public good. Municipalities can pass on costs, because they have a monopoly over the service and the demand is inelastic with regard to price for consumers who pay regularly. But, on the other hand, if the price is raised, the incidence of non-payment increases. Municipalities will have even greater difficulty in recovering costs if they do not increase their level of service. Municipalities will have to increase the quality of discharges primarily through increasing the intake of sewage, rather than by treating existing sewage intakes to a higher standard. This can be done by increasing the number of sewage connections.

  If municipalities are charged for untreated waste emanating from settlements where sewage connections have not been installed, they will weigh up the costs of paying the charge against installing connections and treating the waste. Typically, much of the cost of waste treatment will not be recovered in such cases, as the communities involved will often find it unaffordable. The informal nature of such settlements makes it difficult to install sewage connections, and it is likely that this can only be done in conjunction with housing projects. Another option for municipalities is to make use of constructed wetlands downstream of informal settlements. The cost of constructing wetlands could be far less than installing sewage connections and increasing plant capacity and/or scale. In addition, such wetlands can serve an important environmental function in terms of providing habitat for wetland species and mitigating flood damage.

  As information was not available on the proportion of discharges that originate as untreated waste and which proportion originates from treatment facilities, it was not possible to model the impact to any level of detail. Instead it was assumed that municipalities would respond partly by increasing treatment to avoid the charge, because in this way some of the costs can be recovered. They would also recover the cost by passing on the charge to dischargers who discharge to sewers connected to their sewage treatment works. It was assumed that 30 per cent of the cost will be recovered by extending the sewage reticulation and 70 per cent by charging businesses for waste discharges.



Source: Calculated from BNR sewage treatment costs in Department of Water Affairs and Forestry (DWAF) Waste discharge charge scenarios and costs. Pretoria: DWAF, Appendix I.

Figure 11.5: Total cost, charge and costs passed on for a 10Ml/day sewage treatment plant

It was not possible to derive a demand curve for activities characterised by the free-rider problem, because even if the price is not paid, the quantity is still demanded. Because the demand curve forms the basis of deriving the marginal benefit curve in this study, this means that marginal cost and benefit analysis could not be done. Instead, the situation was analysed from a total cost and revenue perspective. Figure 11.5 illustrates the situation and the assumptions from a total cost and revenue point of view. For this example it is assumed that the treatment works are run at 70 per cent of capacity, shown as level Q1. The curve for the total cost plus (+) charge is horizontal because the charge is meant to cover fixed abatement costs required for the population of the municipal area. A part of the charge (70 per cent of the charge due for the current level of service) is passed on as charges to dischargers in the municipal area. The municipality will then still have to do its part by extending its service so that it operates at level Q2. Figure 11.5 shows that at this level the cost of the charge is recovered.

- *The scale of the plant*

  The scale of the plant determines whether it can operate abatement facilities at a large enough scale to enjoy a unit cost of abatement that is less than the waste discharge charge.

- *Pollution abatement activities*

  Pollution abatement activities are often both dischargers and abatement activities, because the intake waste is treated up to a certain level, after which waste water containing residual pollutants is discharged. Such activities may *increase* their level of output to avoid bearing the cost of the waste discharge charge, as was discussed above.

- *Shareholding*

  Profitability is important for companies owned to a large extent by shareholders, but shareholders are increasingly concerned also with the environmental track record of the companies in which they invest. Hettige *et al.*[19] observe that *the expected profitability of investment in pollution-intensive sectors has also been affected by growing concern over legal liability or reputational damage.* This may induce some of the larger companies to engage in abatement even if the cost is marginally higher than the waste discharge charge.

11.5 Results

11.5.1 Sector-specific outcomes

Based on the data and the model discussed above, the costs and benefits were modelled to ascertain the impact of the charge on different sectors. These impacts influence the firm's response to the waste discharge charge. The results presented here give an overview.

- *Agricultural sector*

  From the survey it was found that the agricultural sector generally has a negatively sloped marginal cost curve. This suggests that unit costs decline with increased production. Generally, the demand for agricultural products is elastic, that is, price dependent, and therefore a horizontal marginal benefit curve applies. Figure 11.4a shows the marginal benefit and cost curves that may be applied to the agricultural sector.

  Most producers in the agricultural sector discharge from a diffuse source, and it has been recommended that such discharges initially not be charged under the WDCS. Of those that produce point-source discharges, production will not be affected, but profitability instead. Charges are likely to be absorbed, as this sector operates in a competitive market. From the available data the impact on the agricultural sector appeared to negligible.

- *Mining sector*

  Generally, a negatively sloped marginal cost curve and elastic demand was recorded for the mining sector (refer to Figure 11.4b). The imposition of a charge is not likely to affect the output level of the mining industry and it was predicted that the mining industries would absorb the increased cost. In general, the mining sector cannot shift the increased cost to consumers, given the fact that metal and mineral prices are set on world markets outside the mining company's immediate control. The profits of this sector will therefore decline. The impact is shown in Table 11.1.

  The mining sector itself is affected adversely by water pollution, hence the benefits it receives as a downstream user of water resources.

Table 11.1: Impact of charge on mining sector (R million)

Scenario	Impact on profits	Downstream benefits
1	-254	7.4
2	-130	4.7
3	-433	7.5

- *Manufacturing sector*

  From the research conducted, activities in the manufacturing sector generally appear to have positively sloped marginal cost curves and downward sloping demand curves, as depicted in Figure 11.4h. This sector will generally be affected through a reduction in levels of output. It is expected that the charge will partly be borne by the producers and partly be shifted to the consumers of their products. Consequently, producers' profits will be adversely affected by the charge. As with mining, the manufacturing sector also receives some benefits as downstream user. The impact is shown in Table 11.2.

Table 11.2: Impact of charge on manufacturing sector (R million)

Scenario	Impact on production output	Downstream benefits
1	-204	2.5
2	-198	1.6
3	-218	2.6

- *Utilities and service sectors*

  For the impact on the municipal sector, the discussion above has relevance. The results of the modelling are shown in Table 11.3.

Table 11.3: Impact of charge on utilities and service sectors (R million)

Scenario	Impact on production output	Downstream benefits
1	35	270
2	23	171
3	63	272

The downstream benefits are large as water utilities and municipalities are the largest consumers of raw water of which the quality determines the cost of treatment.

11.5.2 The South African economy as a whole

When determining the overall effect on the South African economy it is necessary to be conceptually clear as to what can be considered costs and what benefits. The basic charge is not an additional cost or benefit because it reflects only present water quality management costs, which are currently borne by the general tax payer, to be shifted to the discharger under the WDCS. Although this will have structural implications for the economy, these have not been determined, but can be considered positive rather than negative.

The load-based charge is not an additional cost either, from the point of view that it reflects costs already borne by downstream activities. However, because it is necessary to determine the benefits of various charge structures, which could include progressive elements, being additional costs, this charge has to be considered. The engagement of concerns in abatement should be considered for similar reasons.

A reduction in downstream cost is a benefit from which the costs are to be subtracted to determine overall gains or losses. Because the downstream costs of the nutrients nitrogen and phosphorus have not been taken into account, it is necessary to consider the effects of the WDCS with respect to salinity separately, because the downstream cost savings (i.e. benefits) can be determined for salinity.

The overall effect on the economy indicated by the economic impact assessment model is that under Scenario 1 there is an overall gain of R157 million to the economy, R142 million under Scenario 2, and under Scenario 3 only R61 million. Under Scenarios 1 and 2 firms do not have an incentive to engage in abatement because the charge is less than the abatement cost, hence the zero private treatment costs.

Under Scenario 3 the revenue from the charge (benefits minus cost) is less than under Scenarios 1 and 2 since the charge for exceeding authorised loads is not progressive hence firms engage in abatement, thereby avoiding the charge. Additionally, the downstream benefits of Scenario 3 are only marginally better than under Scenario 1. These results are shown in Table 11.4.

Table 11.4: Impact of WDCS with respect to salinity under the three scenarios (R million)

Item	Scenario 1	Scenario 2	Scenario 3
WDCS load-based charge	-309	-155	-190
Private treatment costs	0	0	-219
Downstream benefits	467	296	471
Benefits minus costs	**157**	**142**	**61**

When all pollutants are considered, forming the full picture will not be possible, because the downstream benefits pertaining to pollutants other than salinity have not been taken into account. The results, shown in Table 11.5, include the three pollutant groups, but do not account for the downstream benefits of reducing nitrogen and phosphorus.

Table 11.5: Overall impact of WDCS under the three scenarios (R million)

Item	Scenario 1	Scenario 2	Scenario 3
WDCS load-based charge	-326	-163	-216
Private treatment costs	0	0	219
Municipal treatment costs	-35	-23	-63
Downstream benefits	467	296	471
Benefits minus costs	**106**	**111**	**-28**

The results shown here do not take into account the increased downstream opportunities due to decreased pollution load or broader environmental costs.

11.5.3 An appropriate waste discharge charge structure for South Africa

The possibility of finding an appropriate charge structure does exist, as is indicated by this study, although current data constraints do not allow such liberty. The charge structure will differ, depending on the degree to which the

Tiers 3 and 4 charges are progressive. The fact that these charges are progressive means that there is surplus revenue that can be applied to shortfalls in the Tier 2 charge, which will occur if the value of P1 (proportion of abatement costs paid) is lower than 1. The progressiveness itself cannot be optimised because it is a deterrent linked to behavioural responses, and the latter may vary from discharger to discharger.

When the coefficient P is made variable for the charge scenarios, but the charge structure with regard to Tiers 3 and 4 remains the same, the current model indicates that the maximum gain under Scenarios 1 or 2 is found where the value of the coefficient P (the proportion of abatement costs to be paid at a pollutant concentration equal to the waste discharge standard) is equal to 0.32. Under Scenario 3, the optimum for P is 0.45. The overall effect on the economy is shown in Table 11.6.

Table 11.6: Overall impact of WDCS at an optimal charge rate (R million)

Item	Scenarios 1 and 2	Scenario 3
WDCS load-based charge	-258	-261
Private treatment costs	0	0
Municipal treatment costs	-30	-33
Downstream benefits	431	432
Benefits minus costs	**144**	**138**

The situation for the revised Scenarios 1 and 2 is illustrated in Figure 11.6 (refer to Figure 11.2 for explanation of the curves).

Figure 11.6 shows that when only 32 per cent (P=0.32) of abatement cost is charged in Tier 2, the economy receives an overall benefit of R144 million. At higher levels of abatement, the situation would be less satisfactory according to this analysis.

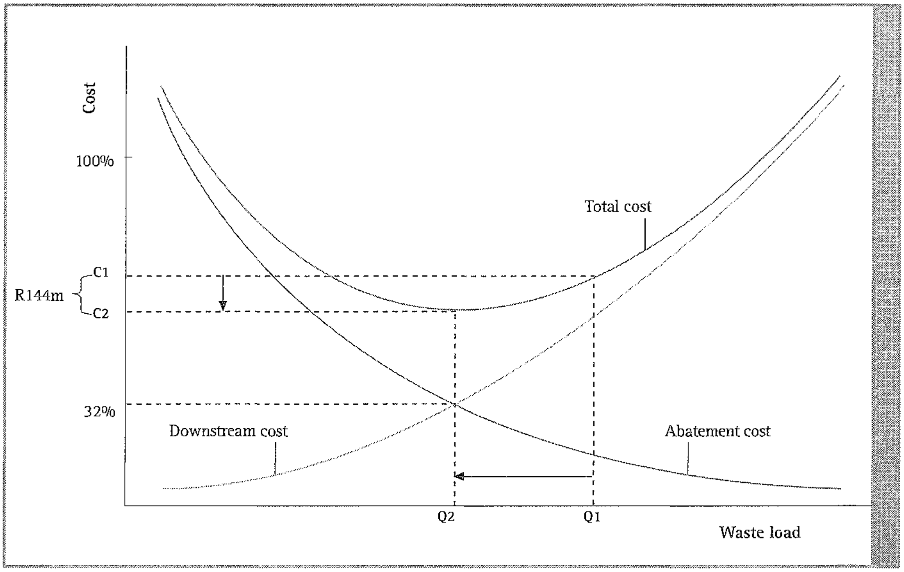


Figure 11.6: Impact of the optimal charge

11.6 Implications for economic development

The most important economic impacts of a proposed WDCS on the South African economy have been outlined here. Results presented indicate that the imposition of such a charge is desirable and will lead to increased economic welfare. As was discussed above, the downstream benefits were underestimated, due to not having accounted for certain kinds of downstream impacts. But, despite this, the analysis shows that the benefits still outweigh the costs. If the full downstream benefits had been estimated, and benefits of production had not been overestimated, the optimal charge would have been higher, and the level of pollution abatement would consequently also be higher.

11.6.1 Structural changes to the economy

In general, those polluting industries that will be most adversely affected are the industries for whose products the demand is sensitive to an increase in price. Such industries will have to bear a large proportion of the increased costs, resulting in reduced profits. Where the demand for a product is not as sensitive to price, polluting industries can shift the increased cost onto consumers.

The waste discharge charge may not only bring about a change in the production processes of existing dischargers, but also a shift in the economy towards sectors that do not discharge significant amounts of waste. The water utilities will benefit, but these benefits may not be passed on to the municipalities and ultimately to the consumers. Where, for example, salinity is not reduced by the water utilities or municipalities, consumers will get direct benefits. The tourism sector is also likely to benefit, as more water courses and dams will become attractive from a recreational point of view. In general, a shift will occur from unsustainable to sustainable production. Although the data available for the study did not indicate it, irrigated agriculture will benefit from the charge system. Saline irrigation water tends to cause an accumulation of salts in soil, making the soil barren. In some cases the soil structure is altered, making tillage impossible.

It is interesting to note that the declining gold-mining sector was responsible for the rapid urbanisation of areas where there is insufficient water to sustain such a large population, requiring large transfer schemes from hundreds of kilometres distant, while the mining sector produces a commodity with very little use value. Instead, it causes a reduction in the utility of water resources which have a much greater use value. Commodity prices, such as for gold, are high, largely for reasons other than their utility; mainly their scarcity, which indicates that the resource has but a limited capacity for sustaining an economy for long. Once it has been depleted, population distribution patterns will be left economically inefficient.

11.6.2 Impacts on the investment environment in South Africa

Although not part of the impacts determined by means of the model, the impacts of the charge system on the investment environment in South Africa, *vis à vis* the rest of the world, was evaluated qualitatively.

The following impacts may be expected:

- disinvestments from discharging industries;
- reduction in potential investment in industries that would discharge waste into water resources;
- possible greater 'ethical' investment in discharging industries which choose to engage in abatement as a result of the waste discharge charge;

- greater investment in industries affected negatively by poor water quality; and
- greater investment in abatement activities.

With regard to the first two issues raised above, it must be noted that the WDCS does not put South Africa at a particular disadvantage compared to other investment destinations in the rest of the world, as South Africa would be a latecomer with the introduction of such a system. Many other countries, including developing countries, already have such systems. Also, rates, and especially cost with regard to waste water, contribute only a small percentage of total production cost of a firm.

In a study undertaken by Business South Africa,[20] a range of countries [21] were identified as having a similar profile to South Africa with regard to either population or income, and could be considered competitors for attracting foreign direct investment (FDI). All of these countries have already introduced waste discharge charges, and all except Turkey fare better than South Africa in attracting FDI. Several other factors contribute to the rate of FDI in these countries, such as the proximity to large markets, human and natural capital, and socio-political stability.

In addition to traditional policies and measures aimed at attracting FDI, it has been said that countries should introduce new policies and measures that will increase competitive advantages in order to attract FDI.[22] Tax rates and other levies and charges should, for instance, be minimised. However, it is important to note that a pollution charge is not an additional burden on the economy. It embodies a cost already borne both by downstream activities and the taxpayer in general. The charge merely shifts the costs back to those who are responsible to induce such entities to minimise the pollution as such. Ultimately, pollution costs will be reduced, rendering the economy more efficient and less wasteful – which can only lead to the country's attractiveness to investors.

11.7 Conclusion

From the assessment of the economic effects of the WDCS it can be concluded that the imposition of such a charge is economically viable and will give rise to increased economic welfare, since polluting industries are forced to consider the social costs of their activities. To ensure that production occurs at a more efficient level, it is essential that such a charge be levied. It is also more likely that investment finance will be attracted to economies that are more efficient with defensible economic activities. Economists have already pointed out that income tax should be systematically replaced with resource-based charges, because income tax generally discourages income generation, while resource-based charges discourage resource depletion. Clearly, income generation should not be discouraged, but resource depletion should.

Endnotes and References

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7 After A.C. Pigou, the British economist who was concerned with externalities and taxes and their adjustment to prices according to the social cost.

8 Adapted from Rosen, H.S. 1985. *Public Finance.* Boston: Irwin, p. 128.

9 At a lower level of production than where Marginal Private Cost and Marginal Benefit intersect, additional costs can be incurred to obtain additional revenue, and at a higher level, costs will exceed revenues.

10 Department of Water Affairs and Forestry (DWAF). 2001. *Discharge Charge System: Proposed Waste Standards for Receiving Water Bodies With an EMS of Classes A, B, C or D.* Pretoria: DWAF.

11 The National Water Act (36 of 1998) specifies in Section 57(5) that *'No charge made under this Act may be of such a nature as to constitute the imposition of a tax, levy or duty'.* A general distinction is made (not in this Act) between a charge and a tax. A charge is considered to be an amount recovered for the use of a service, in this case the right to use the assimilative capacity of a water resource. A tax is not necessarily related to the cost of a service, and is imposed to generate revenue for the general fiscus, and in some cases corresponds with a disincentive required by policy makers. The South African National Treasury also recognises 'earmarked' taxes, of which the revenue is earmarked for certain purposes, but these are still not based on cost recovery. In the case of water pollution, such a tax can be earmarked for purposes other than the pollution abatement required due to the activities of a discharger, and can therefore be used for purposes such as remediation of historically accumulated pollution.

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Appendix 11.1

Selected Monitoring Station, Ecological River Classification and Current Status Water Qualities for Specific Quaternary River Catchments

Secondary Catchment	River/ Quaternary Catchment	Monitoring Station	Ecological River Classification		Median /P90%	Current Status (mg/l)				
			PESC	AEMC		TDS	PO_4-P	NO_3-N	NH_4-N	Total N
A21	Crocodile A21H	A2H083Q01 Hartbees-poort dam	C	C	Med	375	0.083	1.726	0.158	1.884
					P90	425	0.211	2.849	0.768	3.617
A21	Crocodile A21K	A2H019Q01 Roodekopjes dam	C	B	Med	552	0.028	0.364	0.101	0.465
					P90	693	0.131	1.474	0.245	1.719
A23	Pienaars A23L	A2H021Q01 Buffelspoort	C	C	Med	452	0.283	0.42	0.07	0.49
					P90	561	0.629	1.224	0.214	1.438
A24	Crocodile A24H	A2H116Q01 Paul Hugo dam	D	D	Med	531	0.039	0.059	0.044	0.103
					P90	602	0.119	0.734	0.112	0.846
A91	Luvuvhu A91K	A9H011Q01 Paturi/KNP	B	B	Med	98	0.018	0.081	0.046	0.127
					P90	161	0.055	0.452	0.09	0.542
B11	Olifants B11J	B1H010Q01 Witbank dam	*E	*D	Med	372	0.012	0.068	0.035	0.103
					P90	457	0.02	0.426	0.063	0.489
B12	Olifants B12D	B1H015Q01 Middelburg dam	*D	*C	Med	340	0.009	0.087	0.044	0.126
					P90	457	0.018	0.25	0.09	0.34
B50	Olifants B52G	B5H002Q01 Zoekoeigat	D	C	Med	930	0.01	0.884	0.4	1.284
					P90	1 338	0.049	6.865	1.543	8.408
B73	Olifants B73H	B7H017Q01 Balule Rest camp	*C	*B	Med	584	0.016	0.048	0.05	0.098
					P90	1 369	0.031	0.467	0.104	0.571
C11	Vaal C11L	C1H020Q01 Grootdraai dam	E	D	Med	163	0.019	0.259	0.04	0.299
					P90	194	0.042	0.56	0.079	0.639
C12	Vaal C12L	C1H017Q01 Villiers	C	C	Med	208	0.026	0.133	0.047	0.18
					P90	379	0.082	0.668	0.11	0.788
C21	Blesbokspruit C21G	C2H004Q01 Suikerbos rand at Uitvlugt	D	D	Med	703	0.025	0.3	0.05	0.35
					P90	1 381	0.156	1.105	0.13	1.235
C22	Klip C22E	C2H071Q01 Kookfontein/ Vereeniging rail	E	D	Med	611	0.5	4.03	0.12	4.15
					P90	805	0.99	5.95	0.51	6.46
C22	Vaal C23B	C2H008Q01 Lindeques-drift (Barrage)	D	D	Med	573	0.074	2.006	0.117	2.123
					P90	887	0.262	4.56	0.87	5.43

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Secondary Catchment	River/ Quaternary Catchment	Monitoring Station	Ecological River Classification		Median /P90§	Current Status (mg/l)				
			PESC	AEMC		TDS	PO_4-P	NO_3-N	NH_4-N	Total N
C23	Mooi C23L	C2H085Q01 Hoogekraal/ Kromdraai	D	D	Med P90	563 725	0.972 3.463	0.159 0.828	0.048 0.121	0.207 0.949
C24	Vaal C24B	C2HOO7Q01 Pilgrims Estate/ Orkney	D	D	Med P90	579 818	0.036 0.133	0.6 1.479	0.06 0.15	0.66 1.629
C42	Sand C42L	C4H16Q01 Sand River	C	C	Med P90	758 1 034	0.304 1.662	0.701 3.142	0.041 0.129	0.742 3.271
C52	Modder-Riet C52L	C2H035Q1 Tweeriviere	E	D	Med P90	201 456	0.021 0.055	0.604 1.237	0.042 0.087	0.646 1.324
C83	Wilge C83J	C8H001Q1 Frankfurt	C	C	Med P90	128 300	0.029 0.077	0.219 0.47	0.095 0.05	0.314 0.52
C91	Vaal River C91A	C9H021Q1 Bloemhof dam	C	C	Med P90	398 552	0.014 0.038	0.06 0.563	0.06 0.145	0.12 0.708
G22	Eertse G22H	G2H015Q1 Faure	D	C	Med P90	264 394	0.498 1.51	1.85 3.49	0.364 0.085	2.214 3.575
H40	Breede H40J	H4H024Q0 Robertson canal	D	C	Med P90	147 240	0.014 0.03	0.17 0.739	0.04 0.003	0.21 0.742
H50	Breede H50B	H5H005 Bonnievale **(See Note)**	C	C	Med P95	641 1 127	0.115 0.980	0.021 0.046	0.028 0.08	0.049 0.126
M10	Zwartkops M10C	M1H012Q1 Uitenhage Nivens Bridge	E	D	Med P90	941 2 358	0.027 0.102	0.291 1.325	0.034 0.556	0.325 1.881
R10	Keiskamma R10M	R1H05Q01 Farm7/ Howard Shaw bridge	D	C	Med P90	260 409	0.029 0.07	0.316 0.912	0.041 0.089	0.357 1.001
R20	Buffalo R20G	R2R003Q01 Bridle Drift dam	D	C	Med P90	288 355	0.025 0.06	0.813 1.755	0.059 0.13	0.872 1.885
T20	Mtata T20G	T2H005Q01 Sidaba-dabeni/ Coffee Bay	D	D	Med P90	112 181	0.132 0.174	0.45 0.853	0.17 0.249	0.62 1.102
U20	Mgeni U20M	U2H054Q1 Inanda dam	C	C	Med P90	153 195	0.005 0.031	0.28 0.584	- -	0.28 0.584

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Secondary Catchment	River/ Quaternary Catchment	Monitoring Station	Ecological River Classification		Median /P90§	Current Status (mg/l)				
			PESC	AEMC		TDS	PO_4-P	NO_3-N	NH_4-N	Total N
V20	Mooi V20H	V2H008Q01 Keate's drift	C	C	Med	218	0.017	0.236	0.032	0.268
					P90	386	0.055	0.726	0.057	0.783
V30	Buffalo V32D	V3H01Q01 Tayside	B	B	Med	432	0.049	0.81	0.05	0.86
					P90	240	0.308	2.366	0.055	2.416
W12	Mhlatuze W12F	W1H035Q1 Richards Bay	C	D	Med	303	0.032	0.362	0.072	0.434
					P90	453	0.054	0.505	0.055	0.560
W21	White Umfolozi W21K	W2H005Q1 Overvloed/ Ulundi	B	A	Med	244	0.018	0.08	0.036	0.116
					P90	307	0.039	0.377	0.08	0.457
W22	Black Mfolozi W22L	W2H002Q1 Umfolozi Game Reserve	A	A	Med	278	0.009	0.34	0.05	0.39
					P90	400	0.04	0.71	0.423	1.133
W30	Mkuzi W32B	W3H011Q1 Morrisvale/ Lower Mkuzi	A	A	Med	517	0.011	0.13	0.05	0.18
					P90	830	0.033	0.464	0.166	0.63
W44	Pongola W45B	W4H009Q1 Ndume Game Reserve	C	C	Med	286	0.018	0.24	0.041	0.281
					P90	641	0.047	0.6	0.089	0.689
X20	Crocodile X24H	X2H016Q01 Ten Bosch/ Kruger Park	D	D	Med	315	0.017	0.49	0.049	0.539
					P90	563	0.037	0.922	0.097	1.019

Source: Department of Water Affairs and Forestry (DWAF). 2001. An Assessment of Pollution Regimes as Part of the Development of a Waste Discharge Charge System. Pretoria: DWAF, p. 29.

Notes:
* River class determined by investigation
§ Ninetieth percentile value
PESC Present Ecological Status Class
AEMC Attainable Ecological Management Class
H50 Breede River: differs from rest of data. Available data for 1995 to 2000; also used 95% and not 90% percentile

CHAPTER 12

The cost of a decline in air quality

James Blignaut and Mark Zunckel

12.1 Introduction

Natural systems act as sinks that absorb and process wastes resulting from economic activities, but they do not request payment for their services. Since these services are public goods (free goods with no protection by property rights), the economic production and consumption process ignores them. The value of these services can be calculated and internalised through appropriate policies (see Chapters 5 and 6 in this regard). Air pollution is no exception to this general principle, and the question at stake here is: What is the extent of air pollution externalities in South Africa?

This chapter provides a synthesis of research undertaken by various authors[1] towards calculating the social cost of both global (through global climate change) and local (through health effects) air pollutants. Although emissions from the combustion of coal, motor vehicle emissions and the social cost of domestic air pollution are discussed and compared, the results are by no means all-inclusive, nor do they represent the total social cost of air pollution, since such a study has not been conducted yet.

12.2 Air pollution in South Africa

12.2.1 Overview

Air pollution describes the presence of harmful gases and particles in the atmosphere. Air pollutants are released from natural sources such as fires, volcanoes and anthropogenic activities, which are all responsible for much of the pollution present in the atmosphere, both outdoors and indoors. Air pollution affects the quality of life and the economic productivity of those that are exposed to it. The nature of air pollutants and their effects vary from compound to compound. For example, sulphur dioxide (SO_2) and oxides of nitrogen (NOx), released in the combustion of fossil fuels, have detrimental effects of the human respiratory system[2] and may also lead to the acidification of ecological systems.[3] Volatile organic compounds (VOCs) are emitted from natural sources as well as from many industrial processes. The concern regarding non-methane VOCs is twofold. Firstly, the toxicity inherent in each compound is related to respiratory irritation, central nervous system effects and cancer[4] in humans. Secondly, ambient non-methane VOCs (NMVOCs) contribute significantly to the formation of the secondary pollutant ozone.[5] Ozone reduces respiratory function, increases inflammatory reactions in the airways and impairs mucociliary particle clearance from the airways.[6]

In addition to these local pollutants, there are also global pollutants, called greenhouse gases, due to their contribution to the so-called greenhouse effect. Greenhouse gases trap outgoing radiation from the earth which leads to a heat build-up and an ensuing change in global climatic patterns. Greenhouse gases, with carbon dioxide (CO_2) being the most common, are released from all industrial processes where fossil fuels are combusted. Coal-fired power stations, cement manufacturing and the manufacture of synthetic fuels are the major anthropogenic sources of CO_2. The increase in global concentrations of greenhouse gases has been indicated to be responsible for global warming and the associated changes to global climate.[7] Chlorofluorocarbons (CFCs), once used widely as refrigerants and propellants in aerosol cans and fire extinguishers, have atmospheric lives of decades. These compounds are greenhouses gases, and the increase in their global concentrations has been linked to the depletion of the ozone layer, resulting in detrimentally high levels of UV-B radiation at the earth's surface.[8]

Having clean, safe air to breathe is as important to humans as safe water and food. It is estimated that 24 million people in South Africa live in areas where levels of air pollution can be classified as unsafe.[9] For example, poor air quality has been linked to the prevalence of asthma in Durban's southern Durban basin.[10] The implication is that the health of a significant portion of the population may be compromised, which in turn has a negative impact on productivity and the medical costs in treatment. In addition to the negative impact on human health, initial research has indicated that levels of air pollution in South Africa exceed threshold values, above which detrimental effects may be expected in plant production and crop yield.[11] Stress induced by air pollution to food crops may have severe implications in a region where factors such as water stress already impact seasonally on crop yield.

Fossil fuels are combusted to a greater or lesser extent in all of these aforementioned activities, releasing a number of air pollutants, including methane (CH_4), sulphur dioxide (SO_2), oxides of nitrogen (NOx), carbon monoxide (CO), particulate matter and non-methane volatile organic compounds (NMVOCs). South Africa compiled an estimate of greenhouse gas emissions for 1990 after ratifying the United Nations Framework Convention for Climate Change (UNFCCC) in 1997 (see Table 12.1). A comprehensive inventory will not be available until the first National Communication to UNFCCC has been completed.

Long-term monitoring at the Cape Point trace gas station (that monitors atmospheric concentrations of various gases, which include emissions from all global sources) indicates a steady increase in global background concentrations of CO_2, CH_4 and N_2O over time in response to anthropogenic emissions.[12] The trend for CH_4 has remained positive over the past 18 years. However, the average growth

Table 12.1: Main sources of emission by sector: 1990: '000 tons

Source	CO_2	CH_4	N_2O	CO	NOx	NMVOC	SO_2
Energy (electricity, industrial, domestic, mining & refineries)	238 554 (87.4)	751 (33.6)	7 (9.0)	1 660 (29.2)	1 221 (53.8)	88 (10.3)	1 695 (96.3)
Transport	31 390 (11.5)	39 (1.7)	5 (6.4)	2 707 (47.7)	995 (43.9)	569 (66.9)	37 (2.1)
Industrial processes (excludes energy)	23 461 (8.6)	4 (0.2)	2 (2.6)	28 (0.5)	13 (0.6)	194 (22.8)	28 (1.6)
Agriculture, land use change & forestry*	-20 614 (-7.6)	1 064 (47.5)	61 (78.2)	1 286 (22.6)	39 (1.7)		
Waste (landfills, effluent & sewage treatment)		380 (17.0)	3 (3.8)				
Total	272 682	2 238	78	5 681	2 268	851	1 760

Source: National State of the Environment Report 1999. Directorate Environmental Information and Reporting, Department. Environmental Affairs and Tourism. www.environment.gov.za/soer/nsoer/.

Notes: percentage contribution to the total shown in parenthesis
* The negative CO_2 value for agriculture, land use and forestry indicates the carbon that is taken up by woodlands and forest and so represents a net uptake rather than release of carbon

rate declined from 10 parts per billion per year (ppb yr^{-1}) for the period 1983 to 1991 to about 6 ppb yr^{-1} for the period 1992 to 2000. The ambient CO_2 concentration at Cape Point increased by approximately 13 parts per million (ppm) between 1993 and 1999. N_2O displayed an average growth rate of 0.88 ppb yr^{-1} for the years 1994 to 2000. By contrast, background concentrations of CFC-11 increased steadily from 160 parts per trillion (ppt) in 1980 to 260 ppt in the early 1990s, but have remained at this level since, in response to the phasing out of CFCs in accordance with the Montreal Protocol.

South Africa's contribution to the global greenhouse effect ranks among the top ten countries. In 1999, South Africa contributed about 1.6 per cent of the total world carbon equivalent emissions; an increase from 1.2 per cent in 1990. On a global scale, South Africa was the fifteenth highest emitter of carbon dioxide in 1995 and 1997 in absolute terms and was hence the tenth highest non-Annex 1 polluter of carbon dioxide per capita in both 1995 and 1997, or twenty-eighth overall (including the developed economies).[13] In regional terms, South Africa accounts for about 42 per cent of the total carbon equivalent emissions for the African continent.[14] The energy sector was responsible for a large portion of the total South African emission of CO_2 (272 682 kiloton (kt)), N_2O (78kt) and methane (2 238 kt) in 1990 (Table 12.1), with power generation and the synthetic fuel industry the largest consumers of coal and the largest emitters.

On a regional scale, monitoring of SO_2 indicates the highest concentrations in South Africa occur in the triangle formed by Witbank, Middleburg, Bethal, decreasing to the boundary of the highveld.[15] Ambient concentrations of SO_2 in the Vaal Triangle are high, but lower than those of the central highveld. Although the annual South African guideline for SO_2 is not exceeded in either of these major source areas, the hourly and daily guidelines are exceeded on occasion. Concentrations of particulate matter smaller than 10 μm consistently exceed the US EPA annual standard of 50 μg/m3 on the central highveld.

Major urban centres with high-density traffic, industry and local-scale domestic burning are areas where ambient air quality is severely impacted. In Durban, for example, motor vehicles and industry are the major contributors to all of the emitted pollutants.[16] SO_2 concentrations in 1998 in a number of areas adjacent to the southern industrial basin exceeded the new DEAT guideline of 19 ppb. In Cape Town, motor vehicle numbers have increased by 80 per cent in the last 20 years, and are a major source of emission, with diesel vehicles contributing 48 per cent of all particulates.[17] While ambient levels of lead have decreased in Cape Town, particulate concentrations show a steady increase, while NO_2 and SO_2 guidelines are exceeded in places. Motor vehicle emissions, wind-blown dust from mine dumps and gravel roads, and industrial emissions are the major sources of air pollution in Johannesburg, resulting in elevated concentrations of both primary and secondary pollutants with particulate concentrations exceeding the national guideline of 20 per cent to 30 per cent for winter time in Soweto.[18] The actual air pollution emissions are next discussed in terms of their origin, whether industrial coal use, mobile source or biomass burning (including the indoor use of coal).

12.2.2 Coal-based emissions

The major consumers of coal in South Africa are ESKOM and the synthetic fuel industry, primarily SASOL, collectively accounting for between 85 per cent and 90 per cent of all coal used in the South African market from 1999 to 2000 (Table 12.2). Only 1 per cent of the local coal consumption is used as domestic fuel for heating and cooking. The combustion of coal results in the emission of a number of pollutants such as sulphur dioxide (SO_2), oxides of nitrogen (NOx), carbon dioxide (CO_2), methane (CH_4) and particulate matter. SO_2 and NOx released from tall power station stacks may result in local and regional scale impacts. By contrast, pollutants released from domestic coal fires have the most impact in the homes where the fires are burning and in the immediate surrounding vicinity.

Table 12.2: Emissions by sector in South Africa in 2000

	Coal consumed	Share of total	Value	% share	Average price	SO_2	Share of total	CH_4	Share of total	CO_2	Share of total
	Tons	%	R000	%	R/ton	Tons	%	tons	%	tons	%
ISCOR	1 583 865	1.0	178 669	1.89	239.08	28 506	1.4	39 121	1.0	3 195 475	1.3
Metallurgical	1 272 014	0.8	190 016	0.95	149.38	20 861	1.0	31 419	0.8	2 964 507	1.2
Agriculture	69 053	0.0	7 471	0.04	108.19	1 133	0.1	1 706	0.0	142 447	0.1
Iron and steel	2 881 311	1.8	298 751	1.49	103.69	47 234	2.3	71 168	1.9	5 929 036	2.3
Industries	2 630 809	1.6	258 464	1.29	98.25	47 344	2.3	64 981	1.7	5 315 411	2.1
Chemical industries	1 080 816	0.7	105 571	0.53	97.68	19 433	0.9	26 696	0.7	2 208 196	0.9
Merchants and domestics	3 920 241	2.4	374 600	1.87	95.56	64 715	3.1	96 830	2.5	8 146 063	3.2
Gold and uranium mines	24 043	0.0	2 232	0.01	92.83	493	0.0	594	0.0	48 399	0.0
Other mining	120 998	0.1	10 565	0.05	87.32	2 178	0.1	2 989	0.1	243 569	0.1
Water	146 534	0.1	11 946	0.06	81.52	2 403	0.1	3 619	0.1	301 958	0.1
SASOL	51 800 000	32.2	2 845 540	14.23	61.41	293 000	14.1	1 144 469	36.0	57 713 000	22.9
Cement and lime	1 071 221	0.7	65 532	0.33	61.17	19 282	0.9	26 459	0.7	2 156 368	0.9
Electricity (non-ESKOM)	1 556 304	1.0	95 126	0.48	61.12	30 192	1.4	38 441	1.0	2 425 240	1.0
ESKOM	92 300 000	57.5	4 129 021	20.64	44.97	1 505 000	72.2	2 267 733	59.4	161 200 000	63.9
Brick and tile	176 517	0.1	7 525	0.04	42.63	3 177	0.2	4 360	0.1	355 329	0.0
Total	160 633 726	100.0	20 011 267	100.0	56.77	2 084 915	100.0	3 820 585	100.0	252 344 938	100.0

Source: Blignaut, J.N. and King, N. 2002. The externality cost of coal combustion in South Africa. In: Blignaut, J.N. (ed.). Bridging the Economics/Environment Divide. Published conference proceedings. Forum for Economics and Environment, Pretoria, pp. 71-85.

Emissions from coal-based activities by sector are listed in Table 12.2. It is evident that emissions from power generation are dominant, and contributed 64 per cent of carbon dioxide (CO_2) and 60 per cent of the methane (CH_4) emissions in 2000. Despite the National Communication to the UNFCCC not being complete, an indication of the small increase in greenhouse emissions from power generation can be seen (Table 12.3).

Table 12.3: Annual CO_2 and N_2O emissions from Eskom power stations: 1996 to 2000

	Unit	1996	1997	1998	1999	2000
Carbon dioxide (CO_2)	Million tons	159	169	163	159.4	161.2
Nitrous oxide (N_2O)	tons	2 004	2 085	2 031	2 010	2 093

Source: Eskom. 2000. Eskom Environmental Report 2000 – towards sustainability. www.eskom.co.za.

12.2.3 Mobile emissions

Fuels combusted in all modes of motorised transport are derived from coal and oil and are therefore classed as fossil fuels. Their combustion results in the emission of a number of pollutants that have local, regional and global effects. Emissions of greenhouse gases and other pollutants from the various sectors of transport show road transport to be the major contributor (Table 12.4). CO_2 is the principal greenhouse gas associated with the transport sector and it is directly related to the volume of road traffic, the amount of fuel used and the carbon content of the fuel. Diesel engines tend to be more efficient than equivalent gasoline engines, but the carbon content of diesel is higher. A comparison between CO_2 emitted from diesel and gasoline powered vehicles is given in Table 12.5. Other primary pollutants associated with motor vehicle emissions are CO (carbon monoxide), NOx (oxides of nitrogen), SO_2 (sulphur dioxide), VOCs (volatile organic compounds), such as benzene and aldehydes and particulates such as lead (Pb) and particulates (generally <2.5 μm). Photochemical smog with components such as ozone (O_3), is formed in the chemical reaction between NOx and VOCs in sunlight, and results in the formation of ozone.

Table 12.4: Emission levels per transport mode: 1990: '000 tons

Mode	CO_2	CH_4	N_2O	NOx	CO	NMVOC	SO_2
Civil aviation	999.43	0.10	0.00	3.86	29.30	0.86	0.03
Road	29579.04	20.59	1.96	527.94	2 300.20	504.42	34.48
Rail	800.41	18.68	3.00	462.49	377.74	63.72	2.83
Shipping	11.11	0.00	0.00	0.27	0.03	0.01	0.00
Total transport	31389.99	39.36	4.96	994.57	2 707.27	569.00	37.35
Transport share as % of total	42%	5%	60%	94%	66%	88%	15%

Source: National State of the Environment Report 1999. Directorate Environmental Information and Reporting, Department of Environmental Affairs and Tourism. www.environment.gov.za/soer/nsoer/.

Table 12.5: CO_2 emitted from petrol and diesel-powered engines: 1998: tons

	Petrol engines	Diesel engines
Eastern Cape	1 919 547	737 046
Free State	1 486 031	796 069
Gauteng	9 133 090	2 772 408
Mpumalanga	1 742 630	1 051 672
KwaZulu-Natal	4 040 390	2 184 196
North West	1 394 499	604 034
Northern Cape	488 414	350 712
Northern Province	1 318 669	329 599
Western Cape	3 897 711	1 604 042
Total	**25 420 981**	**10 429 778**

Source: National Treasury 2003. Market-Based Instruments to Support Environmental Fiscal Reform in South Africa: A Discussion Document. Pretoria: National Treasury.

Motor vehicle emissions are concentrated in urban areas where traffic volumes are high and populations are most dense. They are released near ground level, peaking with traffic volumes in the morning and evenings. The peak motor vehicle emissions coincide with generally poor atmospheric dispersion conditions of light winds and temperature inversions. These pollutants accumulate in the area where they are released, where they have an impact on the health of concentrated human populations. Since motor vehicle emissions are released at low levels they may be compared with industrial emissions from low stacks. Motor vehicle emissions are dominant when compared with scheduled emissions sources below 10m based on a database compiled from the Department of Environment Affairs and Tourism data over a number of years (Table 12.6). Emissions above 150m are indicative of high combustion efficiency and are released above the surface temperature inversion into generally stronger winds where they disperse more efficiently. These emissions are low in CO and hydrocarbons but rich in NOx. It is noteworthy that the petrochemical industry contributes 83 per cent of the hydrocarbon emissions release between 10 and 150 m.

Table 12.6: Comparisons between estimated internal combustion vehicle (ICV) emissions and schedules process emissions: t/year

Pollutant	ICV	Scheduled industries (release height)			
		Total	< 10 m	10-150 m	>150 m
CO	3 239 280	482 935	263 530	196 339	23 066
Hydrocarbons	443 219	338 996	60 453	277 243	1 300
NOx	277 080	743 337	47 163	86 864	609 310

Source: Terblanche, P. 1995. Motor Vehicle Emissions Policy and Development: Phase 1. Report number EV9404 to the Department of Mineral and Energy Affairs. Pretoria: Department of Mineral and Energy Affairs.

12.2.4 Emissions from biomass burning (natural, controlled and domestic)

Controlled fires are used in South African for veld management, firebreaks, veld clearing, and in processes such as sugar cane burning. Uncontrolled natural fires may include savannah, forest and fynbos fires. Controlled and uncontrolled fires in South Africa are responsible for much of the photochemical ozone and are contributors to greenhouse gas emissions. Biomass burning emissions estimated for South Africa in 1989 are listed in Table 12.7. These do not include emissions from domestic fuel wood and charcoal and burning of agricultural waste.

Table 12.7: Biomass burning emissions estimated for South Africa: 1989

CO_2	CH_4	CO	NOx	N_2O
Million tons/year	Million tons/year	Million tons/year	Million tons/year	'000 ton/year
11.4	0.015	0.449	0.031	5.8

Source: Scholes, R.J., Ward, D.E. and Justice, C.O. 1996. Emissions of trace gases and aerosol particles due to vegetation burning in southern hemisphere Africa. *Journal of Geophysical Research*, 101(D19):23677-82.

In areas where there is no access to grid electricity or where coal burning is the preferred form of producing thermal energy, the main negative impact is that on human health – the so-called exposure to indoor air pollution. It entails mainly the exposure to particulate matter due to the combustion of coal. In addition, low-level emissions from burning devices and chimneys result in high concentrations of pollutants accumulating in the immediate ambient environment, particularly during winter when wind speeds are low and surface inversions are most frequent.

Common pollutants are sulphur dioxide (SO_2), oxides of nitrogen (NOx) and particulates. Where SO_2 and NOx have negative effects on the human respiratory system, particulate matter in itself is not toxic. However, high levels of exposure and long durations may lead to chronic respiratory and other diseases, for example, cancer, low birth weight, upper respiratory tract illnesses, heart diseases and chronic obstruction of the lungs. Pollutant gases bind on particulates and in this way increase their risk to human health. The standards that have lately been set for SO_2 are in line those of the World Health Organisation and are more stringent than the former South African guidelines. The review of guidelines for other pollutants is still in progress and the recommended standard for nitrogen oxide (NO_2) is the more stringent WHO and European Union standard.[19] Similarly, the South African PM10 (particulate matter smaller than 10 μm) guideline for maximum 24-hour concentration is considerably higher than that of the international standards, but the annual average guideline is better aligned with international practice (Table 12.8). Recommendations have been made for more stringent standards for particulates inclusive of PM2.5.[20]

Table 12.8: PM10 Guidelines and standards

Country/organisation	Inhalable particulates (PM10)	
	Maximum 24-hour concentration (μg/m^3)	Annual average concentration (μg/m^3)
South Africa (DEAT)	180	60
United Sates (EPA)	150	50
(old) EU	130 250	80
(new) EC	50	30 20
UK National Air Quality Objectives	50	40
World Bank	70	50

Source: Scorgie, Y. and Annergarn, H. 2002. The impact of coal on people. Paper presented at the Coal and Sustainable Development Conference, a WSSD side-event, Johannesburg, 8-12 September.

The coal sales by sector (see Table 12.2) indicate that merchant and domestic coal sales were less than 2 per cent of the total sales in 2000. Even so, the accumulation of low-level emissions and compromised indoor air quality account for some of the poorest air quality in South Africa. This is mainly a burden on the poor who cannot afford grid electricity or the attendant the appliances; neither can they escape the bad health conditions in which they are trapped. Additionally, the poor have little or no proper recreational facilities, and they often cannot afford the medical treatment required. The housebound young and elderly, in particular, are affected most.

12.3 External cost of air pollution

12.3.1 Coal combustion

Based on the laws of material balance and thermodynamics, matter and energy cannot be created or destroyed, only transformed. This implies that, based on the volume of coal consumed and the carbon concentration thereof it is possible to determine how much carbon has been released into the atmosphere. Technology at present does not provide for mitigation options of carbon dioxide or methane emissions originating from the combustion of coal, although the quest for such options is currently the focus of large-scale research. It is therefore possible to determine various conversion factors to calculate the emissions of the two most important global pollutants, methane (CH_4) and carbon dioxide (CO_2). Methane's conversion factor was obtained from the IPCC 1996 guidelines,[21] namely that of 0.7kg of CH_4 per TJ coal, which translates to 24.7 kg CH_4 emitted per ton of coal. The conversion factor for CO_2 was obtained by calculating the carbon content in coal used by various economic sectors,[22] multiplying it with the total volume of coal used. The total volume of carbon emitted was then multiplied by a factor of 3.667[23] to determine the volume of CO_2. In the case of SASOL and ESKOM, the volume of emissions as published in their annual environmental reports has been used. When compared with the calculated figures, using the conversion factor, a discrepancy of only 4 per cent could be detected.

Sandor[24] estimated the global damage cost of a ton of CO_2 in 2000 to be between US$5 and US$10. Blignaut and King[25] used a conservative $2.50/ton and $5.00/ton in their study (which is comparable to the damage cost calculated in Chapter 6). The price for methane was derived from that for carbon dioxide based on the widely accepted principle of 1 ton CH_4 that has the same global warming potential as 21 tons carbon dioxide, hence multiplying the price for carbon dioxide by 21 to determine the price for CH_4, namely US$52.5/ton and US$105/ton respectively. The Rand values for the global damage cost were obtained by adjusting the dollar price, using the 2000 exchange rate (since all the prices and volumes were for 2000), namely R6.9353/$, and multiplying it by the tons produced for each respective industry. This gives a price of R17.34/ton and R34.68/ton for CO_2 and R364.1/ton and R728.21/ton for CH_4. The results are shown in Table 12.9.

The social cost of environmental global damages due to methane and carbon dioxide emissions only was estimated to range between R5 767 and R11 534 million (US$1.663 million). The higher of the two estimates (based on an assumption of $5/ton) was equivalent to 1.3 per cent of the GDP in 2000 and 130 per cent of the total value of local coal sales. Carbon dioxide contributed 76 per cent of the estimated environmental damage costs. The main contributors to this

Table 12.9: The social cost of carbon dioxide and methane emissions: 2000

	Coal purchased	CH_4			CO_2			Total	
	t	t	R364.1/ ton R million	R728.21/ ton R million	t	R17.34/ ton R million	R34.68/ ton R million	Lower scenario R million	Higher scenario R million
ISCOR	1 583 865	39 171	14	28	3 195 475	55	111	70	139
Metallurgical	1 272 014	31 419	11	23	2 964 507	51	103	63	126
Agriculture	69 053	1 706	1	1	142 447	2	5	3	6
Iron and steel	2 881 311	71 168	26	52	5 927 036	103	206	129	257
Industries	2 630 809	64 981	24	47	5 315 411	92	184	116	232
Chemical industries	1 080 816	26 696	10	19	2 208 196	38	77	48	96
Merchants and domestic	3 920 241	96 830	35	71	8 146 003	141	283	177	353
Gold and uranium mines	24 043	594	0	0	48 599	1	2	1	2
Other mining	120 908	2 989	1	2	243 569	4	8	5	11
Water	146 534	3 619	1	3	301 958	5	10	7	13
SASOL	51 800 000	1 144 469	417	833	57 713 000	1 001	2 001	1 417	2 835
Cement and lime	1 071 221	26 459	10	19	2 156 368	37	75	47	94
Electricity (Non-ESKOM)	1 556 304	38 441	14	28	2 425 240	42	84	56	112
ESKOM	92 300 000	2 267 733	826	1 651	161 200 000	2 795	5 590	3 621	7 242
Brick and tile	176 517	4 360	2	3	355 329	6	12	8	15
Total	160 633 726	3 820 585	1 391	2782	252 344 958	4 376	8 751	5 767	11 534

Source: Blignaut, J.N. and King, N. 2002. The externality cost of coal combustion in South Africa. In: Blignaut, J.N. (ed.). Bridging the Economics/Environment Divide. Published conference proceedings. Forum for Economics and Environment, Pretoria, pp. 71-85.

externality cost are ESKOM and SASOL, respectively contributing R7 242 million (62.8 per cent of total social cost) and R2 835 million (24.6 per cent of total social cost) in damages. ESKOM's turnover for 2000 was R24 459 million[26] and that of SASOL R25 762 million.[27] This implies, according to these estimates, ESKOM's contribution to pollution externalities was equivalent to approximately 30 per cent of its turnover and that of SASOL equivalent to 11 per cent of its turnover in 2000. A comparison between the average private cost of coal and the social cost thereof as expressed in terms of the global damage cost associated with methane and carbon dioxide is shown in Table 12.10. In a large number of cases social cost is comparable with that of private cost or higher, as is the case for ESKOM, implying that on average the social cost is equivalent to 126 per cent of private cost.

Table 12.10: Comparative externality prices and market prices: 2000

	Total private cost	Social cost*	Social cost as % of private cost
	R million	R million	%
ISCOR	379	139	37
Metallurgical	190	126	66
Agriculture	7	6	83
Iron and steel	299	257	86
Industries	258	232	90
Chemical industries	106	96	91
Merchants and domestic	375	353	94
Gold and uranium mines	2	2	95
Other mining	11	11	101
Water	12	13	110
SASOL	3 181	2 835	89
Cement and lime	66	94	144
Electricity (Non-ESKOM)	95	112	118
ESKOM	4 151	7 242	174
Brick and tile	8	15	206
Total	**9 139**	**11 534**	**126**

Source: Blignaut, J.N. and King, N. 2002. The externality cost of coal combustion in South Africa. In: Blignaut, J.N. (ed.). Bridging the Economics/Environment Divide. Published conference proceedings. Forum for Economics and Environment, Pretoria. pp. 71-85.
Note: * Only the global damage cost of CO_2 and CH_4 emissions

As was seen above, the generation of electricity from coal-fired power stations is contributing significantly to negative environmental externalities, which are currently unaccounted for. This has therefore led to various studies[28] which all converge on the same conclusion. Table 12.11 gives a comparative analysis of two of these studies.

The core estimates of these studies are very comparable, indicating that the global externality damage as a result of coal-fired power generation ranges between R5 634 million and R7 242 million or between R0.032/kWh and R0.043/kWh, which translates to between 15 per cent and 30 per cent of the retail price of electricity, depending on the economic sector and the various retail prices.

Table 12.11: Global damage cost per unit of electricity generated by ESKOM

		Low	Central	High
Spalding-Fecher and Matibe:[29] based on 1999 emissions	Damage: R millions	1 625	7 043	16 258
Electricity sales: 1999	TWh	172.6	172.6	172.6
Global damage per unit	R/kWh	0.01	0.043	0.098
Total coal consumed	tons	88 470 000	88 470 000	88 470 000
Global damage per ton of coal	R/ton	18.37	79.61	183.77
Blignaut and King:[30] based on 2000 emissions	Damage: R millions	3 621	7 242	
Electricity sales: 2000	TWh	177.4	177.4	
Global damage per unit	R/kWh	0.021	0.041	
Total coal consumed	tons	92 300 000	92 300 000	
Global damage per ton of coal	R/ton	39.23	78.46	
National Treasury:[31] based on 2000 emissions	Damage: R millions	1 550	5 634	9 711
Electricity sales: 2000	TWh	177.4	177.4	177.4
Global damage per unit	R/kWh	0.009	0.032	0.055
Total coal consumed	tons	92 300 000	92 300 000	92 300 000
Global damage per ton of coal	R/ton	16.80	61.04	105.21

As was stated earlier, the calculation above focuses on the global damage cost associated with methane and carbon dioxide only. The effect on health from local pollutants due to the combustion of coal, such as sulphur dioxide and particulate matter, is not included. The health impacts of these pollutants are difficult to quantify since they are determined by various factors, such as the pollution concentrate, dispersion, the size of population at risk and the degree of risk as determined through epidemiological studies and the compilation of dose-response functions. Spalding-Fecher and Matibe,[32] however, did estimate these local impacts and determined that the impact might be in the order of R0.01/kWh generated or approximately R1 177 million in 1999.

When adding the health effects of the local to the global damage caused by global pollutants, the impact amounts to between 4c/kWh and 5c/kWh, which translates into a significant portion of the actual price of electricity.

12.3.2 Mobile source

Although the negative externalities associated with the automotive industry includes a wide range of aspects such as congestion, injuries and fatalities, road maintenance, and noise, only the effects of the industry on air pollution, namely the impact on health and on global climate change, are of relevance here. Various studies have been conducted to determine the external cost of these externalities and the results are summarised in Table 12.12.

Table 12.12: External cost of air pollution based on 1998 vehicle emissions: R millions

	Gaffen *et al.*[33]	Freeman *et al.*[34]	National Treasury[35]	
			Low	High
Urban air pollution (health effects)	8.405	9.472	4.159	20.509
Climate change	0.391	1.549	0.429	2.886
Total	8.796	11.021	4.588	23.395

With regard to health effects, Gaffen *et al.* used vehicle population figures, calculating the annual average distance travelled by vehicle type and the emissions based on relevant conversion factors, from which they calculated the volume of emissions for hydrocarbons, oxides of nitrogen and particulate matter. These volumes where multiplied by the World Bank's estimates of the cost of air pollution in Santiago in Chile to determine the health costs. Freeman *et al.* used a completely different methodology, but one that duplicates a World Bank study undertaken in Jakarta, Indonesia. They compiled a damage function based on dose-response relationships to estimate the health impacts of air pollution reduction. The dose-response relationship is linked with ambient air pollution to particular health consequences, mainly based on international studies, as follows:

$\Delta Hi = bi * POPi * \Delta A$

Where:

ΔHi = change in population risk of health effect i

bi = slope from the dose-response curve for health impact i

POPi = population at risk of health effect i

ΔA = change in ambient air pollutant under consideration

Additional information pertaining to health cost related to the various diseases is then applied to determine the total cost of the externality. Freeman *et al.*, however, used the 1990 emissions inventory (see Table 12.4) as a base for their calculations, adjusted to 1997 levels. These two studies ignored the externality cost associated, amongst others, with lead and sulphates, which necessarily implies a very conservative approach. The National Treasury study, based on international best practise, used an income and purchasing power adjusted European Union damage cost function, applied to a wide range of pollutants (see Table 12.4), and adjusted the volume of emissions to the 1998 level based on the change volume of transport between 1990 and 1998.

The central estimate of the total health cost of urban air emissions due to transport is therefore approximately R10 billion. This is considerable, when compared to the household expenditure on petroleum products in 1998, namely R15 059 million. This implies that the social cost, based only on health effects, amounted to approximately two thirds of private costs.

To determine the climate change impact, Gaffen *et al.* calculated the carbon dioxide emissions as indicated in Table 12.5 and estimated the global environmental damage to be equal to $5/ton carbon dioxide. Freeman *et al.* included nitrogen oxide and methane in their calculation and used $5.45/ton carbon dioxide equivalent as damage cost. The National Treasury study made use of a wide range of marginal damage cost functions and applied those to the emission totals depicted in Table 12.5.

12.3.3 Indoor air pollution

Though there are many sources of indoor air pollution, no one is more detrimental to health than the high and prolonged exposure to particulate matter due to the combustion of coal for space heating and cooking purposes. Scorgie and Annergarn[36] calculated the health cost of particulate emissions from indoor coal combustion for the Vaal Triangle as between R202 million and R813 million, as is shown in Table 12.13. These estimates are based on morbidity and mortality cost of work days lost and a resultant change in productivity, as well as direct costs incurred.

Table 12.13: Health cost of household coal burning: particulates only: 2001: R million

Health outcome	Low	Medium	High
Asthma attacks	6.82	16.01	67.61
Acute bronchitis	127.5	254.99	381.58
Chronic bronchitis	40.47	109.56	208.74
Outpatient /GP visit	0.15	0.3	0.59
Mortality	11.86	30.24	67.61
Resp. symptoms day	3.56	11.12	21.2
Resp. hospital admission	0.15	0.44	0.89
Restricted activity	12.3	32.77	64.04
Total	**202.81**	**455.53**	**813.3**

Source: Scorgie, Y. and Annergarn, H. 2002. The impact of coal on people. Paper presented at the Coal and Sustainable Development Conference, a WSSD side-event, Johannesburg, 8–12 September.

12.3.4 Synthesis and implications

The extent of the negative externalities associated with air pollution is significant. With regard to the industrial combustion of coal, the social cost exceeds that of the private cost by some margin. Externalities associated with the transport sector add up to approximately two thirds of what is annually spent on petroleum products and, with regard to indoor air pollution, it is the poor who cannot afford clean technologies (prevention measures) or any treatment for resulting diseases, who are at risk. Any disease contracted will result in reduced productivity and consequently a reduction in income, leading to a deepening of the poverty level, which, in turn, leads to higher vulnerability.

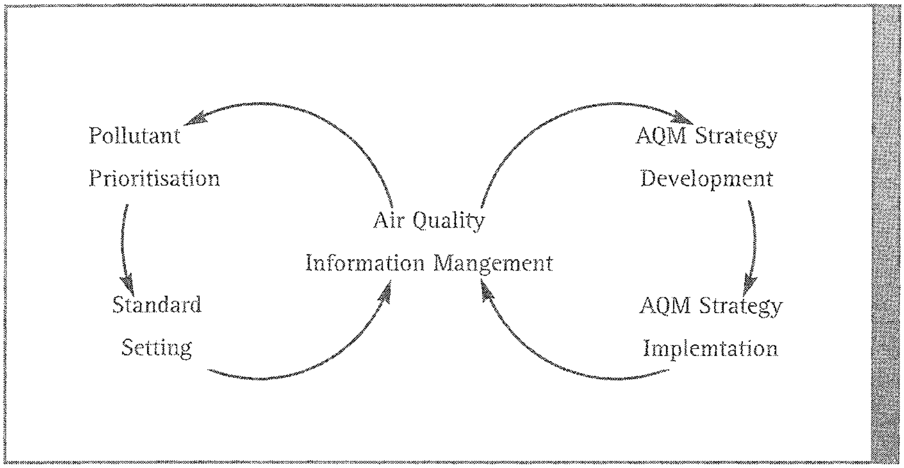
The health effects of air pollution due to transport are considerably higher than its impact on climate change, namely a mid-estimate of approximately R10 billion compared to a climate change effect of approximately R1 billion. This is mainly because the pollutants are emitted in people's living and work environments and, by definition, are higher where there is a concentration of people, increasing the number of people at risk. Exactly the opposite is true with regard to the combustion of coal from coal-fired power generation where the climate change impact is considerably higher than the health impacts, namely approximately R7 billion climate change impact against a R1 billion health impact. These values do not include the damages caused by emissions from other point sources and indoor air pollution due to the combustion of coal.

Due to market failure, viz. the non-existence of a market for clean air, these external values are not internalised within mainstream economic considerations. On the contrary, an increase in health expenditure is seen as an increase in GDP and value added, as likewise with regard to expenditure incurred due to a flood or drought. Only when these values are internalised, fully informed decisions are possible and development can be monitored appropriately. It is ironic, though, that with regard to air pollution both development and underdevelopment are associated with negative externalities. The one main difference, however, is freedom of choice. In a state of underdevelopment, one does not have a choice between various technological alternatives. It therefore becomes an issue of public intervention to ensure that the population at risk is minimised. When considering development and industrialisation, clean technological alternatives are available and the freedom exists to choose between the alternatives. The question, though, is whether the applicable policies provide the necessary framework to stimulate the uptake of these alternative technologies.

12.4 Policy and implementation response

12.4.1 Point source

Late in 2002, the Department of Environmental Affairs and Tourism (DEAT) embarked on a multi-phased initiative known as the National Air Quality Management Programme (NAQMP). The NAQMP focuses on goals and objectives within the following five years to address air quality. The NAQMP may be regarded as a management cycle aimed at continuous air quality improvement (Figure 12.1).



Source: Department of Environmental Affairs and Tourism (DEAT). 2003. The National Air Quality Management Programme, Strategy Formulation Phase. Pretoria: DEAT.

Figure 12.1: NAQMP cycles

The cycle on the left defines air quality that is not harmful to health (i.e. the setting of ambient air quality and other standards that would result in an air quality not detrimental to health). The cycle on the right defines the means of meeting or bettering these standards. These two processes are linked by the steady flow of relevant information pertaining to air quality. The following objectives provide the focus for each of the interlinked components of the cycle:

- *The objective of air quality information management*: Accurate, current, complete and relevant information is readily available and easily accessible to allow for the identification of problem pollutants, informed AQM strategy development and the measurement of the performance against, and efficacy of, implemented AQM strategies.
- *The objective of pollutant prioritisation*: Specific pollutants having unacceptable impacts on safety, health and/or environment are prioritised for management in the NAQMP.
- *The objective of standard setting*: Ambient and/or point-source emission standards are set for specific priority pollutants to benchmark their management under the NAQMP.
- *The objective of strategy development*: Strategies are devised and/or revised, and are described for the effective and efficient management of priority

pollutants at local, provincial and national levels as well as for identified 'hot-spots'.

- *The objective of strategy implementation*: Approved air quality management strategies are efficiently and effectively implemented at local, provincial and national levels.

The Air Quality Management Bill provides the mechanism for all levels of government to implement the NAQMP. Air quality may be managed on a regional or local scale, with a focus on emissions, and reducing emissions where appropriate, in order to meet or better the set ambient standards. All point-source emissions will require licences, and institutions will adhere to an agreed programme of continual improvement with the DEAT. As an example of efforts to reduce SO_2 concentrations in Durban's southern industrial basin, a programme has been adopted to ensure the systematic phasing out of so-called dirty fuels, replacing conventional heavy fuel oil (HFO) with low sulphur equivalents. Furthermore, an attempt is made to make use of landfill gas as well (see Chapter 13).

In addition to the NAQMP, economic instruments to combat air pollution are also available and are widely discussed in the literature, while policy options are available for both local and global pollutants.[37] Arguably, the most noteworthy instrument to combat greenhouse gas emissions is the Clean Development Mechanism (CDM),[38] whereby a company in an Annex 1 country (a developed country) according to the Kyoto Protocol gets credit towards its emissions reduction targets by investing in a developing country. The developing country gains the direct foreign investment and accompanying socio-economic benefits whereas the investor from the developed country claims lower cost emissions reductions as a result of the investment. The CDM envisages that emissions can be reduced through the use of technology and developing countries may enjoy cleaner and newer technology.

12.4.2 Mobile source

The approach that has been adopted to address air pollution from motor vehicles is to provide cleaner fuels. The systematic phasing out of conventional petrol and diesel and replacing them with low-sulphur fuels and lead-free fuels will serve to reduce motor vehicle-related pollutants. No reduction strategy is in place to address diffuse and evaporative emissions of VOCs, i.e. the capture of gases released in the filling of underground storage tanks and vehicle fuel tanks. Similarly, there is no clear policy aimed at reducing the number of vehicles on the roads through, for example, the promotion of the use of public transport.

In the wake of the announcement to phase out lead from gasoline in South Africa by 2006, a new look is being taken at octane standards and the alternative additives available that may be used in future.[39] At the same time, a draft White Paper on Renewable Energy has identified ethanol as one of two common biofuels, implying that its production has the potential to contribute to the tentative 2012 target of 10 000 GW of the total energy consumption being provided by renewable energy sources, while creating employment and empowerment pathways, particularly in rural settings.[40]

12.4.3 Domestic fuel

In accordance with the Department of Minerals and Energy (DME) policy on electrification, ESKOM's electrification programme started in 1989, and about 66 per cent of households in South Africa had been provided with electricity in 2001. In 1994 a stringent target was set to electrify 1 750 000 homes between 1994 and the end of the year 2000. After achieving the target a year ahead of schedule, a further 256 023 homes were electrified during 2000, and 209 535 in 2001. The DME initiated the low-smoke fuel programme in 1994 to assist (along with other integrated measures) in reducing the unacceptable levels of air pollution in residential areas caused by smoke from household coal. The objective of this programme was to replace household coal with low-smoke fuels by 2000. This objective was not achieved, but the programme is going on and currently the focus is on the formulation of an implementation strategy for low-smoke fuels and on other activities aimed at reducing coal-based household air pollution. These include household insulation, coal stove maintenance and low-smoke fuels. Socio-economic issues have to be considered, such as possible subsidies to offset costs of low-smoke fuel opposed to the generally cheaper conventional fuels. Awareness programmes to address changes to lifestyle patterns regarding exposure to emissions from domestic burning are being conducted. This includes systematic demonstration in residential areas of the top-down ignition technique of braziers, the so-called 'Basa Magogo' method that results in efficient combustion and lower smoke.

12.5 Conclusion

Air pollution, irrespective of its source or the pollutant emitted, has a significant ecological and social cost assigned to it. Should these costs be internalised, the cost structures of all the energy-related industries would be affected, and consequently the economic structure as a whole. By not internalising these social costs, the energy sector is subsidised by society. This subsidy implies that the energy market is receiving the wrong price signal according to which the allocation of resources and production of goods and services is done; this leading to market inefficiencies. The wrong products are therefore supplied at the wrong prices.

Furthermore, indications are that, at least in the medium term, the country is bound to have policies aimed at setting, monitoring and enforcing externally determined standards, rather than internalising costs, for example, the application of the polluter-pays principle,[41] green taxes and/or the elimination of hidden subsidies, as well as the formal introduction of the Clean Development Mechanism. These measures tend to be more expensive (inefficient) than market-based solutions, due to high transaction costs.[42] Over and above the efficiency criteria and the fact that the market signal remains wrong, the underlying philosophy of command and control does not support justice and good resource management in the market-place (see Chapter 18).

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CHAPTER 13

Integrating waste disposal management into energy policy: The case of landfill gas

Anthony Lumby, Linda Godfrey and Varsha Harinath

13.1 Introduction

As a developing country, South Africa is faced with numerous waste management challenges that have not been afforded sufficient priority as yet. Such challenges include:[1]

- lack of capacity and financial resources to manage waste adequately, from local to national level;
- fragmentation in waste legislation and responsibilities;
- lack of strategic planning by local authorities responsible for waste management;
- poor cost recovery of waste management services by local authorities;
- markets that do not favour recycling and resource recovery;
- inadequate systems for collecting, transport, treatment and disposal of waste, and a disparity in waste services between low- and high-income areas; and
- environmental degradation through inappropriate management of waste.

South Africa is estimated to generate in excess of 534 million tons of industrial, domestic and commercial solid waste annually,[2] the majority of which is landfilled (see Table 13.1). This statistic is alarming, as it compares more closely with the waste statistics for high and middle income countries. Nowhere is this more evident than when comparing domestic and commercial waste generation among countries. South Africa generates 0.7 kg of domestic and commercial waste per capita/day, while the comparative figure for the UK is 0.73 kg/capita/day and that for Singapore 0.87 kg/capita/day. In stark contrast, for a developing city such as Kathmandu, the figure is 0.3 kg/capita/day.

Table 13.1: Waste generation rates (million tons/annum) in South Africa

	DEAT (1992)	DWAF (1997)
Mining	378	468.2
Industry	23	16.3
Power generation	20	20.6
Agriculture and forestry	20	20.0
Domestic and trade	15	8.2
Sewage sludge	12	0.3
Total	468	533.6

Source: Wates, J.A. and Bredenhann, L. 2002. National Waste Management Strategy: Baseline Studies. WasteCon Conference Proceedings.

A large proportion of domestic waste (42 per cent) is generated in the highly urbanised and industrialised Gauteng Province, with high income communities tending to generate a higher proportion of waste relative to low income communities.[3] Given the important role of the mining industry in the South African economy, it is not surprising to find that, as is shown in Table 13.1 above, the mining sector produces approximately 88 per cent of the total waste stream, or 470 million tons of waste per annum. The industrial sector is estimated to produce 16.3 million tons of waste per annum, or 3 per cent, of the total waste stream.

Population growth, coupled with economic growth, is identified as the major driver behind increased waste generation in South Africa.[4] These two aspects, in addition to the desire for improved living standards, the lack of capacity in terms of knowledge of waste management and ineffective waste generation policies,[5] have had a significantly negative impact on the natural environment and the health of some communities.[6] However, the reintegration of South Africa into the global economy, the recognition of the current waste problems facing the country and the need to align with national objectives of efficient and effective management of the country's resources, have resulted in the Department of Environmental Affairs and Tourism (DEAT) and the Department of Water Affairs and Forestry (DWAF) embarking on a process of policy and strategy development to support improved, and integrated waste management.

These initiatives include the development of the White Paper on Integrated Pollution and Waste Management (IP&WM) and the National Waste Management Strategy (NWMS),[7] which gives effect to the White Paper. Both the White Paper and NWMS recognise a shift in focus from end-of-pipe waste solutions, such as disposal, to an integrated approach to waste management with a focus on waste prevention, re-use, recycling, treatment and finally disposal, which implies a shift from waste management to resource management.

Government, industry and civil society have further demonstrated their commitment to sustainable waste management through the ratification of the Polokwane Declaration, a national target of zero waste to landfill by the year 2020. To support policy and strategy development, a law reform process has been initiated, which will culminate in new pollution and waste management legislation,[8] such as the legislation that intends to reduce the consumption and disposal of plastic bags.[9]

13.2) Energy and the environment

In the meantime, attention should also be paid to the relationship between South Africa's energy policy and the environment. As will be seen, this relationship opens up the possibility of making greater use of landfilled waste in order to ease South Africa's heavy dependence on a non-renewable energy source, namely coal (see also Chapter 12 in this regard).

South Africa's energy development path has been shaped primarily by the interplay of two factors: relatively limited water resources and seemingly abundant reserves of coal. The country's two major sources of water are surface runoff (80 per cent) and groundwater (20 per cent). The former is dependent on meagre rainfall, which in turn places a severe constraint on the use of water as a source of energy (see also Chapters 8, 9 and 15). However, South Africa's recoverable coal reserves are estimated at approximately 58 million tons, which, at present rates of consumption, will last beyond the end of the next century.[10] In these circumstances, it is not surprising to find that coal provides 76 per cent of South Africa's primary energy needs, followed in distant second place by oil (16 per cent), with biomass (6 per cent) and nuclear sources (2 per cent) far behind.[11]

The net result of this pattern of energy consumption is that South Africa's dependence on coal is among the highest in the world.[12] Half of the domestic coal consumption can be credited to the Electricity Supply Commission (ESKOM), a government-controlled parastatal that generates electricity, a quarter to SASOL's oil-from-coal plants, and another quarter is burnt directly by industry or is used for cooking and heating in townships.[13] Coal-fired electricity is therefore central to South Africa's energy consumption.

Not only is South Africa's present energy strategy based on the exploitation of a non-renewable resource, and is therefore unsustainable, but it has also exacted an exorbitant cost in terms of environmental decay. Although most of ESKOM's power stations are fitted with electrostatic precipitators to remove dust and ash particulates, they are not all equipped with the costly flue-gas scrubbers needed to remove sulphur and nitrogen oxides.[14] When these air pollutants are combined with water vapour, they reach the earth in the form of acid rain. Furthermore, the concentration of approximately three quarters of South Africa's coal reserves and electricity generation in the Mpumalanga Province, combined with unfavourable meteorological conditions in the area, has made this one of the worst air pollution regions in the world.[15] To aggravate matters, half of South Africa's agriculturally productive land and commercial forests and a quarter of its surface water runoff are found in this region (Mpumalanga), giving rise to considerable concern about the environmental and economic impacts of acid rain.[16]

Against this background, repeated calls have been vented for greater attention to be paid to the use of *renewable energy technologies* in South Africa, including further research on the viability of landfill gas (LFG) as an alternative, sustainable energy source.[17] These calls are highly opportune, because LFG contains a high percentage of methane, a powerful greenhouse gas (methane has a global warming potential 21 times that of an equivalent quantity of carbon dioxide), which absorbs the earth's infrared radiation and contributes to global warming.[18] Therefore, any attempt to make use of LFG as an alternative source of renewable energy will not only contribute to the development of a more sustainable energy strategy for South Africa, but will also help to curb the exploitation of the global commons. Thus, through this example of the integration of waste disposal policies into energy studies, it becomes possible to take a more holistic approach to environmental management in South Africa.

13.3 The exploitation of LFG as a source of energy

13.3.1 Introduction

It has been estimated that approximately 80 per cent of the municipal solid waste (MSW) generated throughout the world is landfilled, although the figure for South Africa may be as high as 85 per cent.[19] Although the composition of landfilled MSW varies considerably between countries of different socio-economic backgrounds, it usually includes organic material (such as paper and paperboard, wood, textiles, food residues and garden waste), as well as inorganic material (such as builders' rubble, metal, glass and plastics).[20] The organic material – consisting of cellulose, carbohydrates and protein – is readily decomposed by microbes into carbon dioxide (CO_2) and methane (CH_4), and contributes some 6 to 18 per cent to the global methane production.[21]

Consequently, landfill sites cannot be regarded merely as an unfortunate but necessary nuisance, but ought to be seen as a significant environmental and health hazard.[22] Methane gas is explosive at concentrations of between 5 per cent and 15 per cent by volume in air, and is therefore regarded as dangerous.[23] Furthermore, methane is of less weight than air and reacts with ozone (O_3) in the upper atmosphere, thereby posing a threat to the earth's ozone shield. Therefore, the conversion of LFG into usable energy not only represents a shift towards a renewable (and therefore sustainable) energy source, but would also contribute towards a solution to the problem of climate change in the region.

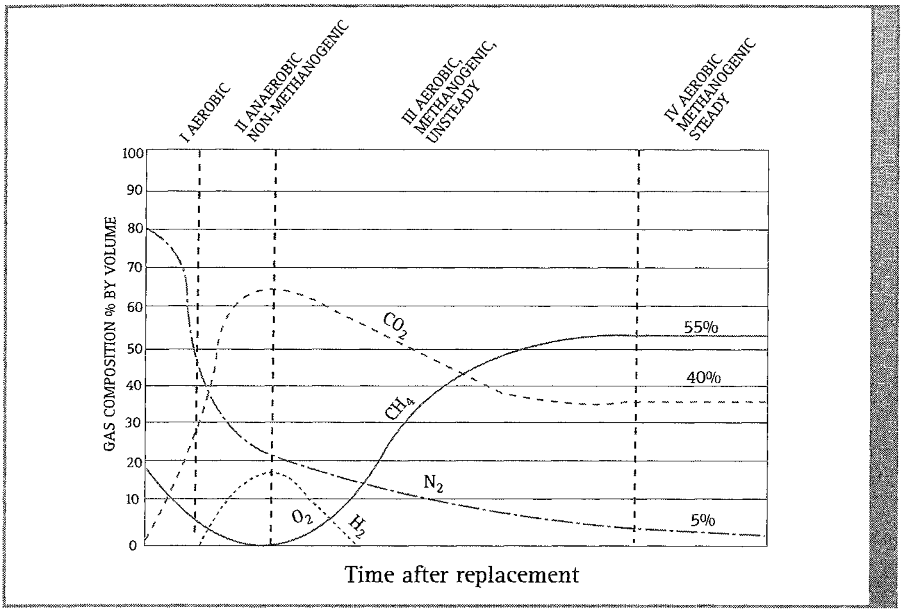
13.3.2 The LFG production process

During the 1960s, feasibility studies on the digestion of MSW were conducted in several centres in the United States, and the recovery of LFG has been practised since the early 1970s.[24] Currently, LFG is being extracted from sites in numerous countries, including the United States, Canada, Germany, Britain, the Netherlands, Brazil and South Africa.[25]

The production of LFG can be seen as a four-stage process, as depicted in Figure 13.1. After dumping MSW, aerobic bacteria first attack biodegradable carbon compounds in the MSW and these convert organic material into, primarily, carbon dioxide, water and heat, all consuming oxygen. Continuous dumping of MSW leads to the depletion of oxygen and moisture in the soil, which tends to inhibit the aerobic decomposition process, and the second stage of anaerobic decomposition is initiated. During this stage, the principal gas produced is carbon dioxide, but quantities of this gas decrease over time until the third stage is reached, when methanogenic bacteria begin to produce a higher rate of methane than of carbon dioxide. Eventually, during the fourth stage, a plateau is reached when steady quantities of carbon dioxide and methane are produced. The initial production of methane may take from two to five years (depending on conditions in the landfill), and methane production can continue for a period of 30 to 40 years (depending on the size, and therefore the life, of the landfill).[26]

The rate of LFG production will depend on the interplay of a number of factors, which may be summarised as follows:

- *Temperature*: Anaerobic decomposition is exothermic, and therefore landfill temperatures are higher than the ambient air temperatures. Ideally, the temperature in the landfill should be in the mesophilic range (20-40°C).[27]
- *Absence of oxygen*: This is essential if anaerobic conditions are to be maintained. Air infiltration is minimised by the use of an impermeable cover (ideally, a multi-layer of soil and clay which will not crack in dry weather) and



Source: Oweis, I.S. and Khera, R.P. 1990. Geotechnology of Waste Management. London: Butterworths. p. 113.

Figure 13.1: Gas composition and evolution in a typical landfill site

by the use of deep landfill sites (with a minimum depth of 10 metres). Daily cover and the capping of the landfill site upon closure is required under the Department of Water Affairs and Forestry's Minimum Requirements.[28]

- *Moisture content*: A minimum moisture content of about 20 per cent is needed for biodegradation to proceed. Although the optimum moisture content for anaerobic decomposition is 40 to 60 per cent, it has been found that a moisture content of 75 per cent can result in a tenfold increase in the conversion rate for short periods of time.[29]
- *Nutrients*: The presence of nitrogen is necessary for optimum bacterial growth, and the low rate of nitrogen to carbon usually found in municipal solid waste (MSW) is one reason for the slow rate of biodegradation. It has been found that the rate of decomposition can be accelerated by seeding the MSW with sewage sludge, which also serves as an additional source of moisture.[30]
- *Compaction*: The rate of compaction, or settlement, within the landfill is significant in that it reduces air space and oxygen content, thereby establishing more favourable conditions for anaerobic decomposition. Gunnerson and Stuckey[31] have suggested that this probably reduces the time before methane is produced.

- *Decomposition rate*: The rate of decomposition varies significantly between the different component parts of MSW. The half-life of biodegradable MSW – that is, the time it takes for half of the material to decompose into carbon dioxide and methane – has been classified by Hoeks[32] into three categories: (a) readily degradable food residues (with a half-life of one year); (b) moderately degradable soft plant waste (with a half-life of five years); and (c) slowly degradable paper and wood (with a half-life of 10 to 15 years).

Assuming that the first five conditions above are met, that the half-life values of the biodegradable MSW are known, and that the volume of biodegradable MSW deposited each year is known, then Letcher[33] has shown that it is possible to develop a simplified kinetic model to estimate the potential methane production over the life of the landfill (see Appendix 13.1).

Despite the lack of uniformity among landfill sites, because of differences in the above-mentioned variables, empirical equations have been developed to predict the volume of carbon dioxide and methane that can be produced from organic waste.[34] Thus the chemical equation for LFG production, using cellulosic waste, is given as:

$$C_6H_{12}O_6 + (0)H_2O = 3CO_2 + 3CH_4 \quad (1)$$

While it is true that the chemicals that comprise organic waste have different molar masses, the above equation is still appropriate because most food and plant materials are composed of carbon, hydrogen and oxygen to the ratio of 1:2:1. Furthermore, the above equation shows that LFG is composed of 50 per cent carbon dioxide and 50 per cent methane; in practice, however, LFG will contain less carbon dioxide because part of it becomes dissolved in the landfill water or leachate. The range of landfill gas composition is shown in Table 13.2, and most studies assume that the methane content of LFG will be in the region of 50 per cent.[35]

From equation (1) it may be deduced that one mole of biodegradable MSW (with a molar mass of 180 grams) will produce three moles of methane (with a molar

Table 13.2: Typical composition of landfilled MSW and LFG

Municipal Solid Waste (MSW)	
Component	**Mass %**
Hard organic material	24
Other organic material	18
Soft organic material	18
Builders rubble, metal, glass and plastics	20
Water	20
Landfill Gas (LFG)	
Component	**Mole %**
Methane	50-56
Carbon dioxide	40-45
Nitrogen	0.5-1
Trace compounds	0.5-1
Oxygen	0.0-0.1

Sources: Letcher, T.M. 1988. Energy from Landfill Refuse Sites. ChemSA, November; Rider, D.K. 1991. Energy: Hydrocarbon Fuels and Chemical Resources. New York: John Wiley and Sons, p. 234.

mass of 25 litres each at standard temperature and pressure). It follows, therefore, that 1 kg of biodegradable MSW will yield 417 litres of methane; expressed differently, one metric ton of biodegradable MSW will yield 417 m^3 of methane. It has been estimated that each individual disposes of one kg of MSW per day – an assumption that would appear to hold true for South Africa. However, not all of that waste will be biodegradable. In fact, the evidence summarised in Table 13.2 suggests that the typical composition of MSW is likely to be 60 per cent dry biodegradable waste, 20 per cent non-biodegradable waste and 20 per cent water.

It must also be noted that not all of the dry biodegradable MSW decomposes into methane, and not all of the methane produced is collected. Small quantities of methane are decomposed by aerobic action in the first stage of the conversion process (see Figure 13.1). Some of the methane produced in the later stages is likely to be lost through lateral diffusion and some of the biodegradable MSW may not in fact decompose because of inadequate moisture or the presence of toxins in certain sections of the landfill. From a case study of landfill gas extraction in

San Jose, Costa Rica,[36] it has been concluded that *the most cost-effective spacing for wells was found to be approximately 50 feet. Under these circumstances, approximately 96 per cent of the methane is captured.* The more conservative figure of 70 per cent is used in the following calculation. If 60 per cent of MSW consists of dry biodegradable waste (see Table 13.2) and 70 per cent of the methane produced is actually collected by sinking suitable wells into the site, then 1 kg of MSW per capita per day will yield:

$(417 \times 0.365 \times 0.60 \times 0.70)m^3\ CH_4$ per capita per annum =
$63.9m^3\ CH_4$ per capita per annum (2)

13.3.3 The energy potential of LFG

Methane gas is combustible and burns according to the reaction:

$CH_4 + 2O_2 = CO_2 + 2H_2O\ \Delta H = 890$ kJ per mole (3)

This reaction is exothermic: for each mole of methane produced, 890 kJ energy is produced. If one mole of methane is equal to 25 litres (or $25m^3$) at standard temperature and pressure, then:

$1\ m^3\ CH_4 = 890/0.025$ kJ $= 35\ 600$ kJ or 36 MJ (4)

From equations (2) and (4), it may be deduced that the potential energy produced by $63.9m^3$ of methane is 2 300 MJ per capita per annum or 73 watts per capita per annum. Therefore, a landfill site serviced by 100 000 persons could produce 7.3 MW energy, *assuming* a 100 per cent energy conversion efficiency. In fact, the conversion efficiency for methane is estimated to be about 33 per cent,[37] in which case the useful energy is reduced from 7.3 MW to 2.4 MW. Letcher *et al.*[38] have estimated that the average annual electrical energy used per household is in the range of 2 000 to 3 000 units, in which case LFG may provide only some 2 per cent of the domestic electricity needs of 100 000 persons. However, it ought to be borne in mind that the majority of poor people live in small homes or shacks in peri-urban and urban townships, and they do not have access to electricity nor do they have high energy-intensive demands. In fact, officials from the Electricity Department of the Durban City Council have indicated that the energy demands of these *informal communities* may be no more than a quarter of that of typical urban households. In these circumstances, LFG may well supply a significantly higher proportion of their more basic energy needs.

Furthermore, the wider economic and environmental advantages that can flow from the commercial utilisation of LFG should not be ignored. It makes use of a necessary by-product of urban living, and in the process can contribute to a significant reduction of the costs of operating landfill sites through cost recovery. In addition, a more rapid rate of settlement of wastes in the landfill (which results from managed decomposition and gas extraction) can extend the life of the landfill by several years, thereby generating sizable capital savings for the municipal authority.[39] It also reduces the pressure, even if only marginally, on non-renewable fossil fuels, and encourages a shift towards a more sustainable energy path. Furthermore, the commercial use of this non-conventional energy source will help to reduce the potential levels of air pollution, especially the threat posed to the global commons by way of ozone depletion and the greenhouse effect. Although it is extremely difficult to quantify some of these advantages, this does not lessen the benefits that can be derived from utilising LFG.

13.3.4 The cost-effectiveness of LFG

Of course, the key issue in determining the practical viability of this sustainable energy option is that of cost-effectiveness. Unless LFG is affordable relative to other commercial sources of energy, there will be an understandable reluctance to become involved in such a project. While there are a number of studies relating to the cost-effectiveness of LFG projects under way in the United States, Britain and Germany,[40] attention here is focused on LFG projects that have been undertaken (or have been investigated) in South Africa. Apart from the Robinson Deep landfill site, located near Johannesburg, which was unique in that it utilised LFG as a chemical feedstock for the neighbouring Klipspruit cyanide factory operated by AECI,[41] there are three LFG projects in South Africa.

In 1986, the municipal authority in Grahamstown in the Eastern Cape Province opened a new one-hectare landfill site which was designed to serve some 70 000 people. Thereafter, the Grahamstown Municipality, working in conjunction with the Department of Chemistry at Rhodes University, tested the feasibility of collecting LFG from this site as a source of energy. It was found that, at its maximum capacity, the site will produce methane at a rate of 3 300m^3 per day; and although the methane collected from this site was burned (or 'flared') and not used for commercial purposes, an analysis was made of the potential cost-effectiveness of methane as an alternative energy source for electricity production and water heating. The results of this analysis, based on 1992 prices, revealed that LFG could be used to produce electricity at a cost of approximately 13c/kWh, which was comparable with ESKOM's electricity tariff (which ranged from 9c/kWh to the Grahamstown Municipality to 17c/kWh to the end-user). It was also shown that LFG could be used to heat water at a cost of approximately 4c/kWh, which was considerably lower than 12c/kWh for coal, 20c/kWh for paraffin and 42c/kWh for liquid petroleum gas (LPG). Therefore, it was concluded that, for these specific energy uses, LFG from the Grahamstown site was more cost-effective than coal, paraffin and LPG, and could be used to produce electricity at a price comparable with ESKOM's charges.

In 1992, following the experiment conducted at Grahamstown, the Department of Chemistry and Applied Chemistry at the University of Natal (Durban) collaborated with Waste-Tech (Pty) Ltd in a landfill project located in the Umlazi township near Durban.[42] It was found that LFG at this location had a methane content of 57 per cent and that the site had a potential for producing at least 2 MW of electricity. On the assumption that this energy would be used by the local community for water heating, cooking, for ablution blocks fitted with showers and for brick-making, it was estimated that the cost of electricity produced from the Umlazi landfill site would be in the region of 2-3c/kWh instead of ESKOM's charge of 10-15c/kWh. It must be noted, however, that these two case studies cannot be regarded as complete. They do not take into account other benefits: that the commercial use of LFG could contribute to the cost of maintaining these landfill sites; that intensified settlement in the landfills will extend their life and so generate capital savings for the control authorities; and, less easily quantifiable, that the use of LFG will ease the pressure on fossil fuels and the damage that these inflict on the environment by way of air pollution and climate change.

The third and most recent LFG project is that which has been investigated for the Bisasar landfill site north of Durban.[43] Landfilling at the site commenced in 1980, and, at current waste deposition rates, it is estimated to have a life of 40 years. In view of the potential environmental hazard posed by LFG emanating from the site for nearby residential and light industry areas, the Durban City Council ordered an investigation into the feasibility of LFG recovery.[44] It was found that the site contained a steady-state methane content of 40 to 45 per cent (a lower rate than the Umlazi landfill because of the larger volume of builders' rubble deposited at the Bisasar landfill), and that it could be expected to produce LFG for a period of some 50 years. It was also estimated that, initially, the site would supply 2 000m^3/hour of LFG which, at a conversion efficiency of 30 per cent, would yield 2.7 MWh of electrical power. By 2004, the anticipated LFG yield would rise to 8 000m^3/hour (and remain at about this figure for another 20 to 30 years), which would produce 6 to 8 MWh of electricity.

It is of particular interest to note, however, that the major finding of the Bisasar investigation was that the primary economic benefit of LFG extraction would be the extended life of the landfill. In most other LFG studies, this benefit has not received the attention it deserves. It was pointed out that the closer management of the site, together with LFG extraction, should result in a faster rate of settlement of compacted MSW. While it is acknowledged that roughly the same amount of settlement may be expected from *passive escape*, this will take place over a greatly extended time period, extending well after the closure of the landfill, so that the additional space that could have been used for MSW disposal is lost. In the case of the Bisasar site, intensified settlement was estimated to be in the region of 5 to 15 per cent. With a projected total landfill volume of 20 million m^3, the additional space made available was estimated to be in the region of 2 to 3 million m^3. This additional space has substantial value in that the capital outlay required to develop a new landfill site would be postponed for several years. It was estimated that the capital savings from a 15 per cent increase in settlement, with an extension of 7.3 years in the landfill's life, would amount to approximately R60 million (net of operating expenses). Notwithstanding the fact that the estimated cost of establishing and operating a LFG recovery programme with a total of 52 wells for flaring the gas was in the region of R10 million,[45] it is evident that there are substantial net gains to be derived from undertaking the project.

Assuming that the methane gas was not simply flared but collected for conversion into energy, the investigation found that the LFG recovered from the Bisasar site could be used most effectively for space heating, boiling water and steam for both domestic and industrial use, firing kilns (for asphalt, ceramics and bricks) and for the generation of electricity to meet the low-intensity demands of the local community. It was estimated that a capital investment of R10 million would be required for the energy conversion process. The investigation did not embark on a comparative cost analysis of LFG and alternative commercial energy resources, but if it is assumed that the cost figures here need to be raised by 15 per cent to account for the lower methane content of the Bisasar site, then it appears that LFG from this site will still be cost-effective. Note that the above analysis relates to only potential economic benefits and costs of the LFG project. The significant environmental benefits to be gained from the LFG project, which have been documented throughout the chapter, and the external costs[46] borne by communities living near the landfill sites, should also be determined.

13.4 Conclusion

South Africa's dependence on a policy of landfilled waste management, with all the attendant environmental problems, has generated calls for the development and implementation of a more effective and environment-friendly waste management policy. Meanwhile, South Africa's heavy dependence on coal has entrenched the country's reliance upon a non-renewable energy source – a strategy that is unsustainable and which has already resulted in severe air pollution problems in the region. Therefore, it is not surprising that calls have been made to explore the feasibility of *renewable energy technologies* that would also have less harmful impact upon the global commons.

One such option has been explored in this chapter: the contribution that LFG can make towards the formulation of a sustainable energy strategy for South Africa. The experience with LFG, both elsewhere and in South Africa, indicates that not only is LFG extraction technically feasible, but that it is cost-effective as well. It is readily acknowledged that this option would make only a small contribution to South Africa's total energy needs – probably no more than 4 to 6 per cent – but it is only one of several renewable energy technologies available and advantage should be taken of it.

Moreover, it should be borne in mind that LFG has a strong methane component, which carries serious implications for the climate in the region. Therefore, when the environmental benefits of LFG extraction are factored into South Africa's current energy strategy, it becomes clear that the adoption of this option will benefit the global commons – and indeed the climate.

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42 The city of Durban and its immediate environs are served by three landfill sites. The Bul-Bul landfill site comprises eight hectares operated by Waste-Services (Pty) Ltd, and primarily services the Indian district of Chatsworth (south of Durban). The Umlazi landfill site comprises 15 hectares operated by Waste-Tech (Pty) Ltd, and primarily services the black township of Umlazi (south-west of Durban). The Bisasar landfill site, operated by the Durban City Council to service the city, comprises 44 hectares (located north of Durban) and is one of the largest landfill sites in South Africa.

43 The following discussion on the Bisasar landfill site is based on information supplied by D.R. Turner, Director of the Solid Waste Department, and D. Dorkin, Research and Development Officer of the MSW Department, both of the Durban Metropolitan Authority. The authors are most grateful to both of them for their kind cooperation.

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Substituting α for k in equation (5), the rate equation becomes

$$d[CH_4]/dt = (0.417 \times 0.693 \times P_0/t_{1/2})\exp(-0.693 \times t/t_{1/2}) \quad (7)$$

Therefore, the potential methane production (in m^3/hour) can be calculated over the lifetime of a landfill, provided that ideal conditions exist at the site, that the amount of biodegradable MSW deposited at the site each year is known and that the half-life of the MSW is known.

Source: Letcher, T.M., Jarmain, D.C., Daneel, R. and Senior, E. 1993. The Exploitation of Methane from Landfill. Unpublished paper, Biotechnology Conference, Rhodes University, Grahamstown, February.

Appendix 13.1

A simplified kinetic model for LFG production

The rate at which LFG is produced is a direct function of the decomposition rate of the organic material in the landfill. The decay of MSW, and hence methane production, can be assumed to be a simple, first-order process:

$$d\ P_t/dt = -kP_t \quad (1)$$

where P_t is the quantity of biodegradable material at time t (kg), k is the degradation rate in years and t is time in years.

The integration of equation (1) gives rise to an exponential term:

$$P_t = P_0 \exp(-kt) \quad (2)$$

where Po is the quantity of biodegradable material at time t = 0.

Differentiating equation (2) with respect to time leads to

$$dP_t/dt = -kP_0 \exp(-kt) \quad (3)$$

Now, given that gas production is dependent on the decomposition of organic material:

$$\alpha dP_t = -d[CH_4] \quad (4)$$

where $[CH_4]$ is equal to the quantity of gas produced and α is equal to 0.417 m^3/kg.

Using equations (3) and (4):

$$d[CH_4]/dt = \alpha kP_0 \exp(-kt) \quad (5)$$

where k is dependent on the nature of the organic material and is a function of its half-life:

$$k = 1n2/t_{1/2} \quad (6)$$

CHAPTER 14

The cost of noise pollution

Martin de Wit, Hugo van Zyl and Nicola King[1]

14.1 Introduction

With an increased rate of urbanisation in South Africa and increased pressure on the environmental quality of cities, it can be expected that the value of changes in environmental quality will increase. The development of rapid commuter rail projects is common in many countries such as the Netherlands, Japan, Germany, France and the USA,[2] and has been on the increase over the past thirty years. The benefits of such projects are often substantial and can extend across a wide segment of society. They include providing people with greater choice of residence in relation to their work, reduced travel times and improved accessibility, among other things. However, not all the ramifications of introducing new modes of transport are beneficial. Some undesirable impacts are also likely to occur, such as increased noise pollution, vibration, visual disruption, loss in cultural heritage and social impacts. Using economic terms, these non-priced external benefits and costs are known as negative externalities. These externalities are not traded in the market system. Since such externalities do have an impact on social welfare, it has become necessary to find another way of valuing them and incorporating them into the decision-making process.[3] For example, noise and vibration can lead to welfare losses through the lack of sleep, lower productivity, physical discomfort and annoyance. South Africa does not have a comprehensive set of noise pollution guidelines, and every municipality can lay down its own guidelines. This chapter will provide some input towards that process as well by quantifying the costs of not managing noise pollution levels.

A useful typology of transport infrastructure impacts is illustrated in Table 14.1. Although this chapter will not discuss alternative evaluation frameworks, it is important to recognise that the monetary quantification of non-priced third party effects form part of a bigger picture of social cost-benefit analysis and environmental impact assessments.[4]

Table 14.1: Typology of transport project effects

	Stakeholders	Priced	Non-priced
Direct	Investors	Profits	Uninsured risks
	Users	Change in transport prices	Travel time, safety
	Third parties		Noise, vibration, visual, air pollution
Indirect		Impacts on the rest of the economy Strategic effects	Congestion Regional inequity

Source: Adapted from Eijgenraam, C.J.J., Koopmans, C.C., Tang, P.J.G. & Verster, A.C.P. 2000. Evaluatie van infrastructuur projecten. Leidraad voor kosten-baten analyse. (Evaluation of infrastructure projects. Guidelines for cost-benefit analysis). Centraal PlanBureau (CPB) and Nederlands Economische Instituut (NEI).

This chapter concerns itself with the issue of quantifying non-priced, or external third party *noise* effects with specific reference to a proposed high-speed railway line (known as the Gautrain) in the City of Tshwane in South Africa. This case study demonstrates that a proper quantification of so-called external costs could have an important impact on the design of such projects, an important conclusion in planning for comparative projects elsewhere. In Section 14.2 a synopsis is given on the vast amount of literature on the topic of noise impact valuation. Section

14.3 suggests a noise pollution valuation model and Section 14.4 reports on the Gautrain case study. Section 14.5 concludes.

14.2 Literature review

The generally accepted best practices for measuring and valuing noise pollution externalities are hedonic pricing (HP) and contingent valuation (CV). Other techniques such as benefit-transfer, avoidance costs, productivity loss costs, replacement costs and health costs are also used in some of the more unique situations for transport infrastructure development projects. The majority of studies carried out use hedonic property pricing because it relies on *revealed* actual behaviour in the housing market where individuals' willingness-to-pay (WTP) for certain environmental characteristics of homes can be observed. The weaknesses of this approach are, however, a sensitivity of implied prices to modelling decisions and the data intensity. Nevertheless, where real-estate agents and assessors have conducted expert assessments in order to determine environmental depreciation indexes, it has been found that the results obtained are similar to those found when using the hedonic approach.[5] The other approach, mentioned earlier, is that of contingent valuation (CV). There are, however, relatively few studies that use this approach to value the welfare changes in environmental goods and services, such as quietness, for infrastructure projects. The reason for this is probably that the development of good CV surveys is a time and budget intensive process. In an overview study it was concluded that a very broad range of WTP values for the reduction of noise currently exists.[6] Although this study has made an attempt to standardise the different assumptions of these studies, it was stated that large variations in values could still be expected, as some strict assumptions cannot be fulfilled. The study went further by concluding that too few stated preference studies currently exist to test for the significance of explanatory factors through a meta-analysis. Therefore, the transfer of values derived from stated preference studies to other studies is highly uncertain and an approach seldom used at this stage.

The most important issues emerging from the numerous HP studies on the noise impacts of roads, airports and railway lines can be categorised as follows:

- the noise sensitivity depreciation index (NSDI) for residential and business areas;
- transfer of the NSDI to other studies;
- noise impacts on educational and medical facilities;
- background noise levels; and
- the time line of impacts.

These issues will be discussed in more detail below.

14.2.1 The value of the Noise Sensitivity Depreciation Index (NSDI)

In order to facilitate comparison of the results of hedonic price studies researchers often quote a Noise Sensitivity Depreciation Index (NSDI). For two residential properties that differ only in their level of noise exposure, the absolute amount of housing depreciation per decibel can be defined as:[7]

$$D = \frac{\text{reduction in property value from noise exposure}}{\text{difference in noise exposure}}$$

NSDI is then defined as

$$NSDI = \frac{D}{\text{property value}} \times 100 = \frac{\text{total \% depreciation in house price}}{\text{difference in noise exposure}}$$

The NSDI is therefore the percentage change in property price arising from an additional unit increase in noise. The impact of noise on property values is relatively well researched internationally, allowing for a relatively high degree of confidence in the estimation of values. A large number of hedonic pricing (HP) studies have investigated the impact of noise pollution on property prices. Most studies report on noise pollution from road or air traffic. Only two original valuation studies on rail noise were identified, but neither reported a noise depreciation index.[8] The studies on the impacts of road and rail transportation also indicate that on the whole the impacts from road traffic tend to be larger than those from rail traffic across most measures of impact such as noise, pollution, congestion and accidents. Rail noise is generally considered to be more acceptable and therefore less severe when compared to road traffic noise. In general, the literature suggests that a given level of noise produced by a freight train is usually perceived as less annoying than noise produced by vehicle traffic on a highway. In one study it was found that the ratio of people 'annoyed' by road noise compared to rail noise was 3.4:1 and the ratio of people 'highly annoyed' was 6.4:1.[9] Therefore, the practice among authorities in Europe and the US has been to give a 5dB(A) 'bonus' to rail when compared to road and air to correct for the fact that rail noise at the same noise level is less disturbing than road traffic and aircraft noise. This means cut-off points of 55dB(A) for air and road and 60dB(A) for rail, implying zero damage costs below these levels.[10] However, as annoyance to noise has been registered at levels far below 55dB(A), and there is evidence of a WTP for noise levels below this level, one could argue that the cut-off point should be below this point. As little information is available in the literature on the economic value estimates for annoyance below a level of 50dB(A), caution will have to be applied in transferring such results in different local areas of impacts (residential, business, hospitals and educational facilities).

When evaluating noise pollution from rail projects, little alternative remains than to use the impacts of road traffic noise as a proxy for rail traffic noise, and it can therefore be expected that this will result in upper-bound estimates of impacts. In a list of road noise studies at 27 different sites in North America, Europe and Japan, NSDI values range from a very low 0.08 to an unusually high 2.22. The simple mean for these studies is an NSDI of around 0.55. In other words, a simple meta-analysis of these studies suggests that an increase in noise pollution of 1 dB (A) will reduce the value of a property by 0.55 per cent. This is represented as a linear relationship, and adjusting these results for situations where the levels of decibel increase move into another band of 'unacceptable' noise should be done with great care. In line with expectations, the greater the average level of noise in a market and the greater the income of the market's households, the higher the implicit price that is paid for noise pollution reductions. Nineteen studies covering 30 sites in North America, Europe, and Australia have also been conducted on the impacts of aircraft noise on property values. The NSDI results of these studies range between 0.10 to a very high 3.57, with a mean of 0.83, not surprisingly somewhat higher then the mean NSDI for road transport. Although it is generally accepted that the annoyance level of aircraft noise is worse than roads, which in turn is worse than trains, these figures cannot be discarded completely. Like aircraft noise, railway noise is also characterised by its infrequency and relatively higher peak noise levels. The variety of NSDI values should not be surprising. Theoretically, it is not expected that different housing markets will have the same hedonic price function and, therefore, one would not expect applications of the hedonic pricing technique in different cities in different years to return identical results. Economic value perceptions will vary across different countries, climates, building designs and income levels.

14.2.2 Transfer of the NSDI to other studies

These NSDI figures have to undergo a transfer exercise to estimate local reductions in property values. In line with accepted practice, and as outlined in Table 14.2, several aspects, such as the relevance of existing studies, as well as their reliability (i.e. the scientific soundness of estimates and the richness of detail of the studies used), have to be taken into account when conducting such a transfer.

Table 14.2: Guidance criteria for evaluating the transferability of existing studies

Category	Specific criteria
Scientific soundness	Data collection procedures
	Empirical methodology
	Consistency with scientific or economic theory
	Statistical techniques
Relevance	Change in environmental quality
	Baseline environmental quality
	Affected services or commodities
	Site characteristics of affected commodity
	Duration and timing of effects
	Exposure path and nature of health risks
	Socio-economic characteristics of the affected population

Table continued on next page >>

Category	Specific criteria
	Property rights
Richness of detail	Definition of variables and means
	Treatment of substitutes
	Participation rates
	Cost of time
	Standard errors

Source: Desvousges, W.H., Johnson, F.R. and Banzhaf, H.S. 1998. Environmental policy analysis with limited information. Principles and applications of the transfer method. In: Oates, W.E. and Folmer, H. (eds.). New Horizons in Environmental Economics series. Cheltenham: Edward Elgar.

In addition, before calculating an average NSDI, the results of certain studies containing obviously unreliable data have to be disregarded. These unreliable studies were mostly conducted in the 1970s when the hedonic pricing technique was still relatively new and not well developed. Some studies were plagued by a lack of observations of sales of properties with higher than ambient noise levels.[11] As one may suspect, the studies excluded due to unreliable results were also those with particularly high or low results relative to the average. Once these outliers were excluded, the average NSDI was estimated to be 0.61 per cent. Interestingly, inclusion of the unreliable results would have resulted in an NSDI of 0.55 per cent, indicating that the exclusion process tended to exclude relatively more studies with below average NSDIs. The NSDI average (0.61 per cent) is therefore considered robust, as it is based on 22 estimates at different sites and is further backed up by studies of aircraft noise at 30 sites that achieved similar results. For the purposes of sensitivity analysis, a maximum decrease of 1.26 per cent and a minimum of 0.21 per cent is recommended, as these were the highest and lowest results found in the literature, excluding results considered unreliable. However, care must be exercised when using this NSDI figure in the context of different property markets.

Where flats were involved, it has to be assumed that each flat in a block would be affected to an equal degree regardless of its height above the ground. In the only known road noise study that explicitly makes a distinction between houses and flats, it is estimated that flat prices are far less sensitive (39 per cent) to noise then residential houses.[12] A railway noise study in Oslo estimated that for single family and detailed houses the impact is 20 to 27 per cent higher than for apartments.[13] It is therefore recommended that a sensitivity analysis for such a scenario be performed. In the case of commercial buildings (mainly office blocks), property value reduction factors equal to those for residences have to be applied in the absence of any data specific to them. Whether this may be an overstatement or understatement is unclear. In some particular cases stronger reactions to increased noise levels can be expected from homeowners relative to businesses. However, the potentially higher mobility of businesses in some areas may also play a role in allowing them to demand lower rents in the presence of increased noise. Whatever the case, and in the absence of better information, reduction factors for residences and businesses have to be assumed to be equal.

14.2.3 Noise impacts on educational and medical facilities

In cases where property markets are not well defined or do not function at all, such as in the case of educational facilities, hospital and cultural heritage sites, the NSDI cannot be used and other methods have to be applied. Researchers are fairly confident that a relationship between noise and its effects on some aspects of learning,[14] educational quality[15] and reading ability[16] exist. However, exposure-response functional relationships and noise metrics measuring impacts on cognitive development or health, rather than annoyance, are not yet well developed.[17] No specific studies were found that evaluated individual welfare losses due to excessive noise in educational facilities. Where it is close to impossible to obtain individual WTP estimates for a reduction in noise levels, non-demand pricing techniques have to be used. In such cases, mitigation behaviour is a response action that can be measured. In the case where benchmark mitigation payouts are pre-determined by government or by the developer, an additional problem occurs, namely that an approximation of welfare losses is set by someone other than the impacted parties themselves. Nevertheless, such methods have been used in pricing environmental goods and services, but should be regarded as conservative estimates.[18] It is therefore suggested that the exclusion facilities approach (or mitigation costs) be used as a proxy for welfare losses to students and patients. Mitigation costs would therefore reflect the willingness-to-pay for quiet or lack of disturbance from the train on a societal level.[19] Policy makers have responded to this uncertainty by placing certain critical thresholds in place. Noise guidelines from the World Health Organisation suggest that an *indoor* ambient sound level of 35dB(A), and an *outdoor* ambient sound level of 55dB(A), measured as LAeq(dBA), are maintained for educational facilities, while an indoor ambient sound level of 35dB(A) and 30dB(A) for wards, measured as LAeqdB, is maintained during day-time for medical facilities. Outdoor guidelines for medical facilities are 45dB(A) and 40dB(A) respectively.[20] Therefore, the costs of reducing noise to reach these guideline levels, or to reach a 'without development' noise level have to be calculated. Engineering cost estimates and expert opinion on the noise reduction potential of alternative mitigation options are necessary.

14.2.4 Background noise levels

A related issue is the background noise level above which impacts are measured. Various studies often use different assumptions on baseline noise, varying from 30-65 dB(A).[21] In cases when the welfare changes of a specific project have to be measured, this issue is of less interest, as baseline noise levels are those before the development takes place. Welfare losses are still possible, but cannot be attributed to the project itself. Very little research has been done on possible variations in reductions in property values at different background decibel levels. In other words, there is little comparison of decreases in property values at low noise levels versus high noise levels at one site or even within one town. Most studies report an average reduction per decibel increase and do not investigate how this may vary given different levels of background noise. Although the literature is sparse on the subject, a tentative recommendation will be to measure noise levels, predict those after development, and only work with the difference between the two. However, when development is proposed in relatively noisy (>60-65 dB(A)) background environments, caution must be exercised in assuming that increased noise levels will have the same welfare losses as those at lower background noise levels.

14.2.5 Time line of impacts

On the issue of including temporal aspects of noise impacts on the model, it was pointed out that cross-sectional datasets could be used as an approximation of impacts over time.[22] However, as markets move through phases of disequilibrium, the long-term effect will be that highs and lows will tend to cancel one another. The exact time line of impacts might vary between different sites, but on average hedonic pricing can be used to link increased noise levels and a decrease in property prices. The hypothesis is that the total value of properties will tend to decline more rapidly than predicted by the hedonic models when a project is announced and construction begins, but will readjust to the new situation and find a new level after construction has been completed.[23] The severity of the impacts will determine what this new level will be, but this is highlighted as an area deserving future research.[24]

14.3 Model

14.3.1 Generic approach

Emerging from the discussion so far, a generic approach for measuring the economic impacts of noise pollution can be established. The approach used for estimating the welfare losses associated with noise for residential and business areas can be broken down into the following generic steps:

- estimate the value of properties potentially affected by noise, based on information supplied by independent valuers;
- assign and map decibel noise increases to each property;
- estimate the reduction in property values per decibel increase in noise, based on estimates from the extensive international literature on the impacts of noise on property values supplemented by local analysis in the study area;
- convert noise increases into percentage reductions in property values through multiplication with the reduction in property values per decibel increase in noise;
- multiply percentage reductions in property values by property values in order to generate reduced values per property or per property cluster;
- calculate the sum of all property values to give an overall value of welfare losses for the proposed lines; and
- in segments of the line where no residential property markets exist, such as educational and medical facilities, the mitigation costs required to reach noise levels in the 'without train' scenario or in accordance with minimum WHO guidelines have to be calculated.

The expected additional, cumulative noise levels must be calculated before an economic valuation study can be performed. Such a study will have to be performed by acoustic engineers, as part of a technical feasibility or environmental impact study. Based on these results and on the basis of the best available information on the economic impacts of noise, functional relationships between changing noise levels and property values can now be established.

Once such estimates of welfare losses are calculated, they have to be expressed in terms of planned and required mitigation costs. The economic decision rule will be where additional benefits of mitigation (measured in terms on less welfare losses) equals the additional costs of mitigation (measured in engineering costs), both per additional dB(A).

14.3.2 Quantifying external welfare losses

The functional relationships between changes in noise and impacts on property values are as follows:

$$EC_N = \Sigma_{i=1}^{i=n} \Sigma_{j=1}^{j=m} (P_{ij} \times N_{ij} \times (dP / ddB(A))) \qquad (1)$$

where:

EC_N = total external cost of noise pollution

n = nr of segments i of the line

m = nr of impact zones j

P= local value of properties

N = unmitigated incremental noise level due to the development

dP/ddB(A) is percentage decrease in value of property per additional decibel, or the Noise Sensitivity Depreciation Index (NSDI)

14.3.3 Quantify costs of mitigation

The ability to control for the noise pollution has been modelled as:

$$CC_N = \Sigma_{i=1}^{i=n} (C_{ai} + C_{bi} + C_{ti} + C_{ri}) \qquad (2)$$

where:

CC_N = total cost to control noise pollution

n = nr of segments i of the line

C_a = total cost of acoustic walls

C_b = total cost of changes to surrounding buildings

C_t = total cost of train design

C_r = total cost of railway design

In all cases only those control costs that are over and above the baseline used to model incremental levels of noise are to be included. Residual welfare losses (those external impacts remaining after mitigation) are calculated as follows:

$$EC_N = \sum_{i=1}^{i=n} \sum_{j=1}^{j=n} P_{ij} \times (NB_{ij} - NM_{ij}) \times (dP / ddB\ (A)) \quad (3)$$

where:

R = residual welfare losses

n = nr of segments i of the line

m = nr of impact zones j

P= local value of properties

NB = Noise levels 'without development'

NM = Noise levels 'with development' and after mitigation

14.3.4 Comparing costs and benefits of mitigation

The economic viability of controlling for noise is dependent on the decision rule that the incremental benefits of control are greater than the incremental costs of control. This means that the additional costs per dB reduced must not be higher than the additional benefit derived from such a reduction. This is depicted in the following equation:

$$dEC_N / ddB(A) > dCC_N / ddB\ (A) \quad (4)$$

where:

EC_N is external noise cost prevented

dB(A) is amount of decibels controlled

CC_N is cost of noise pollution control

14.4 The case of the Gautrain Rapid Rail Link[25]

14.4.1 Study area

The model was applied to evaluate the external costs of a specific section between two stations (Pretoria to Hatfield), for a 61.7 km high-speed train between Tshwane and Johannesburg and a separate diverting track linking the largest airport in the region – Johannesburg International. The study covered all areas affected by two alternative routes (namely the 5.42 km line 6FD and the slightly longer tunnelled options 6A and 6B) between Pretoria and Hatfield Stations. The proposed track turns east from Pretoria Station towards Hatfield, first elevated through a residential area, before dipping into a cut and cover at a university campus (UNISA) and re-emerging to follow an existing cut rail alignment through an affluent suburb called Muckleneuk on the one side and mostly high-rise flats in Sunnyside on the other. Sunnyside is characterised by low to middle income apartment buildings. The latest figures available (1996) indicate a population of 6 450 in the suburb.[26] Approximately 16 street blocks of flats in the Sunnyside area north of the line will experience changed noise levels due to the train while roughly 15 street blocks in Muckleneuk south of the line will be impacted on. Muckleneuk is a relatively higher income area of predominantly single housing units. The 1996 figures indicate a population of 4 697 in the suburb. Deviating from the Metro rail at the eastern sections of Muckleneuk, the track rejoins the railway line north of the green space area called Magnolia Dell and on the southern area of the sport grounds of the Afrikaans Hoër Seunskool. From here the route passes in between University Avenue and the Afrikaans Hoër Meisieskool, the Securicor/Loftus sports grounds and the Pretoria Girls High before entering the business area of Hatfield, proceeding to Hatfield Station. The 1996 figures indicate that Hatfield had a population of 10 692. The alternative tunnelled Park Street routes (6A and 6B) proceed from Pretoria Station in a tunnel underneath the Pretoria CBD and Park Street, before resurfacing in a cut in Hatfield, east of Burnett Street and opposite the Girls High – where it joins an existing Metro railway line.

14.4.2 Model results

The first main finding of the baseline model (before a sensitivity analysis was done) was that line 6FD would lead to an estimated R7.3 million property welfare losses (a loss of 1.3 per cent in property values for the impacted area 100 metres on each side of the line at an NSDI of 0.61) and R8 million additional mitigation costs at educational facilities. These results only account for mitigation measures included in the initial design of the project (including floating slabs and vibration chairing), as these were internalised in the physical noise impact specialist studies. This compares to an estimated R1.3 million additional property welfare losses due to noise pollution on lines 6A or 6B (a loss of 0.5 per cent in property values for the impacted area at an NSDI of 0.61). The second main finding was that a total of almost R15.7 million (including R8 million at educational facilities) is required to mitigate a 10 dB(A) for noise impacts on line 6FD and R150 000 on line 6A and 6B. This compares to a budgeted R4.9 million for the line, leaving a shortfall of R10.8 million for the mitigation of noise. The third main finding is that residual welfare losses, when a minimum of 10dB(A) noise reduction takes place, are expected at R1.6 million. The model is tested for its sensitivity to a range of factors namely percentage drop in property prices, noise impacts on flats, the noise mitigation budget, flat and building modifications, and combined highest and lowest scenarios. Following this analysis, it is concluded that third party welfare losses will occur due to noise pollution, but that most can be mitigated in a cost-effective way – that is if external costs are included in the planning and evaluation of the project. It was pointed out that a shortcoming of the proposed project is an inadequate provision for noise mitigation measures. These third party impacts and mitigation costs were then included in a financial-economic analysis on alternative alignments before a final recommendation was made to the provincial government.

14.4.3 Limitations of the study

The model can be improved by having access to better quantified mitigation measures and costs. This will enable the performance of calculations on the costs and benefits of mitigation and inform the question of up to what level it will be economically optimal to mitigate for noise impacts. Although such an attempt was made in the study, the results are crude. A precautionary approach was followed after discussions with acoustic engineers, by quantifying the costs of a standard 10dB(A) reduction in noise impacts throughout the line. Another limitation was that only acoustic walls and changes in surrounding buildings were considered as mitigation measures, as final design specifications for the train and railways themselves were not yet available.

14.4.4 Impacts on decision-making

The implications of this applied work is that external costs such as noise pollution cannot be neglected when infrastructure projects are proposed. In this particular case the proposed design of the lines through a suburban area was influenced by the quantification of external welfare costs and the required costs of mitigation. Although welfare losses can be determined more accurately when specific local information is available, the orders of magnitude derived from this study were sufficient to inform the political decision on which line to choose and the level of mitigation measures required to reduce the effects of noise pollution in a cost-effective way. The methods used in this study should be beneficial to similar studies elsewhere.

14.4.5 Use of the results

The single biggest concern with studies like this one is a misinterpretation of the results. As was mentioned in the introduction, the quantification of third party impacts is part of a broader project evaluation and should be interpreted within this context. In absolute terms, quantified welfare losses might appear to be high, but these should always be seen in the context of the total project when statements are made on the height of these costs.[27] A second and related issue is the fixation on the absolute numbers. Although such studies have to be sensitive to key uncertainties, and results expressed in ranges that indicate orders of magnitude, communication about these results often take the form of 'number-fixation', which is obviously wrong. Another issue is that such a study will not solve the question of how to deal with emotionally involved affected parties. Estimates on the costs of their welfare losses will not, and were never meant to, reach consensus in their own, but they will help to facilitate the process of working towards the best available solutions, whether through bargaining and compensation, physical mitigation, fiscal measures or offset projects.

14.5) Conclusion

With increased development, social upliftment and increased rates of urbanisation comes an increased demand for mobility and transport. One of the most important externalities of such developments will be increased noise pollution in cities. Noise does have an important negative impact on humans, and would lead to welfare losses as are often measured through changes in prices of properties in proximity to the sources of noise. This chapter provided a method that can be used in the evaluation of projects that have a significant noise impact, or are perceived to have such an impact, and will assist in facilitating the process where developers, affected parties and authorities work towards the best available solutions. The model was succesfully applied to a case study of a high-speed train in the Gauteng Province, and made a meaningful impact on the budget proposed for mitigation.

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CHAPTER 15

Natural Resource Accounts and their application in South Africa

James Blignaut and Rashid Hassan

15.1 Introduction

Natural resources accounts (NRAs) attempt to augment conventional measures of economic activity by accounting for missing environmental values and integrating environmental and economic information in one unified framework for macroeconomic and environmental management. Such an integrated framework allows for the improved measurement of the contribution of environmental resources to economic well-being and for effective monitoring of the interactions between the environment and economic activity. As a result, more accurate indicators of well-being and macroeconomic performance are generated, and improved signals about environmental impacts of economic activities are conveyed. This enhances the capacity of resource managers, policy makers and development planners to evaluate the complex trade-offs between economic expansion and environmental degradation associated with alternative resource management strategies and intervention options, including the use of environmental regulation and market-based policy instruments. Therefore, in addition to providing an operational framework for implementing the notion of sustainable development through improved indicators and environmentally sensitive measures of income, wealth and welfare, NRAs can be, and have been, linked to economic planning and policy analysis models for evaluating alternative development strategies in terms of their environmental impacts.

Many industrialised countries construct and use various versions and/or frameworks of NRAs. In contrast, there are very limited applications of NRAs in developing countries. One notable exception is the effort in some countries in southern Africa to construct and use NRAs for policy analysis and evaluation.[1] This chapter first provides an overview of the origins and scope of NRAs. The structure of NRAs is described in Section 15.3 and examples of their application and use in South Africa are presented in Section 15.4. The chapter concludes with a synthesis on implications and future challenges.

15.2 Origin and scope of NRAs

Concerns about achieving rapid economic growth at the expense of depletion of natural resource endowments and environmental degradation provided the motivation for finding ways to correct conventional measures of economic performance and welfare for omissions related to the natural environment.[2] NRAs were accordingly conceived to provide the necessary operational framework for integrating economic and environmental information for prudent management and sustainable utilisation of environmental resources for development. The first effort in this direction led to the revision of the system of national accounts (SNA) to address some of its shortcomings with respect to the treatment of natural resources and the environment. However, the revised SNA remained deficient in many ways in terms of providing adequate and accurate information on the consequences and impacts of current economic activities on the state of our natural environment. Efforts to improve further on the revised 1993 SNA led to the development and publication of the System of Integrated Environmental and Economic Accounting (SEEA), which served as the basis for the United Nations' *Handbook on National Accounting.*[3]

The SEEA is in fact a collective noun for various tables and versions of environmental accounting techniques. Therefore it does not prescribe a singular set of valuations or presentation techniques. Given a country's environmental accounting requirements as well as data availability and constraints that may prevail, a specific version may be used and implemented. However, the core SEEA tables and concepts are linked to the existing SNA, which provides the framework for calculating key sectoral and macro-aggregate measures of economic performance that are widely used in all countries, such as gross domestic product, investment, savings and consumption. By using the same structure (including definitions and classifications) of the core SNA,[4] the SEEA satellite accounts provide a direct link between environmental and economic accounts data. This ensures consistency of the structure of the two databases and continued validity and feasibility of using existing time series data. The United Nations[5] reflect as follows on the objective as well as on the necessary link between the SNA and the SEEA:

> The objective of the environmental accounting system should be to monitor the environmental changes caused by economic activities and thus to become the basis (in terms of data) for integrated environmental and economic policies. Such an aim can only be realized if both the direct and the indirect impact of the economic use of the environment on economic activities can be analysed. This implies the existence of close connections between the traditional economic accounting system and the new satellite system. The links between the two data systems could be used to establish comprehensive economic models comprising not only economic but also environmental variables.

The SEEA makes use of SNA data, but also focuses on the shortcomings of the conventional framework. These shortcomings have been mentioned frequently before, mainly in Chapter 2, and relate to the measurement of welfare and the treatment of externalities, degradation and resource depletion. Having said this, what do NRAs do that is beyond the conventional SNA and why are they required? The following few examples will serve to illustrate:

- *Measurement and consumption of wealth.* The direction of change in a country's wealth is important when its true performance in terms of a change in welfare is being assessed. NRAs expand the definition of wealth to include all forms of natural capital (such as minerals, fisheries and wildlife), which are generally either excluded from, or only partially included in, conventional measures. The latter applies when natural capital serves an economic purpose and property rights exist. By accounting for natural capital, NRAs record consumption of natural assets and hence the corresponding depreciation of total wealth. As well-being is dependent on whether the total stock of capital is being maintained for future generations, or depleted, NRAs provide improved measures and indicators of change in well-being.

- *Non-market environmental goods and services.* The national accounts often do not record the value of many environmental goods and services that are not traded in the market, such as direct harvesting of products of nature. However, the livelihoods of poor people in particular are highly dependent on such ecosystems, goods and services (fuel, wild foods, flood control, water quality, etc.). While some countries attempt to estimate the value of these essential goods, the coverage is usually incomplete in national accounts. NRAs attempt to measure and account for the value of such non-market environmental services. This does not only apply to tangible products of nature, but also to intangible services of ecosystems that are essential for supporting life on earth. For example, NRAs attempt to measure and adjust the SNA for the social costs of environmental damage (i.e. pollution, soil erosion, etc.) as well as for the benefits of ecosystem services (pollination, flood protection and carbon storage).
- *Environmental protection expenditures.* Protective expenditures to prevent pollution and damage caused by environmental externalities are, in general, improperly treated in the SNA as current income and expenditures. NRAs correct for this by treating protective expenditures as investment outlays.

NRAs therefore assess the economic value of a country's natural resources and the way in which they are used. They provide a much better measure of economic performance than the conventional economic indicators based on the SNA. They also link problems such as land degradation, groundwater depletion and deforestation to the economic activities that cause them, or are affected by them. NRAs should encourage policy makers to regard the nation's natural resources as capital assets – which they are – and not free goods. The appropriate use of NRAs should promote sound economic decision-making.

15.3 Types and uses of NRAs

Two main categories of NRAs are typically compiled and used: the physical and monetary resource accounts. The following sections provide a brief description of the structure and components of the said accounts.

15.3.1 Physical resource accounts

Physical resource accounts (PRAs) are compiled both for stocks (assets) and flows (supply and use) of the resource in question. Stock accounts attempt to report changes (decrease or increase) in the stock of a natural asset. This is usually done by compiling closing and opening balances of the resource stock and accounting for changes during the accounting period (withdrawals and additions). Withdrawals include extraction for economic use as well as damages due to natural factors (fires, pests, etc.). Additions represent, for instance, new discoveries of mineral resources and natural growth or planned expansion of biological resources.

Flow accounts, on the other hand, record the sources and users of current changes in resource stocks; for example, how extracted timber and minerals and fish caught are supplied and used by various economic entities. One can also construct flow accounts by focusing on the generation and disposition of energy and pollution within an economic system, which provide a direct extension of the supply and use tables of the current SNA. Furthermore, PRAs are useful for addressing important environmental management and economic planning questions through integrating resource use and waste generation with economic activity models. Examples of these are:

- Analyses of patterns and rates of extraction and use of key natural resources by various economic activities, which may reveal a need for reallocation of such flows to more efficient users. An example is the allocation and use of scarce resources, such as water, by various sectors and sources of supply.
- Improved pollution management by establishing the link between waste generation and economic activity to evaluate trade-offs between economic growth and environmental quality, for example, air pollution.
- It is also possible to construct tables that link an economic activity with

emission levels and to construct accounts, that monitor the change of pollutants; for example, the carbon sequestration and water consumption values of industrial plantations can respectively be calculated.

- The construction of indicators for monitoring resource scarcity or depletion and the distance from risky ecological limits and thresholds. One such possibility is the calculation of the extraction rate of wood from natural woodlands and forests and to compare it with the regeneration rate.

15.3.2 Monetary resource accounts

Despite the fact that PRAs greatly contribute towards ecological sustainability indicators, they do not assign monetary values to the physical flows and consequent changes in resource stocks. Their contribution to correcting economic accounts measures of sustainable income and welfare is therefore limited, though essential to gain better understanding of the interaction between the economy and the natural environment. The direct link between economic accounts and environmental resources is consequently established through monetary resource accounts (MRAs), which assign monetary values to resource flows and their stock changes.

Many natural resources are exploited for commercial purposes and accordingly command market prices. Examples include extractive industries such as mining, fishing and logging. For these resources, information on ruling market prices is generally used to value their flows, after adjustments for market distortions. On the other hand, many other environmental resources and their services (biological diversity, climate regulation, flood control and aesthetic and cultural services) are not traded in the market and therefore no market information is available on their value to society. Various non-market valuation techniques have been developed as alternative measures of environmental values (see Chapter 4 for an exposition thereof).

While neither ruling market prices nor non-market valuations are suitable for valuing resource flows, resource assets require different treatment for their valuation. Valuation of resource assets must be based on the calculation of resource rents, which measure the scarcity value per unit of the resource stock *in* *situ*. The resource rent should therefore reflect the discounted sum of the stream of all future net benefits from an additional unit of the resource asset, for example, the net present value (NPV).[6] NPV is recommended by SEEA as the appropriate, and theoretically correct, method of asset valuation, and is based on a constant resource rent over the entire period of depletion. This is, however, only one possible valuation option of projecting future value. One could, for example, also apply the Hotelling rule with increasing resource rent over time. An important contribution of MRAs is accordingly the determination of resource rents and assessment of their rates of recovery and how the recovered rents have been spent.

15.4 Examples of application of NRAs in South Africa

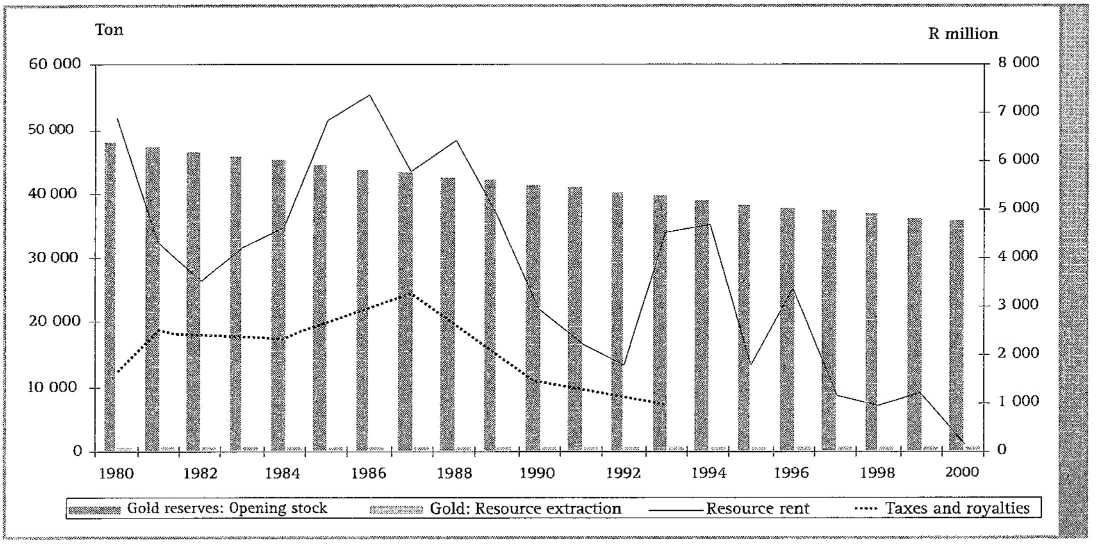
Efforts to construct and use NRAs in South Africa started in the mid-1990s with pilot studies focusing on the forestry sector as a collaborative venture between the CSIR, the Development Bank of Southern Africa and the Department of Water Affairs and Forestry. These pilot efforts have been extended under partial funding from the Environmental Economics Network for Eastern and Southern Africa (EENESA) to produce a comprehensive set of forest resource accounts.[7] These initial efforts were formalised in 1998 under the Natural Resource Accounting in Southern Africa (NRASA)[8] project, under which a number of comprehensive resource accounts have been compiled and used for policy analysis and natural resource planning and management. These and other parallel independent efforts have extended the forestry resource accounts work to water and subsoil assets. The construction of NRAs is now institutionalised under the new strategy of Statistics South Africa, which has made environmental accounting part of its regular functions and hence undertaken to update and expand the existing sets of NRAs periodically. The following sections provide examples of selected applications and use of NRAs in South Africa.

15.4.1 Mineral resources accounts

The mining industry used to play a very prominent role in the South African economy, but this role has been steadily declining. This is evident from the fact that the contribution of the mining industry to GDP declined from 20.4 per cent in 1980 to only 6.5 per cent in 2000, with initially gold and coal, and later platinum, being the dominant minerals.[9] The questions that have been pursued recently relate to how subsoil assets have been developed and to what extent they have been sustainably exploited.[10] Specific issues analysed by minerals resources accounts included questions about the amount of rent on exploiting subsoil assets that has been recovered and how the recovered rent has been appropriated. This is such an important question, due to the difference in economic growth rates among mineral-rich African countries and those with no minerals, which, with a few exceptions, tend to be higher. This has become known as the *curse of the mineral-rich.*[11] Both physical and monetary mineral accounts have been developed and used to address these questions for gold, coal and platinum as well as other mining and total mining.[12] A summary of the results is given as an example.[13]

Figure 15.1 indicates that the total volume of reserves declined by 25.8 per cent over the period 1980 to 2000 from 47.8 billion tons to 35.4 billion tons. Correspondingly, the extraction of gold declined by 36.3 per cent from 675 million tons per year in 1980 to 430.9 tons. This rapid decline was mainly the result of a decline in demand and, consequently, receding prices. At current extraction rates and with no significant new discoveries made or resource losses that might occur, South Africa's gold reserves could last for approximately another 80 years. Though this is still a significant number of years, it represents a finite time horizon, which raises the question of whether continuing extraction at current rates will be a prudent strategy for exploiting gold resources in the future. It is also important to examine the manner in which rents recovered from extracting these resources have been managed and used to support sustainable development in the country.

Solow, the 1987 Nobel Prize winner for economics, was among the earliest researchers to assess the impact of resource depletion on intergenerational equity.[14] He demonstrated that the max-min criterion[15] was a reasonable criterion for intertemporal planning decisions. By introducing exhaustible resources into his analysis, he also found that the elasticity of substitution between natural resources and labour-and-capital goods was less than unity. He concluded that earlier generations are entitled to draw down the pool of natural resources, provided they add to the stock of reproducible capital. Investigations into



Source: Statistics South Africa. 2002. Natural Resource Accounting: Mineral Accounts for South Africa 1980 to 2000. Draft discussion document. Pretoria: Statistics South Africa.

Figure 15.1: Gold reserves (t) and extractions (t) and resource rent (R million) and taxes and royalties from gold (R million): 1980 to 2000

intergenerational equity undertaken by Mikesell[16] also suggest that mineral resources should be regarded as a form of capital asset, the value of which should be preserved for future generations even though the minerals may be extracted and consumed by the present generation. This view supports the weak sustainability rule of typical neo-classical environmental resource economists who argue that various forms of capital are substitutable for one another. (See also the discussion regarding asset substitution and environmental economics in Chapter 3.)

To pursue the above questions one has to determine the resource rent recovery rates and the use of the recovered rent. The resource rent for gold is also shown in Figure 15.1, based on a social discount rate of 3 per cent. For the initial periods, significant resource rents were generated, as high as more than R7 billion per year, but the rents declined significantly during the latter years because of higher input costs and a declining gold price. The South African government also neglected a significant portion of the resource rent through taxes and royalties. From 1966 to 1993, taxes and royalties comprised at best about 50 per cent of resource rent, but on average no more than 20 per cent. This implies that mining companies enjoyed by far the greater share of the gain. This result, should, however, be interpreted in the light of the fact that traditionally only rent from mines on government land, which was less than 30 per cent of gold mines, was collected, and data on rest collection from mines on private land are not available. Another teasing, unanswered question is to what extent total private investment by gold mines, which was aimed at social development, i.e. schools and clinics, could be considered contributing to building social capital and improved economic opportunities for future generations as a compensation for depleting subsoil assets.

Regardless of whether the gold mining industry invested sufficiently for the development of future generations or not, it is clear that not only is the resource base consistently being depleted, but that the current levels of resource rent are also very low. This implies that it is unlikely that gold will become a major force towards stimulating economic development within the immediate future.

15.4.2 Water resources accounts

The first comprehensive national accounts for water resources in South Africa were produced in 2000 under funding from the Natural Resource Accounting in Southern Africa (NRASA) project.[17] The first national water resource accounts built on secondary information from various sources, consolidated in one comprehensive set of physical and monetary accounts for the country for the period 1991 to 1998. The physical water accounts in this first treatment for South Africa followed the Australian approach[18] of constructing asset and pathways tables. Asset tables showed the expected average annual runoff yield and potential and current groundwater yield. The pathways analysis tables traced the pathways of water from initial source through all uses to final disposition (Table 15.1).

Although South Africa uses surface and groundwater resources, the country relies heavily on surface water for its total supply of fresh water. By far the largest portion of annual precipitation is used up in the form of evapotranspiration and deep seepage (91 per cent in 1998/99). This implies that only 8.3 per cent of precipitation is available in the form of total inflow (indicated as row i in Table 15.1). The fact that South Africa's dams are relatively shallow and that they extend over huge surface areas is a major contributing factor to the high evapotranspiration share.

Table 15.1: Water pathway analysis for South Africa: 1991/92 to 1998/99

			1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99
Mean annual rainfall	Mm	A	515.2	499.3	372.2	424.1	519.7	416.0	659.9	640.9
Precipitation	Million m^3	B	630 193.2	610 744.3	455 275.4	518 759.5	635 697.6	508 851.6	807 190.3	783 949.5
Evapotranspiration & deep seepage	Million m^3	C	573 204.4	555 514.3	414 104.6	471 847.8	578 211.1	462 835.9	734 195.6	713 056.5
Net annual runoff	**Million m^3**	**d=c-b**	**56 988.7**	**55 230.0**	**41170.8**	**46 911.7**	**57 486.5**	**46 015.8**	**72 994.7**	**70 893.0**
Streamflow reduction	Million m^3	E	6 403.4	6 388.0	6 105.7	6 247.4	6 493.6	6 260.4	6 925.7	6 910.4
Groundwater	Million m^3	F	1 449.4	1 449.4	1 449.4	1 449.4	1 449.4	1 449.4	1 449.4	1 449.4
Transfers in	Million m^3	G	4 672.0	4 672.0	4 672.0	4 672.0	4 672.0	4 672.0	4 672.0	4 672.0
Transfers out	Million m^3	H	4 672.0	4 672.0	4 672.0	4 672.0	4 672.0	4 672.0	4 672.0	4 672.0
Total inflows	**Million m^3**	**i=d-e+f+g-h**	**52 034.8**	**50 291.4**	**36 514.5**	**42 113.7**	**52 442.3**	**41 204.7**	**67 518.4**	**65 432.0**
Instream flow requirement	Million m^3	J	17 737.7	17 737.7	17 737.7	17 737.7	17 737.7	17 737.7	17 737.7	17 737.7
Households	Million m^3	k	1 773.9	1 812.6	1 852.2	1 892.7	1 934.0	1 945.5	1 976.3	2 013.2
Irrigation agriculture	Million m^3	l	10 548.9	10 470.6	8 571.0	10 791.2	10 932.1	11 509.8	11 526.0	12 361.9
Bulk uses	Million m^3	m=n+o+p+q	1 153.0	1 186.3	1 232.7	1 172.8	1 130.0	1 132.8	1 165.2	1 135.8
Mining	Million m^3	n	527.2	535.1	555.1	526.8	500.6	480.8	484.2	453.2
Electricity	Million m^3	o	217.3	226.1	235.3	224.3	225.5	226.4	236.5	237.0
Other strategic	Million m^3	p	187.2	194.8	202.7	193.3	194.3	195.1	203.7	204.2
Other bulk	Million m^3	q	221.3	230.3	239.6	228.4	229.6	230.6	240.8	241.4
Other industrial	Million m^3	r=s+t+u+v+w+x+y	893.1	876.8	874.9	892.7	930.0	948.1	964.4	992.3
Manufacturing	Million m^3	s	199.9	192.3	192.0	195.9	210.1	209.8	216.1	223.4
Construction	Million m^3	t	48.8	44.7	40.7	40.7	40.9	41.4	41.7	41.9
Trade	Million m^3	u	150.9	146.4	146.7	152.1	161.5	167.2	167.6	176.1
Transport & communication	Million m^3	v	104.5	105.7	108.2	111.9	117.3	120.6	123.3	128.0
Finance, real estate, business services	Million m^3	w	164.3	162.5	161.7	164.9	169.7	174.1	176.7	181.2
Other private services	Million m^3	x	40.7	41.2	41.2	42.2	42.9	43.7	44.5	45.2
Other	Million m^3	y	184.0	183.9	184.0	185.0	187.6	191.2	194.4	196.5
Other incremental use incl. in-stream flow reduction	Million m^3	z	5 163.4	5 186.2	5 209.9	5 226.7	5 242.8	5 259.2	5 337.4	5 367.9
Total economic use	**Million m^3**	**aa=k+l+m+r+z**	**19 532.2**	**19 532.5**	**17 740.7**	**19 976.1**	**20 189.0**	**20 795.4**	**20 969.3**	**21 871.0**
Total consumptive use	**Million m^3**	**ab=% of aa**	**17 521.4**	**17 513.6**	**15 772.8**	**17 909.0**	**18 089.5**	**18 665.9**	**18 812.0**	**19 663.8**

Table continued on next page >>

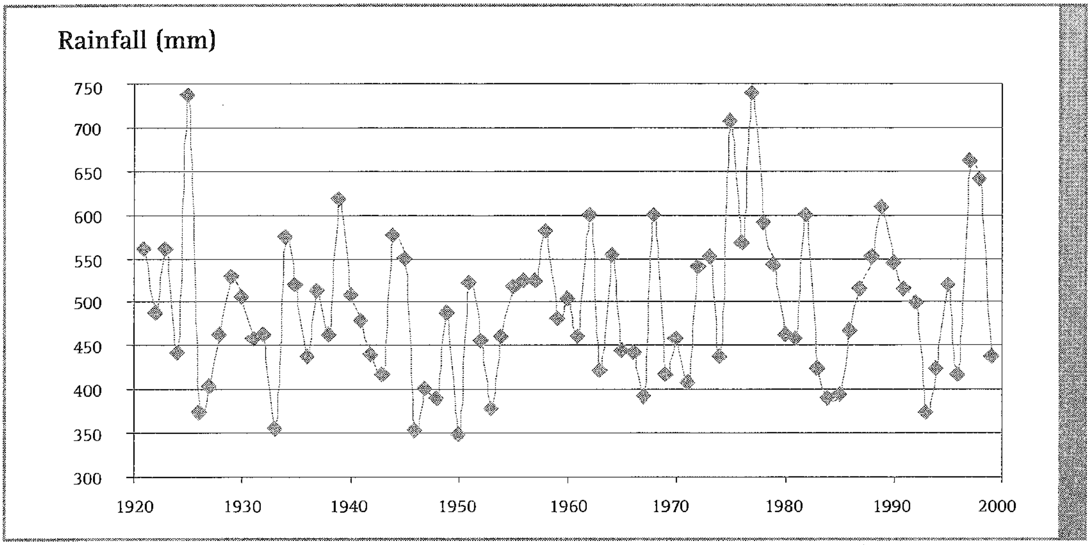
			1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99
Non-consumptive use	Million m^3	ac=% of aa	2 016.9	2 018.9	1 967.9	2 067.1	2 099.5	2 129.6	2 157.2	2 207.2
Total use	Million m^3	ad=j+ab	35 259.0	35 251.3	33 510.5	35 646.7	35 827.2	36 403.5	36 549.7	37 401.5
Theoretical outflow	Million m^3	ae=i-j-ab	16 775.7	15 040.1	3 004.0	6 467.0	16 615.1	4 801.2	30 968.7	28 030.5
Outflow as % of inflow	%	af	32.2	29.9	8.2	15.4	31.7	11.7	45.9	42.8
GDP / total consumptive water use	R/m^3	ag	29.1	28.2	31.5	28.1	28.4	28.1	28.2	27.5
Employment / total consumptive water use	R/m^3	ah	0.8	0.8	0.9	0.8	0.8	0.8	0.8	0.8

Source: CSIR. 2001. Water Resource Accounts for South Africa. Report to Statistics South Africa and The Department of Environment Affairs and Tourism. Report number ENV-P-C 2001-050. Pretoria: CSIR.

The instream flow requirements (row j of Table 15.1) comprised the largest single user of water inflow, namely 27 per cent. This flow is necessary to keep the river runoff and ecological balance intact. Irrigation agriculture followed as the second largest user of water, consuming 63 per cent of the total economic consumptive use of water in 1998/99. On the other hand, households consumed 10.2 per cent and bulk users 5.8 per cent of the total consumptive use of water.

The increase in water use by 12 per cent was offset by the fact that the inflow had increased by almost 26 per cent, mainly because the latter two years had been abnormally wet. The mean annual rainfall for these years was 659.9 mm and 640.9 mm respectively, which was approximately 34 per cent higher than the mean annual rainfall over the period 1921 to 1999, which was 482.6 mm (comparable with the early 1990s).[19] Disconcerting, however, is the fact that despite 1996/97 having been a dry season with the lowest recorded outflow of water, the water use efficiency did not improve.

Indicated in Figure 15.2 is the fact that rainfall had become increasingly more erratic during the latter part of the previous century. The years 1998 and 1999 were the fourth and fifth wettest recorded over the period 1921 to 1999, but, evidently, both the frequency and intensity of the swings between dry and wet years are increasing. This implies that water supply management is becoming more difficult. It is therefore not surprising that some[20] are of the opinion that water will become an important factor to take into consideration with regard to development in future (see also Chapter 9 in this regard).



Source: CSIR. 2001. Water Resource Accounts for South Africa. Report to Statistics South Africa and The Department of Environment Affairs and Tourism. Report number ENV-P-C 2001-050. Pretoria: CSIR.

Figure 15.2: Mean annual rainfall in South Africa: 1921 to 1999

In addition to natural sources, the physical water accounts also generated information on institutional sources of water. Those ranged from suppliers of bulk water such as the Department of Water Affairs and Forestry (DWAF) and irrigation and water boards to district councils and local authorities, which provide water supplies to end users (domestic, industrial and services sectors). In addition, self-providers, consisting mainly of livestock and irrigation farmers and mining companies, supplied about 10 per cent of total water use in 1998.

The first monetary water accounts provided information on contributions of value-adding uses to GDP and employment and water tariffs and subsidies. Over the period 1991/92 to 1998/99 the total economic consumptive use of water (row ab in Table 15.1) increased by more than 12 per cent, whereas the GDP increased by only 5.8 per cent. This implied that GDP per economic use of water declined from R29.1/m^3 to R27.5/m^3 over the same period. Instead of water being used more efficiently, it seems as if the pathway analysis indicates otherwise. The corresponding figure with regard to employment has remained stable. Another important contribution of the water monetary accounts is that the extent of water delivery costs recovery from, and thus the direct subsidies enjoyed by, the various water use sectors is revealed.

Since the construction of water resource accounts was institutionalised within Statistics South Africa, the latter body subsequently undertook a study applying the SEEA framework to construct elaborative resource accounts for the Upper Vaal Water Management Area for the period 1991 to 2000.[21] Moreover, resource accounts for all of the 19 Water Management Areas in the country for 2000 are being developed.[22] These latter accounts depict the water use, water supply and water asset tables of the country in physical terms, while the former also included monetary accounts based on raw water prices and the delivery cost of water.

15.4.3 Forest resource accounts

Comprehensive resource accounts for natural woodlands and forest resources have been compiled for South Africa.[23] These attempt to account for the impact of industrial plantations (human-made forests) on carbon sequestration and water use and the economic value of fynbos. Interesting from an economic development perspective, are the direct and indirect use values of natural woodlands and forests, which are typically directly harvested by rural communities living around them. In addition to direct use values, the study also estimated indirect use values of forests, such as the change in ecosystem functions (for example, loss of carbon sequestration, water yield, etc.) because of changes in standing resource stocks (biomass). Indirect use values of ecosystem services are addressed in Chapter 5, therefore the focus here will be on direct use values.

In the conventional calculation of GDP, the direct consumption of products from the wild is not included. Gathering and consuming these resources do, however, constitute final demand activities by households, which implies an underestimation of GDP. These direct use values include firewood, wood for construction purposes, edible fruits and medicinal plant material. Table 15.2 shows the harvest of products from natural woodlands and forests for domestic purposes in three South African provinces for 1998. The primary use of biomass (wood) is for energy and construction purposes. Harvest rates of these two items were estimated to be 0.885t, 1.19t and 0.78t per person in the Eastern Cape, KwaZulu-Natal and the Limpopo Province, respectively. Based on the user population and harvest rates, the study determined total harvest volume and harvest rate in terms of t/ha. To assess whether the use of these resources are sustainable or not, the rate of regeneration of these biological resources has to be determined and compared with harvesting.

Table 15.2: The harvest of products from natural woodlands and forests for domestic purposes: 1998

	Unit	Eastern Cape	KwaZulu-Natal	Limpopo Province
Fuelwood	Kg/person/year	806	1 097	728
Construction:	Kg/person/year			
Buildings		19	12	31
Fences and kraals		60	81	21
Carving timber	Meters	1.8	In 'Other' below	0.08
Medicinal products	Kg/person/year	1.0	-	0.36
Edible fruits	Kg/person/year	11	5.2	15.6
Edible herbs and vegetables	Kg/person/year	-	-	2.4
Thatch grass	Kg/person/year	8.1	90	66
Weaving reeds	Kg/person/year	-	-	0.9
Livestock	Kg/person/year	5.9	-	-
Other	Kg/person/year	13.7	6.8	-
Total area	Ha million	17.05	9.495	12.231
Original wooded area	Ha million	4.94	6.09	11.851
Accessible wooded area	Ha million	3.3	3.2	7.2
Rural population	Million	3.666	4.603	2.473
User population		0.710	1.551	1.456
Harvest rate	Ton/person	0.885	1.19	0.78
Total harvest volume	Million ton	0.628	1.846	1.136
Harvest rate	Ton/ha	0.19	0.577	0.158

Source: Hassan, R.M. 2002. Stock and Flow Values of Woody Land Resources. Pretoria: CEEPA, University of Pretoria.

The products listed in Table 15.2 are, however, also marketed products. Using study estimates of their market prices as a basis, monetary accounts of the direct use values of the harvested products were compiled (Table 15.3). The total adjusted direct consumption value of these products was estimated at R396 million, R1 529 million and R842 million for the Eastern Cape, KwaZulu-Natal and the Limpopo Provinces, respectively. This translates into 31.3 per cent, 21.2 per cent and 59.1 per cent of the gross geographic products for agriculture of the respective provinces. Evidently, these numbers are significant and constitute a considerable underestimation of the respective gross geographic products and hence the value and contribution of the natural environment in these provinces to the livelihood of their people and to their economic development.

Table 15.3: Direct use values of natural woodland and forests products: 1998

	Unit	Eastern Cape	KwaZulu-Natal	Limpopo Province
Fuelwood	R/person/year	132.99	229.27	89.54
Construction:	R/person/year			
Buildings		12.96	32.04	16.68
Fences and kraals		11.22	39.69	11.30
Carving timber	R/person/year	19.8	-	0.77
Medicinal products	R/person/year	15.84	91.33	49.50
Edible fruits	R/person/year	4.6	3.41	2.81
Edible herbs and vegetables	R/person/year	-	-	93.36
Thatch grass	R/person/year	6.02	60.30	72.60
Weaving reeds	R/person/year	-	0.72	1.78
Other	R/person/year	18.08	135.39	15.43
Total: Products from the wild	R/person/year	221.51	592.15	353.77
Livestock	R/person/year	64.90	314.38	-
Total: All	R/person/year	286.41	904.63	353.77
Conservative average	R/person/year			515.60
Adjusted totals	R/person/year	558.88	985.76	578.69
Adjusted average*	R/person/year			707.48

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	Unit	Eastern Cape	KwaZulu-Natal	Limpopo Province
Adjusted average*	R/person/year			707.48
Total use value: Conservative estimate	R million	203.351	1 406.183	433.015
Total use value: Adjusted estimate	R million	396.180	1 528.914	842.573
Adjusted total use value as % of Agriculture GGP		31.3	21.2	59.1
Harvest value: Conservative estimate	R/ha	61.62	439.43	60.14
Harvest value: Adjusted estimate	R/ha	120.06	477.79	117.02

Source: Hassan, R.M. 2002. Stock and Flow Values of Woody Land Resources. Pretoria: CEEPA. University of Pretoria.
Note: *50 per cent adjustment made for products excluded from the survey

15.5 Conclusion

Conventional measures to determine changes in welfare and progress are inadequate and in some cases inappropriate. This is especially because changes in both the quantity and quality of the natural environment are not internalised. To rectify this situation natural resource accounts can be complied as satellite accounts to the conventional systems of national accounts. These accounts are potentially very important datasets in understanding the interrelationships between the natural environment and its economic use. Furthermore, based on this improved understanding of the relationship between natural systems and the economy, natural resource accounts are potentially also very important tools in determining economic development strategy and policy.

In summary, it has been indicated that natural resource accounting tools and methods indicate that the likelihood of gold to become a major player in future economic development in South Africa is dubious. It has also been shown that water use efficiency is declining and that water resource management will become increasingly important. Lastly, the direct use value of the natural environment through the harvest of products of the wild, such as fuel wood and wood for construction purposes, form a significant proportion of the gross geographic product of three of South Africa's poorer provinces. These values are not accounted for in the conventional measures, while the natural environment is not being valued accordingly either.

Endnotes and References

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CHAPTER 16

Economics in impact assessment: The role of environmental and resource economics

Anthony Leiman and Hugo van Zyl

16.1 Introduction

In this chapter two important questions are addressed, namely where economics, particularly environmental and resource economics (ERE), should be located in the project appraisal process and what questions it should address. Initially the status quo is outlined, that is, the current roles of these disciplines in environmental impact assessments (EIAs). A number of locally successful uses of economics in the current project planning context follows. Finally, standard questions that should be addressed by economists are suggested and recommendations are made for the way forward.

16.2 The status quo

As the EIA process has evolved over the years, so has the contribution of economics to the process. In part, this evolution has been a response to a

Date and phase	Trends and innovations
1. Prior to 1970 (Pre-EIA)	Project review based on engineering and economic studies, e.g., *cost benefit analysis*; limited consideration of environmental consequences.
2. 1970-1975 Methodological development	EIA introduced in some developed countries; initially focused on identifying, predicting and mitigating bio-physical effects; opportunity for public involvement in major reviews.
3. 1975-1980 Social dimensions included	Multidimensional EIA, incorporating social impact assessment (SIA) and risk analysis; public consultation integral part of development planning and assessment; increased emphasis on issues of justification and alternatives in project review. The stress on extended cost benefit analysis with inclusion of environmental impacts began to emerge at this stage.
4. 1980-1985 Process and procedural redirection	Efforts to integrate project EIA with policy planning and follow-up phases; research and development focusing on effects of monitoring, on EA audit and process evaluation, and on mediation and dispute resolution approaches; adoption of EIA by international aid and lending agencies and by some developing countries.
5. 1985-1990 Sustainability paradigm	Scientific and institutional frameworks for EIA are rethought in response to sustainability ideas and imperatives; search begins for ways to address regional and global environmental changes and cumulative impacts; growing international cooperation on EIA research and training.
6. 1990-present	Strategic environmental assessment (SEA) of policies, programmes and plans introduced in some developed countries; international convention on transboundary EIA; UNCED places new demands on EA for expanded concepts, methods and procedures to promote sustainability (e.g., through sustainable development strategies). *Ex ante and ex post economic appraisal of projects*. Integrated environmental management (IEM) introduced in South Africa.

Adapted from: Roe, D., Dalal-Clayton, B. and Hughes, R. 1995. A Directory of Impact Assessment Guidelines. London: IIED.

Figure 16.1: The international evolution of environmental impact assessment

perceived need. At the simplest level, economics entered EIAs because of public demand. Its role in EIAs has been similarly affected: increased awareness of the EIA process and the increasing economic sophistication of both the public and final decision makers have steadily changed the questions asked of the economist. In part, the changing role of economics has also been due to the changing structure of the EIA process internationally. This evolution is summarised in Figure 16.1.

In South Africa, the earliest EIAs were voluntary compendia of impacts, typically ecological, and often pitched at inappropriate levels of detail. Partially in response to this, in 1992 the Department of Environmental Affairs issued guidelines for the conduct of EIAs (though these only became compulsory in 1997). The guidelines brought South Africa into line with international best practice.[1] Sowman *et al.*[2] posit that South Africa's need for development meant that emphasis had to be placed on positive aspects of proposals, identifying appropriate mitigatory measures and ensuring that the social benefits of the preferred alternatives outweighed the social costs. The guidelines were named *integrated environmental management* (IEM), as the term EIA was perceived as too limited in scope, reactive, anti-development, too separate from the planning process, and often the cause of costly delays.[3] The emphasis on positive net social benefit immediately enhanced the role of economics – the identification of such net benefits being the essential feature of cost-benefit analysis.

The risk of inappropriate detail is still existent – it is the nature of any expert-driven process that 'experts' regard their own disciplines or areas of expertise as crucial. The problem remains to be: How does the manager of the EIA process ensure that only relevant data and thinking are given in the final report? One way is to restrict the level of detail by asking of every opinion proffered: Does this issue have the potential to derail the project, or to influence the development path selected for it? Only where it has the latter potential should the material be retained. At an economic level this means asking (at the very least) whether:

- the project is financially viable;
- the project is economically viable; and
- alternative forms of the project would be more economically efficient.

The outline above does not refer to ERE as a specific discipline, nor does it suggest that an economist's contribution improves if he or she has specific expertise in this field. However, the stock in trade of the environmental economist is the identification and quantification of significant opportunity costs. In particular, ERE addresses the value and nature of production and consumption externalities, the implications of missing markets for efficiency, and the opportunity cost of current consumption/harvest/extraction in terms of future utility/profits (i.e. sustainability). Where these are likely to be significant (and this may be especially relevant in strategic assessment), the environmental economist can be of value.

Economic questions on the topics above have been asked for many years. Classic cost benefit analysis (CBA) dates back to the US Flood Control Act of 1938 – predating the first use of EIA by decades. This raises the question whether the formal discipline imposed by specifically *environmental* economics can offer services (beyond those of a simple CBA) to the parties that are involved in, or have a stake in the bulk of, EIAs: to EIA study coordinators, to other specialists, to interested and affected parties (I&APs) and to government authorities.

It will be seen later in this chapter that the impacts of a project on job creation, income generation and distribution, linkages to the local and regional economy, and induced further development, are *key* features which an economic appraisal should identify and describe. They should feature at all four of the levels at which economics can contribute to the EIA procedure shown in Figure 16.2. The income-related aspects in particular tend to feature more strongly in local EIAs than in first-world ones, especially since the use of income distributional weights was dropped from the American practice of CBA.[4]

The point at which ERE slots best into the process is open to debate. At the one extreme stand those who argue that the role of ERE is to inform policy makers and project designers beforehand (at the planning or *ex-ante* stage) about the full set of environmental, and sometimes even financial, opportunity costs involved. This is one justification for the existence of bodies such as Resources for the Future and the Environmental Protection Agency in the USA; bodies that can fund and organise the sort of broadly based policy level research that can inform the design of projects *ahead of time*. They can do so at both the broadly strategic and the project levels.

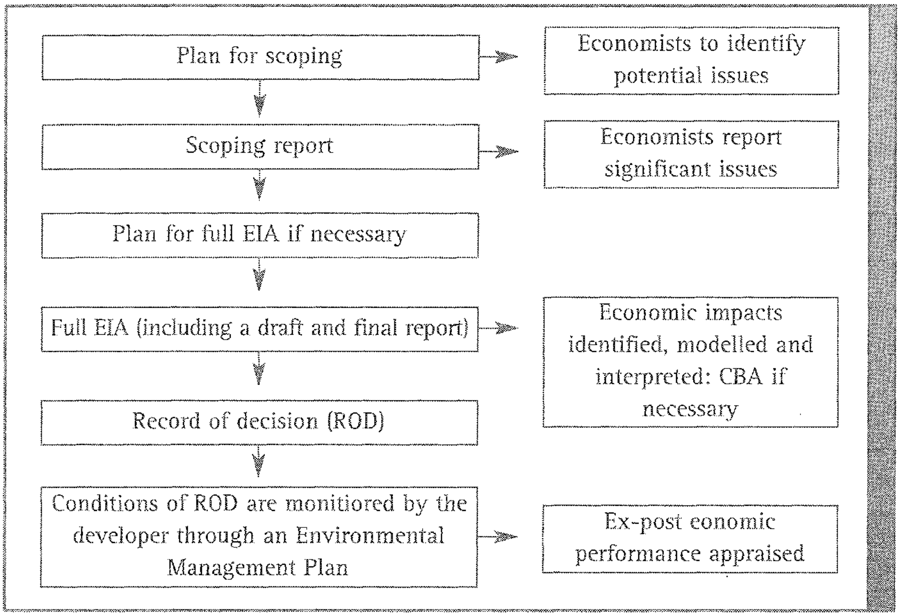

Figure 16.2: The legal EIA procedure

At the strategic level, business and government operate within parameters. These parameters include the contractual system (contract law), labour (for example, minimum wages and rules governing dismissal) and sales (regulations on acceptable advertising standards and misrepresentation). They also include the use of the environment as a *de facto* input into the production process. Thus there are regulations governing emissions: to the extent that pollutants are unregulated, clean air and water are inputs into the production process, and fouled air and water are its consequences. Business has to operate within the constraints of the regulatory parameters set by parliament and its agents. There can be no production and no consumption without environmental impacts. When the regulatory framework is under review, the role of the economist is to help inform reviewers about the socially optimal level of environmental degradation!

At the project level, ERE can inform both initial assessment and scoping as to the 'questions that should be asked'. Although ERE can formulate the appropriate questions, only once a project has been proposed and the relevant bio-physical/social assessments have been performed, can an economist actually begin to assess the full range of costs and benefits involved. This places ERE in the EIA process.

Lastly, there are those who advocate analysis after the event, i.e. *ex-post*: economic assessment of the success or failure of projects *after* they come on-stream (economically equivalent to the later periods of the IEM process). This increasingly powerful group is currently led by the World Bank, which now requires *ex-post* assessment to ensure accountability from its own project managers and designers.

The view upheld here is that all of these are valid, and each has a role. The record of decision-making in the IEM process has meaning precisely because appraisal is ongoing. Where a project has been given the go-ahead because of promised economic spin-offs, it makes sense that these be checked after the event. This is not a new view; the risks and costs of ignoring the logic of ERE were convincingly demonstrated by the Nader study group in the early 1970s.[5] Though the *ex-ante* and *ex-post* uses of environmental economics are important, this chapter will keep as its primary focus the EIA process itself and the place of economics within it.

Today it is common practice for an EIA to incorporate an economic component. Indeed, the nature of the process makes it almost a formality. After the project concept has been defined, the pre-feasibility component of EIA begins. Screening, initial assessment and scoping can all be informed by economics. When, in the course of these, interested and affected parties are identified and questioned about their problems or concerns, one of their standard concerns is: What about the economics? This query is duly noted and, as the process runs its course, an economist is appointed with terms of reference (ToR) that amount to, 'Say something about the economics of it'. Such ToRs are useful neither to the public nor to the decision maker. They are certainly not helpful to the economist. What the public often has in mind is a set of questions along the lines of:

- How much will this cost and what is the likelihood that we will end up paying for it?
- What are the benefits and who will get them?
- Might it collapse and leave us with a clean-up bill?
- Or more simply put: Will the project or policy be 'good' for us?

Ideally these points will be signed off – the specialists will determine whether the identified problems are significant at the scoping level or not – thereafter the ToRs for specialists will be constructed. The expectations of specialist reports in EIAs are generally clear. There is seldom much doubt as to when and how vegetation, hydrological, noise, visual, archaeological, etc. studies should proceed. It is the authors' experience that this is not always the case with economics. Moreover, EIA coordinators vary in their understanding of what is meant by economic impacts and what an economic report can offer. This is reflected in the ToRs: some specify the positive linkage effects of projects, the employment they induce, multiplier effects, etc. Others focus on the role of market failure and the externalities present. Some ToRs (controversially) identify pecuniary externalities (changes in relative prices) as impacts, while others stress exchange rate effects. Some EIAs proceed with economic specialist studies focusing only on microeconomic issues, others on micro and macro issues. In some instances separate macro- and local (i.e. micro-) economic impact studies are commissioned.[6] In addition, socio-economic impact studies have become more commonplace, requiring the combining of social and economic impacts in one report (see, for example, the Vissershok landfill extension EIA[7] and the Saldanha Bay iron ore terminal expansion EIA[8]). This profusion of approaches relative to other specialist study areas has led to unnecessary confusion and, arguably, has lessened the efficacy of economics as a component in impact assessments.

Apart from the confusion created by the various ways in which economic impacts are assessed, there is also some difficulty in establishing consistency in terms of what is to be expected from economic specialist studies (i.e. What are the questions that should be addressed regularly in economic specialist studies?). In the authors' experience, the ToRs of some economic specialist studies give them a macroeconomic focus, stressing linkages between the project and the remainder of the economy. Although environmental externalities may affect other economic sectors, such impacts are not captured in conventional input-output tables, social accounting matrices or computable general equilibrium models, and are not yet captured in the national accounts.[9] Their absence from these basic tools of macroeconomic impact assessment means that such studies take little or no consideration of potential negative environmental impacts. On the positive side, the national accounts of Namibia, Botswana and South Africa are currently being amended to include satellite accounts that capture natural resource depletion (see Chapter 15 in this regard).

The phrasing of ToRs can be an unexpected problem. Colloquial terms may have a specialist meaning for the economist. Therefore, should they specify a cost-benefit analysis (which certainly sounds as if it should include all relevant costs and benefits), it is almost certain that there will be little consideration of multiplied impacts on economic variables (since cost-benefit studies follow a relatively standard format which generally excludes multiplier impacts[10]). The same outcome might follow if they direct the economist to focus narrowly on direct local economic impacts. Economists should inform EIA coordinators when terms of reference will have unexpectedly narrow interpretations.

To date, the application of ERE techniques and, in particular, environmental valuation has been patchy in South Africa. The conceptual and practical reasons for this state of affairs outlined by Crookes and de Wit[11] were as follows: First, the lack of communication between disciplines has led to their polarisation. Disciplinary boundaries often remain rigid and environmental practitioners may be unaware of the role that valuation can play in EIAs both in the economic assessment and in fulfilling a potential integrative role at a higher level of analysis. Second, time and budgetary constraints can lead to the exclusion of ERE inputs. This was historically particularly easy, as the authorities and public did not generally demand that ERE analyses be carried out. Increasing public awareness of ERE as a discipline, though often limited in detail, has meant that such exclusions are becoming more rare. Third, the nature of the EIA process dictates that the economic specialist studies occur in tandem with other specialist studies. After the completion of the biophysical specialist studies, little time is available for the translation of these impacts into monetary estimates. Finally, some projects will go ahead on political grounds, leaving no room for ERE analysis to highlight environmental costs that may challenge political decisions.

The authors' experience in EIAs mirrors the findings of Crookes and de Wit. Another key point worth emphasising is the critical role played by the EIA study coordinators. Given the way EIAs are currently conducted in South Africa, the primary responsibility for selecting the required specialist studies and drawing up ToRs for these studies lies with these coordinators, although the environmental authorities have to approve scoping reports containing ToRs. The environmental assessment profession has become increasingly competitive and firms often compete on the basis of price and study duration. This means that the incentive structure which they face does not encourage the inclusion of studies not absolutely required in the EIA process. If the EIA authorities and I&APs do not specifically call for an ERE analysis, then firms have no compelling reason to include it. This is especially true of the valuation studies, which place monetary values on non-market impacts of projects. It is up to the economist to indicate at the scoping level of a study whether the outcome of such a study could feasibly influence the final decision or not.

16.3 Local successes

What is the environmental economist (as opposed to the general economist) able to offer? The more successful recent local applications of ERE in EIAs have been focused studies where those commissioning the studies have had a clear understanding of what was required and how ERE could contribute largely by highlighting opportunity costs. Recent examples include two assessments for the proposed Gautrain in Gauteng[12] (see Chapter 14), an assessment for the proposed R300 toll road in Cape Town,[13] an assessment for the proposed Meyersdal Estates development in the Klipriviersberg in Gauteng[14] and a study for a tannery in Wellington near Cape Town.[15]

In the case of the Gautrain, the first assessment focused on choosing the preferable routing for the train through selected areas based on its impacts on green environments. First the value of the affected green environments was determined using a combination of open space values adjusted and transferred from Cape Town, environmental values reflected in property prices and recreational use values (see Chapter 10). These values were then adjusted downward, based on expert opinion, to determine which routing would result in the lowest decrease in environmental value. The second assessment for the Gautrain focused on a comparison of the costs and benefits of two alternative routings through Pretoria. Decreases in amenity value from noise, vibration and visual impacts were valued using impacts on property prices and visual and heritage impact indexes. These impacts could then be added to engineering cost differences to determine which route through Pretoria would have the highest net benefit.

Part of the economic impact assessment for the proposed R300 toll road in Cape Town required the analysis of the routing of the road through an ecologically sensitive area comprising Zeekoevlei, Rondevlei, the Cape Town City Wastewater Works (known for its rich birdlife) and the fynbos patches in between. It was not feasible to conduct a full CBA of routing the road through the area. In retrospect, while this would have been useful, valuation alone would not have been adequate to come to sound conclusions, due to the strategic nature of the questions that had to be answered. Instead, a reasoned consideration of the trade-offs involved was done, focusing on the impacts of the routing on the high recreation and tourism potential of the area as an ecology park.

The Meyersdal Estates study was commissioned by the Gauteng Department of Agriculture, Conservation, Environment and Land Affairs after the developers of the proposed Meyersdal Estates housing development challenged a decision by GDACEL to refuse permission for the partial development of a rare and ecologically sensitive part of the Klipriviersberg. A combination of the benefits-transfer technique, ecological uniqueness ratings and a consideration of the recreational and tourism potential of the area was used to highlight more clearly the ecological and economic opportunity costs of development.

The Mossop Western Leather (MWL) Tannery began its Wellington operations in 1845, predating the establishment of the town and contributing to its growth. The need to inform future planning at the tannery was recognised by MWL in 1999 and an assessment of the relationship between the tannery and the local economy of Wellington was commissioned. A hedonic property price model was used to quantify negative economic impacts arising from odours, using property prices as a proxy for residents' welfare. It was found that the benefits to the community of changing processes at the tannery to reduce odours would significantly outweigh the technical costs incurred by the tannery.

Essentially the focus in these studies was the highlighting of trade-offs or opportunity costs. The important point is that this was done both with and without valuation of environmental impacts. Whether to spend time on these trade-offs and how to do so will depend first on the viability of the project and its alternative forms and then on the appropriateness of valuation along with time and budget constraints. Moreover, CBA might not be the ideal tool for addressing such trade-offs. Multi-criteria decision analysis (MCDA) may be more suitable, especially where public sentiment is a key issue and opinions are mixed.

16.4 A more useful approach

Given that the role of ERE and, to a lesser degree economics in general, is not well defined and therefore less useful than it could be in EIA, what can be done to improve the situation? While there is no simple answer to this question, it is proposed that, in resolving economic issues and questions, the core concept/focus used by the environmental economist should be that of opportunity cost. This is the net benefit sacrificed by adopting one option ahead of its next best alternative. In impact assessment, a second point of reference should also be provided; the net benefit of doing nothing. Focusing on opportunity costs allows for a clear consideration of the trade-offs involved in all projects.

It is important to note that opportunity cost is a concept that, in theoretical economics anyway, need not involve prices or pecuniary values. From an impact assessment perspective too, opportunity costs can be described without reference to monetary units, although where financial values can be given, they allow a breadth of comparison that would otherwise be denied. They provide a yardstick familiar to all, and identical to that used for all other costs and benefits of projects. For this reason there is a tendency to conflate ERE practice with valuation. In this chapter it is stressed that whilst the two may overlap, they are not identical.

Although 'doing nothing' is a useful component of opportunity cost analysis, one problem with pricing and valuation exercises is that they use the status quo as a reference point. They are based on what economists call 'partial equilibrium analysis'. In other words, they ask: Assuming all other things (like income distribution, national product, climate, traffic levels, local amenity, values, etc.) stay the same, what will be the value of losses as a result of this project or policy?

The two questions one really wants to be answered are: How will the key variables in decision-making (like income distribution, national product, etc.) be affected by this project? And, is there a reasonable likelihood that, after these changes, you'll wish that the project had not gone ahead? The simplest approach is to assume all other variables constant, allow one to change, and then to predict the outcome (partial equilibrium analysis). Naturally, this misrepresents the complexity of economic interrelationships: once one recognises that a change in one variable is likely to influence the others, and that these in turn affect others, and that these may reflexively influence the first, one has entered the world of general equilibrium (GE). Unfortunately, GE is far more difficult for the economist to model, and when used at a macroeconomic level in computable general equilibrium (CGE) models, its predictive power is weakened by its use of historic intersectoral linkages. It does, however, have heuristic value and at least it purports to reflect reality.

Typically, microeconomic impacts are treated using partial equilibrium analysis, and the economic report will only offer a general equilibrium treatment if macroeconomic impacts are specified. Historically, the macroeconomic dimension was rarely specified in the economist's ToR. In recent time, however, it has been more commonly required, especially on large-scale projects (for example, the proposed zinc smelter at Richards Bay, some of the more recent SANRA toll roads and the most recent Sasolburg conversion). Typically, however, such studies have taken the form of multiplied impacts on GDP, employment, tax, income, etc. using input-output tables and not CGE models. Why should there be a need for a macroeconomic study when the project is a single, and by definition micro, issue?

In the First World, wealth and the associated levels of consumption are the key environmental problems. The environmental impact of a project or policy is consequently linked to its impacts on the public's ability to enjoy consuming the goods and services that are already theirs. Identifying and valuing project and product externalities are consequently key aspects of project appraisal. The environmental threats facing the Third World are far simpler, but also far less tractable. Poverty and population growth throw people onto the environment, not as a source of recreation, but for their very livelihood.

A consequence of this situation is that while increasing public incomes in the Third World may decrease environmental costs, increasing public incomes in developed economies might increase environmental costs. This idea (the Environmental Kuznets Curve) is not proven, but is widely argued (see discussion in Chapter 1). In South Africa there is no doubt that rapid population growth combines with unemployment to degrade the environment in rural areas and, stimulating rural-urban population flows, to stress it in urban areas. Overgrazing, shantytown growth and an environment unable to absorb the pollutants deposited in it, are symptoms of a general economic malaise. For this reason the classic partial equilibrium microeconomic approach, which attempts to offset economic gains against environmental impacts, misses a key feature of the local economy. The impacts of a project in terms of job creation, income generation and distribution, linkages to the local and regional economy, and the likelihood that it will induce further development, are key features that environmental economic appraisals should identify and describe.

There is, of course, a danger that this sort of study will degenerate into vague hand-waving and wishful thinking. To obviate this, therefore, a set of key issues that economists should identify and comment on in their reports is highlighted here. Collectively, they address the economic efficiency, equity and sustainability of projects.

- Is the project economically worthwhile? In other words, does its apparent viability result from missing or distorted markets, implicit subsidies, etc.? To determine this, a cost-benefit approach should be taken in determining whether the project will lead to net benefits for society as a whole, and which segments of society are losing and which are winning. Cost-benefit is locally[16] and internationally accepted (World Bank, United Nations, Organisation for Economic Cooperation and Development, Asian Development Bank, etc.) as the main tool in determining the economic desirability of projects. It can be used to answer the question: Does this project make economic sense, and if so, to whom? In others words, is it viable at a private level? Is it still viable after correcting for state distortions (taxes, subsidies, tariffs, etc.)? Is it still viable after correcting for market distortions (monopoly, etc.)? Is it still viable after correcting for missing markets (externalities, etc.)?[17]

Unfortunately, the availability of information is a major potential pitfall for the economist wishing to apply CBA in an EIA. The proponent may not be willing to part with sensitive financial information necessary to do cost-benefit calculations. While this may be a source of frustration for the economist, it is also understandable if the client wants to keep sensitive information out of the public realm. The EIA regulations do not stipulate that all financial information be made available. This is in contrast to, say, a development finance institution that is financing a project and can demand the financial information necessary to conduct a CBA.

If information is not forthcoming, the economist has to look for ways still to complete a satisfactory analysis that is less invasive. In the case of private projects, one way to do this is to assume that the proponents would not be undertaking a project unless they were confident of financial gain to themselves. This places the burden of proof on the proponents. Once the value of distortions has been estimated, the proponent is asked to reassess the project. A positive response suggests that the project is publicly (or economically) rather than just privately (or financially) viable. This allows the proponent to maintain confidentiality while carrying the burden of proof for viability. This is of course not ideal, as it does not allow for proper checks by the economist. It is, however, better than ignoring the issues altogether, and at least there is still the opportunity for the economist to compare the rates of return claimed by the proponent with averages for that type of project. If the project seems to rely on financial returns well in excess of the average, alarm bells should ring and explanations should be sought and scrutinised.

- A question that should be asked during scoping is whether the environmental externalities of a project seem significant enough to outweigh its net benefits feasibly. If a reasonable chance exists that they do, they should be analysed further. In the full report this might mean attaching a value to the externalities, to obtain true net benefits. Such issues tend to re-emerge in the course of an EIA. Consequently, the question should be asked again towards the end of the study. This allows for the possible extension of the CBA to include the valuation of environmental externalities; but, more important, asking it at the end means that sometimes time-consuming and resource-intensive valuation exercises can be avoided if they are found to be unnecessary. The implication for project timing is that the economic specialist study can proceed at the same time as the other specialist studies. Only once externalities have been judged significant enough to stand a chance of outweighing net benefits will it be necessary that added time be allocated to further analysis by the economist. This eventuality should be clearly stipulated and accounted for in project planning.
- If linkage effects are recognised, does the project have the potential to 'punch above its weight' in stimulating growth, income and employment in the district/region/country? For example, a CBA may show that two projects have a similar net benefit. However, this considers only direct costs and benefits and, if the linkages associated with each project are analysed, a different picture may emerge. One project may import the bulk of its inputs and then

export its outputs, while the other makes use of a variety of locally manufactured inputs and its primary outputs and waste products can be used locally to add value to other upstream industries. These upstream industries may even be encouraged to locate near the project and thus form clusters that boost the local economy.

- Will the project lead to real growth when it results in spending pattern changes, or will it merely displace spending from other areas? For example, a new shopping mall in a large city is likely, at least for the first few years of its operation, to rely on drawing shoppers away from existing malls. Only after this initial period may it come to rely more on growth in overall spending levels associated with increased income levels and population growth. If the mall is highly successful it may even result in the closure of others. Its success therefore comes at a price that should be recognised. Other projects, notably tourism projects that attract new expenditure into the country, may result in no displacement. It is also important to consider displacement effects at different scales. Displacement between local areas often does not imply displacement at a regional scale.
- Exchange rate and interest rate effects: Could the project involve 'Dutch Disease' or 'crowding out'? A large project can affect the price of capital in a small open economy. This is particularly important in underdeveloped economies. Recent developments in Maputo, for example, influenced the international exchange value of the Mozambiquan Metical. If the domestic currency's exchange rate shifts, the viability of other sectors in the economy may be affected. Similarly, large projects may soak up local funds and lead to rises in interest rates; again, the impact on other sectors could be important.
- Where a project is described as 'international', establish whether it genuinely constitutes 'foreign direct investment'. This can be done by analysing sources of funding and foreign exchange flows. For example, a project proposed by a foreign company may seem as if it constitutes foreign direct investment, while it is in fact relying on local loans for funding and actually has a high import content.

It is tempting to recommend the formulation of a minimum standard to govern the use of economics in EIAs. However, since no standard is applied to other specialist study disciplines, it would be hard to justify setting one for economics. Instead, a request could be made for fuller information about what ERE can offer. Historically, contact between practising economists and impact assessment practitioners was limited. There is clearly a case for encouraging such contact and encouraging debate among economists on the role of economics in EIAs. The objective is a common vision of the role of economics among all stakeholders.

16.5 Conclusion

This chapter commenced with a review of the current role in environmental impact assessment of economics, and environmental and resource economics in particular. Studies undertaken earlier showed that, despite a few successes, its application was patchy and not well focused. The assessment of economic impacts in general has also been characterised by an unnecessary profusion of ways in which impacts are assessed relative to other specialist studies and the difficulty in establishing consistency in terms of what is to be expected from economic specialist studies (i.e. what are the standard questions that should be addressed in all economic specialist studies).

Enhancing the application of economics in EIA is deemed expedient. Towards this end, it was suggested that the focus of economic specialist studies should be directed to analysing opportunity cost, whether quantified or not. Suggestions for specific aspects that have to be considered in economic specialist studies were also offered. These include a consideration of costs and benefits adjusted for distortions and externalities, multiplier and linkage effects, displacement effects and foreign exchange flows.

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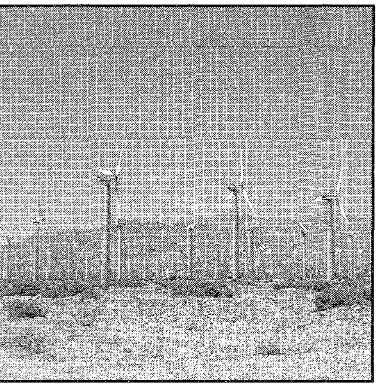
part c

interlude



South Africa stands before a window of opportunity. However, this window is at the same time a threshold between disaster and success with regard to the eradication of poverty and the application of prudent environmental and resource management. It was indicated in Part A that the various layers in the South African 'double-decker' economy are not functioning in harmony, neither do they respond similarly to policy intervention. Policies and measures to improve the welfare of the country as a whole seem to benefit only a small portion of the economy, or, alternatively, the top-deck. The policies applied during the last decade seem not to have had a significant impact on the majority of the population (the bottom-deck). This asymmetrical growth performance and response to policy measures emerge within the context of an increasing use of natural resources. The use of these resources can, and has been, quantified as was indicated by the selection of case studies in Part B. By quantifying the value and extent of resource use, it is possible to design policies and measures to internalise both negative and positive externalities. It was further indicated that these policies can be designed in such a way as to address, and redress, poverty. By doing so, it is possible to maximise social welfare for the benefit of all of the people of the country.

The question at stake now is: So what? How can the lessons that were learnt, and the suggestions and recommendations that were given, be applied in practice? How can the best use be made of the window of opportunity? This is addressed in Part C, even though only partially. In Chapter 17, the policy-making process and the intricacies surrounding the process are discussed. The chapter highlights the meaningful differences in the approaches towards socio-economic-environmental policy-making among science practitioners, civil society and policy makers. Recommendations are made towards addressing this gap. In Chapter 18, a normative development ethic, based on the principles of justice and management, is developed as a counterproposal to the current neo-liberal and neo-classical ethics based on consumption and self-interest. In conclusion, a road map is provided in Chapter 19 towards a just and sustainable economy, implying the application of sustainable options. It pleads for a notion of *JustAfrica* under the call for a prosperous, clean and green economy in which everyone participates.

CHAPTER 17

Economics, the natural environment and public policy-making

Martin de Wit

17.1 Introduction

Given the developmental and environmental challenges facing South Africa, the pertinent question remains to what extent will the case studies presented here (and many other studies that communicate a similar message) have relevance towards policy-making and address these challenges?[1] To some extent, this question underlies Chapter 16 as well, although on a more project specific level, and some recommendations were made. Important here, however, is the interaction between policy-making and the various socio-economic and environmental challenges which the country is facing.

In the socio-economic field, South Africa has embarked on a road of *redistribution through growth*, with tight fiscal and monetary discipline and prudence in government spending, coupled with programmes on meeting the basic needs of the people, i.e. jobs, land, housing, water, electricity, communications, health care and social welfare (see Chapter 1). From these case studies, it is clear that environmental and resource economics approaches and tools are relevant towards bridging the gap between the socio-economic and environmental domains. In many cases the management of natural and environmental resources and their associated challenges, such as water availability and its quality, land availability, soil quality, subsistence agriculture, indoor and outdoor air pollution, solid waste, noise pollution and even seemingly more remote problems such as climate change, cannot be detached from the basic needs and overall quality of life of people. Where these links are at first less obvious, such as in the conservation of biodiversity, the availability of minerals and the health of plantations, these resources still constitute an important part of the South African formal economy, and in the process they create income and employment for an important section of the population. Natural and environmental resources, quality of life and good economics are inseparable concepts; so are the policies governing them.[3]

One can hold the view that good analysis will bear good decision-making, but, as will be pointed out in this chapter, this will be too much of an idealistic and simplistic view. The role of economics in environmental policy-making has been a subject of study for a few decades already, and much can be learnt from previous experiences in other countries and in other disciplines. For instance, the choice between policy instruments is more complex than was initially thought, and aspects such as different values of interest groups, socio-cultural issues and geographic locations have to be included. It will also be argued that policy development and implementation processes mostly cannot be viewed as a rational, linear process, but one that it is often dependent on key individuals and the strength of their networks, the power dynamics within and outside government and the prevailing policy discourse.[4]

In this chapter the responses are analysed that have been and can be provoked by economic policy recommendations on environmental policy, using mostly the wealth of experience gained in the United States. This will be the focus of Section 17.2. In Section 17.3 a short review will be presented on alternative normative and positive economic approaches to environmental policy-making. This section will demonstrate the complexity in the political choice of policy instruments. Section 17.4 will provide an overview of theories and approaches that highlight the complexity in the process of policy-making. A few suggestions on how to improve the policy relevance of an economic approach to socio-economic and environmental challenges in South Africa are presented in Sections 17.5 and 17.6. Section 17.7 concludes.

17.2 Economics and environmental policy: Learning from previous experiences

The environmental economics viewpoint of environmental problems is one where markets fail to internalise the costs of degradation, depletion, pollution and waste, largely due to economic agents having free access to natural and environmental resources. The resulting policy prescription is to define property rights and to correct prices through environmental taxes.[5] Despite the fact that this perspective on environmental regulation was well embedded in academic literature and textbooks by the time amendments to the Clean Air and Water Acts were considered in the United States, it was completely ignored. The question why this happened intrigued prominent environmental economist Wallace Oates and led to the publication of a short article entitled *Forty Years in an Emerging Field. Economics and Environmental Policy in Retrospect.*[6] Oates furnished three reasons why this mismatch between environmental economics theory and policy-making initially occurred in the United States.

First, he stated that the economist's view and ensuing policy proposals had no constituency for whom it had much of an appeal. Environmentalists rejected the proposal on the basis that putting a price on the environment is morally repugnant and, that the proposal would not work as polluters would simply pay the tax and keep on polluting. Industry did not like the idea of new taxes and it had vested interests in the existence of command-and-control regulations that provided barriers to entry for new firms. The authorities were not enthusiastic either since they did not want to abandon traditional methods of command-and-control for an untested system of taxes on pollution. In short, there was no one to champion the economic approach to environmental policy.

A second reason was that only very few economists at that time were working on bridging the gap between theory and policy design. Very little guidance was given on the actual design and implementation of a system of environmental taxes.

A third explanation was what Oates calls 'the pervasive ignorance of the economic approach to environmental policy outside the economics profession itself'.[7] Very few individuals in the environmental policy-making community understood what this proposal entailed and how radical this alternative really was.

The situation has changed since the formative years of the discipline in the United States. Other policy instruments such as tradable permits have become more widely accepted, as they combine the economic efficiency of market allocations with a restriction on the extent of pollution, the so-called cap-and-trade options. Environmentalists and authorities have turned out to be more sympathetic to this instrument, as environmental objectives can be achieved by restricting the numbers of permits. Industry also proved to be more receptive to the idea, as it gains an asset to validate its own emissions or sell to others. Environmental programmes are now subject to cost-benefit analysis (despite its obvious weaknesses[8]), and agreements have been made on how to estimate the total economic value (TEV) of environmental goods and services[9] (see Chapters 3 and 4). As Oates points out, despite an initial difficult start, economic approaches to environmental policy are taking hold, but much is still left to accomplish.[10] Important for this book is whether any insights can be gained in the South African setting so as not to duplicate those shortcomings, while at the same time being sensitive to the unique South African developing country context.

17.3 Political choice of policy instruments[11]

At the same time that the lack of influence by economic approaches to environmental policy-making was sensed, the way in which economists perceived the choice of political instruments and the lack of theory on the public policy process itself came under scrutiny. In an overview of environmental policy instruments (see Table 3.3 in Chapter 3), it can be concluded that most of the *economic* instruments are price-based solutions, with the exception of property rights allocation, market creation and negligence-based liability rules. Quantity-based instruments are all command-and-control instruments, such as performance standards or technology standards. A marketable permit system is a hybrid between the two, as standards are set within which the market can operate.[12] The debate on the application of using a price or quantity-based approach has moved to a search for an optimal mix of instruments, given certain normative criteria such as economic efficiency, social equity and environmental sustainability.[13] This research, although valuable in demonstrating trade-offs between alternative policy mixes, will not answer the question *how* the interaction between economic approaches and environmental policy-making actually happens.

In reality, policy instruments are not chosen simply on their relative scores to certain normative criteria; instead, they are chosen because of interactions between interest groups, socio-cultural circumstances and the geographic distribution of costs and benefits. The majority of the research projects within this positive, as opposed to normative,[14] economic approach to policy-making have continued to focus on an analysis of the behaviour of the interest groups, but taking a much broader perspective, ranging from a process of cooperation[15] to a rent-seeking contest.[16] In a seminal study, Hahn concluded that the 'design of systems that make sense and fall within the realm of feasibility requires an understanding of political institutions, political forces, economics and science'.[17] The geographical distribution is especially important when the costs of improvements in environmental quality are concentrated but the benefits are widely dispersed, such as in the case of global warming. Environmental policy can be designed in such a way that representatives of regions that experience strong negative impacts can have the opportunity to leverage their opposition to such proposals for environmental policy-making. The set of acceptable environmental policies is also influenced by public perceptions of its acceptability, which are in turn influenced by the culture of society.

These developments in the literature of public policy-making and as an application to environmental issues will provide a much more varied and rich analysis of real world political processes. It does not exclude normative approaches, but rather complements these approaches by providing a better understanding of the context in which choices on political instruments are made.[18] In reality, such a political choice on policy instruments is influenced by many different events. The question remains what these events are and how they can best be planned for and leveraged – the topic of the next section.

17.4 The process of policy-making

One can be forgiven for assuming that those economic sub-disciplines which are concerned with processional realities, such as institutional and evolutionary economics (see Chapter 3 for a discussion), might have some answers. However, the question whether the evolutionary approach has anything to add to policy-making would be a possible criterion for success.[19] Evolutionary economists differ in their perception of the need and impact of policy. Some earlier institutional economists, for example, often resorted to a description of historical processes, with no attempt to change the current status quo through targeted policy-making, a position that has attracted its fair share of criticism.[20] Some progress has been made, however. It appears that, at least at this stage of development, the evolutionary approach can give some guidance on policy design principles, such as including flexibility and leaving room for novelty, but that any tangible and practical insights on understanding policy processes themselves are still outstanding. The amount of literature on an evolutionary or co-evolutionary approach to environmental policy is relatively meagre and inconclusive. This is not surprising, as the evolutionary approach to economic policy is a relatively new field with many different strands of thinking.[21]

Various attempts outside the traditional economic literature have been made at constructing policy process models. The logic of defining a policy process model lies in the fact that one will then be able to understand, predict and manage the impact of scientific inputs, and, more specific, economic inputs in such processes. In broad terms, two distinct policy process models can be defined, namely the linear model and a systems approach.[22] With respect to the former, following the work of March and Simon,[23] it is assumed that policy-making follows a linear and one-dimensional three-stage process of intelligence, design and choice. In the first stage, problems are identified and data collected, the design phase consists of planning for possible alternative solutions, and the choice phase entails the selection of an alternative and the monitoring of its implementation. The alternative is to view the policy process and the influence of science in this process as a dynamic nexus, where the policy process *co-evolves with the problem situation.*[24] In this case, the focus shifts from following a pre-defined process to one where the unique elements or components of a co-evolutionary policy process are emphasised – with different models emphasising different elements in the process.

In a recent publication[25] entitled *Understanding Environmental Policy Processes: Cases from Africa*, the authors do not mention the systems approach explicitly, but refer to additional approaches over and above the linear model, namely:[26] 'understanding policy processes means understanding the interaction of networks and relationships, agency and practice, and knowledge and power dynamics in particular contexts'. This is a useful framework, and is used for further discussion.

An analysis of the interaction of groups, networks and relationships can occur at different levels. First, on a macro-level, such as followed in political economic and political science analysis, the processes of interaction, bargaining and coalition-forming paint an aggregate picture of the broader trends shaping the political landscape of a particular country or region.[27] However, this approach is not useful to understand *how* science will influence this process as it is assumed that research is applied directly in the policy-making process.[28] Secondly, on a more micro-level, policy network models explain *how* actors affect policy change. Such models are rooted in pluralistic approaches to public policy, emphasising that the processes of interaction, bargaining and coalition-forming will all have interests reflected and conflicts resolved.[29] In such approaches, it is theoretised that an understanding of how networks are formed and are operating enhances the likelihood that policy will be influenced.

An alternative approach is to move towards an understanding of *agency and practice* – focusing on the question why certain subjects and alternatives are considered for the policy agenda while others are not.[30] The focus is on certain individuals or champions in the government apparatus who push policies through the mobilisation of knowledge and expertise. Such policy entrepreneurs, as they are often called, will act when the political return on investment is lucrative enough, whether in terms of securing their part in the formulation of policy, being part of a participation process, or for more personalised reasons such as job security and career advancement. Policy entrepreneurs should at least have a level of expertise, have the ability to speak for others in an honest way, sit in an authoritative decision-making position, have good political connections and negotiating skills and be very persistent. When an overlap exists between certain problems facing the country, when science can provide a solution and when the politics is right, policy entrepreneurs can play a vital role in pushing scientific inputs to the policy agenda.

The last overall approach gives explicit attention to *knowledge and power dynamics* through policy discourse.[31] The way in which issues are highlighted will have important implications for what views are considered important or not, and not to whom. Support for political problems can be gained by framing it in the *neutral language of science*,[32] which may help to explain perceptions of policy makers and researchers about the role of research in informing public policy. Not a separate approach, but one that can be employed in all of the above, is to transfer knowledge about policy processes gained in one place and time to another place and time. The general rule is that the simpler these policies are (single goals, direct relationship between the problem and the solution, fewer perceived side-effects, availability of information and predicted outcomes), the more prone to transfer. Knowledge of science-policy interactions in one area can therefore inform a process somewhere else.

The role of science in these policy process models warrants some attention. Like political processes, scientific processes can also be dynamic and complex. It cannot be safely assumed that science will have its facts ready when the policy process demands it. The idea of policy-making where science provides the facts and policy makers will use this information for the development and implementation of policy options, is, although the dominant view, not very suitable to understanding the science-policy interaction. Science in itself is also practised in the context of organisational values and the individual researchers' world-views. Although one can debate the extent to which this impacts on the scientific process itself, it is certain that scientific agendas and policy positions are informed by certain strands of research at different points in time and space. The politics of science becomes important: who the authorities are, which policy issues should warrant scientific deliberation and which not, why non-scientists should engage in debates on scientific issues, and what the requirements and preconceptions of the funders are. Those that argue that the scientific process in itself is neat and tidy will have to answer the questions of how uncertainties are dealt with in this process, how facts are often created falsely by closing controversies, and why the drive for universal applicability will ignite pressure to accept certain procedures, measurements, classifications and modelling routines. These actions all push alternative valid viewpoints to the periphery of scientific debate.[33]

International evidence on policy processes and the role of science in these processes is emerging already, but the general conclusion is that there are no standard approaches, especially to more complex environmental problems. Every case has its own characteristics, different kinds of people steering policy processes and different cultures of science. An interesting observation made in a review of soil management processes in Ethiopia, Mali and Zimbabwe, was that in these countries, development paradigms are often shaped by science-led, managerial, instrumental and interventionist approaches.[34] This does not automatically lead to the extreme conclusion that science should be replaced by participative approaches alone, but rather that science is an actor in the policy process and should be advised to act on its perceived elitism by including local knowledge and expertise.

17.5) Policy researchers and policy makers: Shall the twain ever meet?

Apart from highlighting some of the analytical attempts to model interactions between research and policy-making, as was done in the previous section, it should be mentioned that economists and policy makers have divergent objectives and values. It will therefore be wise to follow some guidelines on how to increase utilisation of economic approaches on (environmental) policy-making when these groups communicate and interact with each other.[35] In general, the following divergent views are held:[36]

- Policy makers tend to emphasise distributional concerns; economists emphasise efficiency.
- Policy makers tend to define goals in (sometimes arbitrary) quantitative terms; economists in financial terms.
- Policy makers assess costs and benefits in terms of numbers of people affected; economists in financial terms.
- Policy makers tend to assess performance in terms of inputs rather than outputs (percentage of land set aside for conservation or numbers of hospitals built rather than improvements in biodiversity or human health).
- Policy makers weigh losses more heavily than gains.[37]
- Policy makers emphasise the sunk costs of a project while economists emphasise the future costs.[38]
- Policy makers do not usually pay attention to opportunity costs, as projects and plans are assessed in their own right. Alternatives will often fall outside the control of the decision maker.
- Policy makers will place emphasis on the actual compensation of losers, while economists will be satisfied if losers can be compensated in theory.
- Policy makers tend to favour legal and regulatory instruments; economists emphasise incentive-based mechanisms.

These divergences are surmountable and can be dealt with by being sensitive to the policy maker's needs without compromising on the content of economic approaches to certain issues, such as environmental policy-making. For example, specific attention should be paid to distributional impacts of projects, plans or policies where possible, especially in developing countries such as South Africa, where the upliftment of the poor is a priority. These and other issues mentioned dominate the way in which policy networks are formed and sustained, how interactions are shaped with policy entrepreneurs and how the discourse of policy is formed. In all these cases, it is individuals or groups of individuals who have the daunting task of communicating between two groups with very divergent objectives and values. A broader vision of improved social and environmental conditions will have to be shared by policy makers and researchers alike, strong enough to counter any challenges on the way.

17.6 Improving the policy relevance of economic approaches to environmental problems in South Africa

Given the insights from previous experiences, the literature on policy processes and the divergent objectives and values of economists and policy makers, the question remains how the policy relevance of economic approaches to environmental problems can be improved. Given the experience from the United States, some problems can be mitigated and others will be more challenging to do so. The science and application of environmental resource economics are much further developed now than 40 years ago, especially on designing successful environmental tax systems and tradable permit schemes. The challenge will be to apply these results in the context of a developing country with, often, inadequate institutional frameworks and the reality of 'double-decker' economies, as discussed in Chapter 1.[39] Command and control systems are placing significant pressure on government administrations. Given the recent development of several Acts and White Papers in the field of environmental management that leave the door open for the use of economic instruments,[40] an opportunity exists to start applying economic approaches in the design of policy instruments for, among others, the use and quality of water, the use of energy, side-effects caused by pollution and waste and the conservation of specific areas of high biodioversity. An area of concern parallel to that in the US 40 years ago is the few economists working in this field and their limited impact on policy-making processes. Substantial efforts should be poured into the development of a national competency in using economic approaches to environmental management in the country, supported by nationally accredited natural resource accounts. It should be clear that, if environmental and resource economics applications would have to make an impact on the management of natural resources and on the quality of life of the people of this country, the focus should extend beyond good analysis alone. In short, the country is in need of environmentally benign development success stories with high social and political visibility.

Universities are teaching, and advancing on, the theoretical approaches as developed in the science of environmental and resource economics. Other more applied research organisations and private consultants apply these theories and tools to specific problems as defined by their clients, mostly government, business and donors. The interaction with policy processes is usually sporadic and ad hoc, often spearheaded by individual connections and larger environmental policy processes such as inputs to draft bills and presentations to portfolio committees. This means that an understanding of the underlying dynamics, and thus the levers for effectively improving interaction, is largely non-existent.

Another issue would be to gain an understanding of the likely political choice of instruments for environmental management. An analysis of interest groups and their objectives will greatly enhance the ability to focus on specific areas where economic approaches to environmental problems can be used fruitfully in the policy process. This will mean that such approaches in South Africa will have to move beyond a traditional focus on normative approaches alone such as cost-benefit analyses and the use of environmental impact assessments, as was discussed in the preceding chapter. An understanding of the players and political relationships regarding natural resources, especially in relation to the acceptability of economic approaches to environmental management, is therefore necessary. On the micro-level, it should be understood how interaction, bargaining and coalition-forming is taking place in policy-making for natural resources – how actors impact on policy change and what the role of science is in these processes. A specific course of action is to identify specific policy entrepreneurs to place a combination of socio-economic and environmental issues on the policy agenda. In all these cases, it is important that the correct messages are sent out to shape the political discourse on environmental and resource economics and what it aims to achieve. Policy makers and economists have divergent objectives and values, and weak communication processes could provide much harm to an otherwise promising partnership.

17.7 Conclusion

In this chapter some insights into understanding and managing an effective use of environmental and resource economic study results were presented in response to the socio-economic and environmental challenges facing South Africa. These were drawn from previous experiences in the United States and an acknowledgement of the political choice of policy instruments and the complexities of policy processes on a micro-level. It is concluded that there is no single model able to interpret policy processes and the overall role played by science in these, at least not on the scale that is relevant to manage how such processes work. Macro political economic or political science models will give a sense of the broader direction in natural resource and quality of life issues, but lack explanations where, when and how science and policy must interact to increase their impact. Various political models have been presented that give some tools to analyse these processes of interaction, focused on actors, networks and relationships, agency and practice and policy discourse. An attempt was made to identify the key factors that need attention to increase relevance of economic approaches to environmental problems in South Africa. These factors have to be broken down into specific focus areas, and empirical work is required, as science-policy interactions are highly case specific.

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13 For further discussions on the prices vs. quantity debate the reader is referred to: Baumol, W.J. and Oates, W.E. 1971. The use of standards and prices for protection of the environment. *Swedish Journal of Economics*, 73:42-54; Baumol, W.J. and Oates, W.E. 1988. *The Theory of Environmental Policy.* Second edition. Cambridge, UK: Cambridge University Press; Bohm, P. and Russell, C.S. 1985. Comparative analysis of alternative policy instruments. In: Kneese, A.V. and Sweeney, J.L. (eds.). *Handbook of Natural Resource and Energy Economics, Volume I.* North-Holland: Elsevier, pp. 395-460; Pizer, W.A. 1996. *Optimal Choice of Policy Instrument and Stringency Under Uncertainty: The Case of Climate Change.* Resources for the Future (RFF) discussion paper 97-17. Washington, DC:RFF; Pizer, W.A. 1997. *Prices vs. Quantities Revisited: The Case of Climate Change.* Resources for the Future (RFF) discussion paper 98-02. Washington, DC: RFF; Shrestha, R.K. 1998. Research note. Uncertainty and the choice of policy instruments. A note on Baumol and Oates propositions. *Environmental and Resource Economics*, 12:497-505.

14 The normative economic approach to environmental policy-making compares the outcome of policy to a pre-defined norm, such as economic efficiency, equity or sustainability. The positive approach to environmental policy-making asks the questions why a certain policy has been followed in the first place, which can only be answered with an analysis of the real-world political process itself. See Segerson, K. 1996. Issues in the choice of environmental policy instruments. In Braden, J.H., Folmer, H. and Ulen, T.S. (eds.). *Environmental Policy with Political and Economic Integration. The European Union and the United States.* Cheltenham: Edward Elgar.

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17 Hahn, R.W. 1989. *A Primer on Environmental Policy Design. Fundamentals of Pure and Applied Economics.* Government Ownership and Regulation of Economic Activity Section, vol. 34. Chur: Harwood, p. 114.

18 Hahn, R.W. 1989. *A Primer on Environmental Policy Design. Fundamentals of Pure and Applied Economics.* Government Ownership and Regulation of Economic Activity Section, vol. 34. Chur: Harwood.

19 Schwefel, P. 1993. Round table discussion. In: Day, R.H. and Chen, P. (eds.). *Non-linear Dynamics and Evolutionary Economics.* Oxford: Oxford University Press.

20 In a sense this is Buchanan's critique on the institutional school (a subset of the evolutionary approach): 'The institutionalists were broadly on target in many of their criticisms of orthodoxy,

but their whole effort was largely wasted because of their scorn of theory, of analysis. Their methodological naiveté caused them to think that observation and description somehow automatically give rise to predictive theories, to hypothesis, when in fact, we now know that almost the reverse holds' (Buchanan, J.M. 1968. An economist's approach to 'scientific politics'. In: Parsons, M. (ed.). Perspectives in the Study of Politics. Chicago: Rand-McNally).

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23 March, J.G. and Simon, H.A. 1958. *Organizations.* New York: John Wiley and Sons; Simon, H.A. 1977. *The New Science of Management Decision.* Revised edition. Englewood Cliffs, NJ: Prentice-Hall. See also the work of Thomas and Grindle on 12 case studies in developing countries where a similar linear process in the implementation of policy reforms, following the stages of agenda setting, decision and implementation was followed (Thomas, J.W. and Grindle, M. 1990. After the decision: Implementing policy reforms in developing countries. *World Development,* 18(8):1163-81).

24 De Greene, K. 1993. *A Systems-based Approach to Policy Making.* Boston: Kluwer.

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26 Keeley, J. and Scoones, I. 2003. *Understanding Environmental Policy Processes: Cases from Africa.* London: Earthscan, pp. 4-5.

27 For an example see Reed, D. and de Wit, M.P. 2003. *Towards a Just South Africa. The Political Economy of Natural Resource Wealth.* Cape Town: Naspers.

28 Nielson, S. 2001. IDRC-*Supported Research and its Influence on Public Policy. Knowledge Utilization and the Public Policy Processes: A Literature Review.* Unpublished, International Development Research Centre (IDRC), p. 20.

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31 A discourse can be defined as an *extended verbal expression in speech or writing* (See Lewis, A. 2002. *WordWeb 2.0,* Freeware Version. Princeton University).

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35 Glover, D. 1993. Policy researchers and policy makers: Never shall the twain meet? www.eepsea.org/publications/spaper/David.htm (accessed 6 September 2000).

36 Glover, D. 1993. Policy researchers and policy makers: Never shall the twain meet? www.eepsea.org/publications/spaper/David.htm (accessed 6 September 2000), pp. 3-4.

37 'A policy that hurts five people and helps five, produces five enemies and five ingrates' (Verdier, J. 1984. Advising Congressional decision makers: Guidelines for economists. *Journal of Policy Analysis and Management,* 3(3):421-8, as quoted in Glover, D. 1993. Policy researchers and policy makers: Never shall the twain meet? www.eepsea.org/publications/spaper/David.htm (accessed 6 September 2000), p. 3.)

38 See Behn, R.D. 1981. Policy analysis and policy politics. *Policy Analysis*, Spring, 7(2):199-266, as quoted in Glover, D. 1993. Policy researchers and policy makers: never shall the twain meet? www.eepsea.org/publications/spaper/David.htm (accessed 6 September 2000), p. 4.

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CHAPTER 18

Towards an economic development ethic

James Blignaut

18.1 Ideology revisted

In Chapter 2 it was contended that the world is possessed by an ideology of growth to the extent that growth in itself has become the ultimate objective. While this contention has profound implications on the construction of a comprehensive ethic for economic development, it justifies a revisit.

In distinguishing between ethics and economics, Wogaman[1] states that it is important to distinguish between intrinsic and instrumental values. An intrinsic value is something that is good in itself and requires no further justification. Examples would be friendship, justice, music, etc. An instrumental value, on the other hand, is something that is good because it contributes to the fulfilment of an intrinsic value. In other words, it is an instrument in the realisation of an intrinsic value, or an enabler. Examples of instrumental values would be political power, owning a hi-fi, etc. Having said that does not imply that instrumental values are not important; they could be essential to the realisation of intrinsic values, so these instrumental values are to be taken seriously. The fact remains, though, that they are means to an end and not an end themselves.

In most cases economics has to do with instrumental values, i.e. commodities. These commodities are supposed to serve an intrinsic value, a greater good.

Modern economics is driven by neo-classical economics, and the main premise thereof is the maximisation of individual utility, i.e. consumption, through the pursuit of self-interest. Consumption is therefore the intrinsic value, whereas the instrumental value is individual self-interest. Storkey[2] identifies the origin of this change-over from classical economic thought to neo-classical economics during the early 1800s as a result of the work done by Jevons, Menger and Walras. The classic outlook focused on the cause-effect relationship between production and consumption. With the emphasis on production, the production factors of land, labour and capital were valued in terms of their intrinsic properties and what they could contribute. The shift to neo-classical economics implies a change in the cause-effect relationship from consumption to production. Consumer choices and preferences, i.e. people's desires, are now the determining factor (the end) and production methods and volumes have to adapt to these. Consequently, the concept of value has also changed and the value of the production factors becomes equivalent to the market price of the goods or service (see the discussion on value in Chapter 3). Under this system, prices, i.e. market values, determine the value of labour and human services. This paradigm change from classical to neo-classical economics has had a serious impact on human dignity and the concept of work *per se*.

As is seen above, consumption is the intrinsic value, the value that finds justification in itself. The argument of consumption as highest good has been further developed by the work done by Mill, Bentham and Pareto in the construction of what has become known as welfare economics. There is, however, an important implication to the ideology of consumption should one link consumption, intrinsic values and a specific world-view, namely:

> Our accumulation and use of possessions and commodities effectively become symbols of our world-view. This is crucial in that it raises the question whether possessions are evil per se, whether they can become evil once a degree of wealth is achieved, or whether their moral legitimacy is contingent not so much on their monetary value or status value, but on the power exercised by them over those who acquire them and signals emanating from them to those around us.[3]

Since consumption acts as intrinsic value, consumption gains control over the person who consumes and it directs and manipulates the thoughts and thought processes of such a person. Consumption has become the greater good, and those serving consumption the slaves.[4]

The proponents of neo-classical economics would deny this contention since they argue that neo-classical economics is value free and morally neutral. Friedman states:

> Normative economics is speculative and personal, a matter of values and preferences that are beyond science. Economics as science, as a tool for understanding and prediction, must be based solely on positive economics which is in principle independent of any particular ethical position or normative judgements.[5]

Should one literally apply Friedman's definition of economics as a science, it would imply that an economist should be a hedonist who can calculate but not think. It is under these circumstances that the efficiency criteria (calculation) gain supremacy above other values such as fairness, obligation, prudence, honesty, loyalty, expediency, feasibility, cost-effectiveness and practicability.[6] The efficiency rule is therefore elevated, but does this mean that neo-classical economics is value free? How value free could neo-classical economics be if its central values are consumption, personal satisfaction, self-interest, competition, etc.? Intrinsic to the efficiency criteria lies a value judgement concerning being efficient pertaining to the choices: for whom, why and how. Value-free neo-classical economics is therefore an illusion only possible in theory and in textbooks, but not in practice, and hence inappropriate to describe and explain human behaviour. The fact is that neo-classical economics is very powerful and the values upon which it is built give rise to the need for an engine, a dogma or a force to drive itself forward in an unrelenting manner. This dogma or ideology is called welfare maximisation on an individual level or economic growth on the macroeconomic level. It is this ideology that will be responsible for the allocation of resources in an effort to wipe out scarcity. McFague[7] describes this system as follows:

> In sum, the world-view and basic assumptions of neo-classical economics is surprisingly simple and straight forward: the crucial assumption is that human beings are self-interested individuals who, acting on this basis, will create a syndicate or machine, even a global one, capable of benefiting all eventually. Hence, as long as the economy grows, all individuals in a society will sooner or later participate in prosperity.

McFague also remarks that the neo-classical anthropology (i.e. individual gratification through consumerism) and world-view of continual growth would not have been such a serious issue if it was but one of many competing ideologies. The problem is that it is currently by far the dominant one, at least for the West.[8]

18.2 A critique of the ideology of growth

Is neo-classical economics driven by its ideology of growth (with its ethic of individual self-interest-based consumerism) adequate and appropriate to solving the economic, social and environmental crisis of this century? Surely not. A number of reasons can be mentioned:

- Economics should deal with instrumental values, not intrinsic values, otherwise economic objectives become ends in themselves rather than means to an end.
- Neo-classical economics superimposed itself above other realms of human activity by ascribing to itself an intrinsic value, which implies the economic colonialisation of other spheres of existence.[9]
- Markets and market decisions have become the moral standard based on the efficiency rule only.
- Social priorities are weighed in terms of their market values and not evaluated through an appropriate system of justice and morals.
- The anthropology of consumerism has led to the dehumanisation of humankind.

- The concept of value has become completely distorted as a result of mixing intrinsic and instrumental values.
- Consumerism does not know an end, or point of saturation – this leads to a Hegelian dialectic false infinity, i.e. the more goods and services you have, the more you want to have, implying that the problem of scarcity would not be solved through a notion of consumerism.
- Neo-classical economics is a linear model that considers no constraint as absolute.
- 'It' has led to an imbalance of power and a hidden ruling class.[10]
- Subsequent to the belief in unconditioned progress according to the linear model, all environmental quality and quantity changes are treated through the *ceteris paribus* assumption, perpetuating the notion of unlimited abundance, while the focus of the theory is increased consumption to solve the scarcity problem. An inherent dialectic is therefore embedded in the theory.

Just in case the reasons provided are not enough to be convincing, one can also discuss the consequences of the application of neo-classical economics and ask whether it is an appropriate system. Two examples will be highlighted in an effort to answer this. The current environmental problems that this generation are facing globally, such as global climate change, are a direct consequence of anthropocentric behaviour based on a neo-classical and neo-liberal economic frame of mind.[11] This problem, and many others also caused by this mindset, cannot be solved by the mindset that created them.

The second example relates to poverty and the increasingly skew distribution of income and seemingly scarce resources. Since this is an acute problem within a developing context, it is worth our while to deliberate this issue in more detail. Conventionally a large array of explanations are given for the increase in global poverty. A non-exclusive list of reasons for the existence of poverty in a country would entail:[12]

- lack of natural resources;
- overpopulation, based on the Malthusian theory that populations would grow faster than food supply;
- lack of infrastructure;

- the communication barrier (not being able to communicate because of language differences);
- lack of sophisticated technology;
- too rapid, uncontrolled and unplanned urbanisation;
- land degradation and deforestation;
- totalitarian political systems;
- mercantilist or socialist economic systems;
- tribalism;
- acts of nature; and
- colonialism.

The question is whether these reasons, either independently or in combination, provide a satisfactory explanation of the prevalence of poverty across developing nations in particular. The answer to this question must be no, since there are examples of exceptions to each one of these listed reasons. This does not imply that these reasons do no contribute, and even accelerate, the prevalence of poverty, but they are not sufficient in themselves to explain it.

Should one look at the issue of resource availability, for example, one sees that Zambia, Zimbabwe and the Democratic Republic of Congo combined have enough fertile farmland and other resources such as water to provide food for the entire Africa, but their peoples are faced with starvation. On the other hand, Japan has a higher ratio of population density to natural resources than these (and many other poor) countries, and is not poor. With regard to the issue of colonialism, one sees that wealthy countries such as Switzerland, Sweden and Denmark never had colonies through which they could enrich themselves. However, former colonies such as Hong Kong, Australia, Canada and the United States, are currently wealthy. On the other hand, countries such as Ethiopia, Thailand, Liberia and Afghanistan were never colonies, but are poor.

So the question is: What would be the actual reason for the prevalence of poverty? The answer lies in the unfettered application of global neo-classical economics within the prevailing culture and world-view of the respective countries. All the reasons listed above are external to economic and social systems. The reasons upheld here are intrinsic to the economic and social system. As long as the current application of global neo-classical economics, also called neo-liberal economics in its form of neo-colonialism or multi-national advanced capitalism[13] and the prevailing mindset or culture of both the developed and the developing world persists, so long will poverty persist and be exaggerated in its interaction with the items listed above. Why the focus on an economic and social system? Simply because they are so interlinked, as is clearly indicated here:

> Economic development, or any kind of economic change, does not occur in isolation, but is part of a much larger and more general cultural transformation ... In other words, economy and culture are dynamically interrelated; economic development will both influence and be influenced by other aspects of culture.[14]

18.3 World-view defined

The remainder of this chapter is dedicated to the development of an economic development ethic that would be internally consistent and that attempts to redress the current social, economic and environmental problems. First, one should reconsider what such an ethic must entail by defining it.

A world-view can be defined as a set of assumptions which each person holds individually (consciously or unconsciously) about the basic makeup of the world and how the world works. An all-encompassing world-view would imply addressing four philosophical areas simultaneously, namely:

- The metaphysical: Addressing issues that are beyond the physical, such as: *Who am I? Is there a God?*, etc.
- Ethics: rules of human conduct, answering the question: *Is it good or bad?*
- Logic: rules of correct reasoning, answering the question: *Is it right or wrong?*
- Epistemology: scientific knowledge, answering the question: *Is it objectively testable or not?*

Positivist economics, and for that matter all other positivist sciences, is limited to the realms of logic and epistemology. This results in a reductionist approach when it comes to defining a world-view and ignoring the question whether the outcome or result of the approach is good or bad; it only addresses the issue indirectly. It is assumed that the research is conducted according to the value-free principles of logic and epistemology, and then the outcome would be desired and hence good. As is indicated above, this is a fallacy and will inevitably lead to disasters and wrong decisions, decisions of which the outcome would be bad, i.e. unethical, rather than good.

It is not the intention to construct an all-encompassing world and life view here. That would imply addressing all four areas as indicated above. In such a case various relational issues should have been addressed, for example:

- relationship: human and God, or theology;
- relationship: human and self, or psychology;
- relationship: human and human, or sociology;
- relationship: human and nature, or ecology;
- relationship: human and knowledge, or epistemology;
- relationship: human and work, or kinesiology; and
- relationship: human and time, or historiology.

The focus of this chapter is an economic development ethic. In order words, what would the moral parameters be to determine whether development is good or bad? In constructing an economic development ethic, one should take cognisance of the role of ideas or thoughts, as they have implications. A person's world-view and hence one's ethic are heavily influenced by the way he or she thinks. It is an internal matter. It is ideas that either liberate or imprison. The problem of not thinking or not allowing ideas, also ideas about ethics, to surface into one's mind, is that one becomes a slave and prisoner of another person's ideas and systems that one might not even support. It is therefore important that any development ethic should aim at stimulating ideas while generating new ideas in itself, and hence endeavour to liberate a situation or condition that might be persistent as a result of a ruling ethic. While being an internal matter, a development ethic should meet the following criteria:[15]

- Reason: It should be internally consistent and reasonable.
- Reality: Does the ethic make any sense, i.e. does it match reality?

- Breadth: Does it encompass all of reality?
- Practice: Can one apply it?
- Transcends culture: Does it apply to all since truth is truth, no matter where it is found?
- Enhancer of culture: Does it liberate and foster progress?

18.4 An economic development ethic

18.4.1 Introduction

Some would argue that it is unethical to restrict the market by introducing moral guidelines, since the outcome of the market process would be moral by definition.[16] The moral solution to all economics-related aspects would be to extend the boundaries of private property rights to be all-encompassing.[17] This view therefore supports the commodification of all public goods,[18] which is a prerequisite for consumerism. Human needs, however, are much broader, and include aspects such as subsistence, protection, affection, understanding, participation, recreation or leisure, procreation, identity and freedom.[19] Commodification is therefore in stark contrast with the views of Kant and Habermas regarding the presence of a context-relevant common moral denominator, which finds its expression in equality or human rights,[20] since consumerism is biased towards inequality and marginalisation of the weak in favour of the progress and self-interest of the strong. Monod,[21] the 1965 Nobel laureate for physiology and/or medicine writes, however:

> ... one of the fundamental characteristics common to all living beings without exception is that of being objects endowed with a purpose or project, which at the same time they exhibit in their structure and carry out in their performance ... we shall call this teleonomy.

Based on the mentioned Kantian principle, the common moral denominator (ethics) should provide guidance to all living beings on how to operate collectively to enable them to achieve their respective purposes. Ethics should therefore provide the moral framework within which all the relationships mentioned above could be exercised in harmony, or with equality in rights. The primary intrinsic value that would achieve this harmony between the various cosmic objects is justice. Justice would be achieved through proper and appropriate management; hence management becomes the instrumental value.

18.4.2 Justice

Should one consider the set of relationships above, one would be able to express them all, one way or other, in terms of the justice/management framework. This framework also passes the criteria posed above of reason, reality, breadth, practice, transcendence and being an enabling force. Much has been written with regard to justice. Arguably, one of the most notable is the work of Rawls[22] who proposes two principles:

First principle: Each person is to have an equal right to the most extensive basic liberty with a similar liberty for others.

This principle is based on the anthropological viewpoint that human beings are all fundamentally equal and have equal intrinsic human rights, or as one commentator puts it:[23] *People shall be treated equally because they are fundamentally equal.* This principle implies that everybody, irrespective of colour, race, gender or religion, has a fundamental right of access to resources needed to satisfy all basic human rights. This includes future generations, since they should be considered equal to the current generation. No negative discrimination with regard to access to resources can therefore be allowed, and no greater social or economic advantages can compensate or replace this first principle of equality of access to resources for development. One therefore cannot justify current misbehaviour in whatever way; wrong is wrong. Equality among humans, however, does not imply uniformity. Diversity and uniqueness among all should be appreciated and respected in an equal way.

Second principle: Social and economic inequalities are to be arranged so that they are both: a) reasonably expected to be to everyone's advantage; and b) attached to positions and offices open to all.

The adaptation of this principle attempts to make provision for economic and social inequalities in society. It applies to the way in which income and wealth are distributed, and pertains to those who are involved in the generation, procession (adding value) and distribution of products and services. According to this principle, unequal treatment is permissible on two grounds, namely as a result of obtained rights and merits. Obtained rights refer, amongst others, to the right of ownership of a resource. It is argued that a person has a right to be compensated for the creation, compilation and distribution of a resource. Such compensation will contribute to the stimulation of future resource development and creativity (regarding the creation of knowledge). This right is subject to the first principle, which implies equal access to resources necessary to satisfy all basic human rights. Merit, as a ground for unequal treatment, recognises that an individual must be compensated according to the work that has been done. This implies a distribution according to outcomes.

There are, however, certain prerequisites regarding these permissible inequalities in the basic structure of a society. Firstly, it must be to the benefit of all. Rawls[24] emphasises this by stating that inequality is only permissible when each person can benefit from it. Inequalities that are not to society's benefit are unjust.

The creation of equal opportunities also comes into play in the second principle and can be seen as the second prerequisite pertaining to possible permission of inequalities. It can be explained as follows: although the outcomes may be uneven, there must at least be equality in the starting position, allowing everybody an equal opportunity to take part in the various economic processes including the creation, processing and use of resources.

The third prerequisite pertains to the higher expectations of those who are better off. Such a situation of higher expectation is only considered just if it would also improve the expectations of the least advantaged members of society.

In the last instance, it must be stressed that these permissible inequalities are subordinate to the first principle. It can therefore be argued that the right to own and use a resource, and the right to gain economic profit from the resource through products and services, can never be at the expense of the right of access to the resource.

Based on these two principles, the following five categories of social justice can be distinguished:[25]

- *Participatory justice.* Based on the first principle of Rawls, all have equal right to participate in society, which comprises an antithesis to marginalisation. No action, whether lawful of unlawful, could be considered just if it excludes some members of either the present generation or any future generations from enjoying the privilege to participate in society. This would also imply the privilege to observe and interact with other creatures, hence, should any action of the present society lead to the extinction of another species, it should be considered unjust since it precludes future generations from interacting with it.

- *Commutative justice.* Commutative justice calls for fundamental fairness in all agreements and exchanges between individuals or social groups. In its economic application, it calls for equality in transactions. Commutative justice underscores the importance of the relationship between buyers and sellers of goods and services.

- *Distributive justice.* In its broad sense, distributive justice is concerned with the fair allocation of the benefits of a particular society (i.e. income, wealth, power and status) to its members. It can be seen as an expression of Rawls's first principle. Distributive justice pertains to the fair distribution of goods and services to people, and the accessibility, in order to satisfy basic needs. In accordance with this form of justice, it can be argued that government has a responsibility to ensure the fair distribution of essential goods and services that are needed for development.

- *Contributive justice.* This form of justice pertains to both principles of Rawls's social justice. Contributive justice implies that an individual has an obligation to be active in society (individual responsibility), and that society itself has a duty to facilitate participation and productivity without impairing individual freedom and dignity. One of these duties would therefore be the creation of equal opportunities. This form of justice also implies that the generators and distributors of the resources have a responsibility to add value to, and maintain their accessibility, in such a manner that it benefits the society. Based on the viewpoint that contributive justice implies society's responsibility to facilitate participation and enhance productivity, it can be argued that society also has a responsibility to create an environment that will stimulate creativity and productivity – for example, the encouragement of R&D programmes. Contributive justice, can, however, be applied wrongly in cases where, for example, disaster relief and donor aid create permanent dependency on the aid and/or destroy local industrial development, as was the case in the textile industry in Zambia.[26]

- *Retributive justice.* This category of justice, also known as punishable justice, refers to the fair and just punishment of the guilty. Retributive justice is also applicable to Rawls's first principle. For example, this form of justice can be applied to protect the basic human right of access to resources needed to exercise other basic human rights.

18.4.3 Management

Whereas justice provides the intrinsic value of a common moral denominator for economics, the instrumental value, the enabler thereof, is management. It is through appropriate and proper management of resources, relationships and institutions that the intrinsic value of justice will come to realisation. Justice is a good in itself but this good will not be upheld if it is not sufficiently enabled through management.

Interestingly enough, the word *economics* originates from two Greek words, namely *oikos* (house) and *nomos* (law or rule), which then combine as *oikonomia*, to be understood as household administration, household management or the law of the household. Likewise, the word economist in the original Greek would be *oikonomos*, which translates to administrator, who, in ancient Greece, was also regarded as *the ruler of the house* or the manager – Greek: *epitropos*. This links the function of an *oikonomos* or *epitropos* to the science of *oikonomia*.[27] Historically, therefore, economists were supposed to be managers who view their function as one of management. This managerial role is far removed from the value-free calculation and prediction role which neo-classical economics imposes.

Various questions should be addressed regarding the issue of management. First, who is to manage? The answer is everybody. Every person manages that which is under his or her authority. For some it may imply a small household, for others a large international corporation, or a non-governmental organisation, or the government itself. The essence is that all people are managers. The same individual might also have a distributed managerial obligation, first as member of a household, secondly as the CEO of a large multinational corporation, thirdly as chair of the local tennis club, fourthly as member of a charity, etc.

Second, what should be managed? One cannot manage that which is not under one's control or supervision. Some would therefore have a small sphere to manage, others a large one. A manager is not without power, nor without any sense of value; he or she must exercise his or her managerial role.

Thirdly, how should the manager manage?[28] A few operating principles are highlighted:

- The various facets of justice should always be the greater good towards which the economy, the economic system and those participating in it should work, namely enabling participation through accessibility, fairness and equality, resource allocation, responsibility and lastly security.
- Being a manager implies that one is not the owner with absolute rights; that would be society at large.
- Though absolute ownership is based in the collective right of society at large, individual legislative property rights subject to the principles of justice are a right as well.
- Humans stand in relationship with themselves and others, either in the present generation or those past and future, and how they express these relationships will determine whether justice is done or not.
- Humans must use the resources at their disposal to their own greater good and that of society.
- Each individual has the right and obligation to participate in society and the economy by applying his or her trade and through these means provide for his- or herself, his or her household and society.
- Work is to be seen as a social activity towards achieving a certain purpose, as

indicated by Monod earlier, and its value should not be equated with its associated remuneration.

- Each individual is accountable for his or her deeds before society in terms of whether they contribute to the greater good or not.
- The cosmos and the natural environment is an open, but constrained, system that could regenerate in multiplicity through appropriate management (positive-sum societies), but, through mismanagement, could collapse completely.[29]

18.5 Conclusion

This chapter considered both the intrinsic and instrumental values of neo-liberal economic thought as embedded within neo-classical economics. These are identified as consumption and individual self-interest respectively. It has been found that an economy based on these values is not sustainable, and these values are inappropriate for solving the current economic problems of massive resource use and poverty. It is argued that a more appropriate set of values would be that of justice (as intrinsic value) and management (as instrumental value).

A last remark regarding the role of scarcity should be made since it is such a dominant concept in neo-classical economics and does not feature at all in the economic development ethic discussed here. It is accepted here that scarcity cannot be solved from a mindset that assumes scarcity as its point of departure. Stated otherwise, the issue of scarcity cannot be successfully addressed by using a paradigm that needs the existence of scarcity in order to exist. Solving scarcity is like aiming at a moving target, and the means of aiming at it is through the perspective of scarcity itself, and hence the dominance of consumerism. In the context of a development paradigm based on an intrinsic value of justice and an instrumental value of management, one does not have such a moving target, but, instead, one has firm parameters within which development could take place, addressing issues such as the scarcity of resources.

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9 Gary Becker, Nobel Laureate in economics, states: 'I have come to the position that the economic approach [the means-end maximisation approach] is a comprehensive one which is applicable to all human life'. (Storkey, A. 2000. Postmodernism is consumption. In: Bartholomew, C. and Moritz, T. (eds.). *Christ and Consumerism.* Carlisle: Paternoster Press, p. 66).

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28 Bwalya developed a checklist to evaluate whether or not a policy or programme adheres to sound managerial principles, this checklist is reproduced as Appendix 18.1. See Bwalya, M. 2001. *A Theological-Ethical Framework for Economic Development: The Case of Zambia.* Unpublished Ph.D. dissertation. Pretoria: Department of Theology, University of Pretoria.

29 Kuyper, A. n.d. In: *Christianity and the Class Struggle.* Grand Rapids: Piet Heirr Publishers, p. 19, states as follows: 'We with our own human nature are placed in nature around us, not to leave that nature as it is but with an urge and calling within us to work on nature through human art, to enable and perfect it ... Human art acts on every area of nature, not to destroy the life of nature, much less mechanically to juxtapose another structure, but rather to unlock the power which lies concealed in nature; or again to regulate the will power that springs from it.'

Appendix 18.1

Checklist of a set of principles that could be used in the evaluation of economic development programmes.

Type of principle	Required principle	Evaluation: Principle is:			
		Strongly supported	Supported	Not supported	Transgressed completely
1 Applicable to social life	1.1 Acknowledgement of the wholeness of human needs				
	1.2 A recognition of the dignity of humans				
	1.3 Affirmation of the just treatment of all humans				
	1.4 Affirmation of work as being part of being human				
	1.5 Recognise care and sociality for humans				
	1.6 Inclusive of all humans in the market				
	1.7 Affirmation of individual rights to property				
2 Applicable to the environment	2.1 Acknowledgement that the natural environment is the platform of all welfare and prosperity				
	2.2 Eco-justice is entrenched				
	2.3 Recognises human care and sociality for the earth and all that is in it				
	2.4 Contributes to environmental development and regeneration				

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Type of principle	Required principle	Evaluation: Principle is:			
		Strongly supported	Supported	Not supported	Transgressed completely
3.1 Business	3.1.1 Acknowledges both technical and moral choices				
	3.1.2 Acknowledges that proper management is a prerequisite for productive, distributive and consumptive forces				
	3.1.3 Productive machinery principles:				
	i Awareness of the sensitivity of natural resources and systems				
	ii No compromise on environmental sanity				
	iii Contributes to meeting basic needs of all				
	iv Produce is not threatening to human survival				
	v Recognises that some values cannot and should not be quantified				
	vi Affirmation of positive government intervention in the role of the market				
	vii Encourages non-market society-enhancing values				
	viii Affirms that just incomes are interlinked to participation in the market				
	ix Affirms that the creation of jobs are interlinked to participation in the market				

Table continued on next page >>

Type of principle	Required principle	Evaluation: Principle is:			
		Strongly supported	Supported	Not supported	Transgressed completely
	x Recognises the concerns of the unemployed, homeless, widows, handicapped and orphans				
	xi Departs from manipulating market forces				
	xii Affirms that consumption should not compromise human life or the environment				
	xiii Avoids wastage and extravagance				
	xiv Acknowledges that there should be enough for all to sustain life and a basic standard thereof				
	xv Affirms accountability to posterity				
3.2 Government	3.2.1 Acknowledges that government is the accountable custodian of a country's resources				
	3.2.2 Affirms the good management of the talents and skills of the country's citizens				
	3.2.3 Admits that corruption is stealing from the public household				
	3.2.4 Acknowledges that senior officers' conditions of service should be proportionate to the levels of welfare in the country				
	3.2.5 Affirms that a prosperous, healthy and				

Table continued on next page >>

Type of principle	Required principle	Evaluation: Principle is:			
		Strongly supported	Supported	Not supported	Transgressed completely
	fulfilled citizenry be the purpose of political economy				
	3.2.6 Ensures that social and environmental sustainability are not compromised				
	3.2.7 Ensures and enforces property rights				
	3.2.8 Ensures and enforces worker rights				

CHAPTER 19

Reflecting on: Sustainable options

Martin de Wit and James Blignaut

19.1 Towards an agenda for action

In this last chapter it seems appropriate to return to the key question put forward in the first paragraph of the book, namely: Does South Africa have the prospects of achieving the vital sustainable interaction between the economy and the environment? Given the series of case studies presented here it should be clear that the answer to this question is yes. Indeed the ways to develop do exist, i.e. the creation of welfare in such a way that it will support sustainable interaction between economy and environment. There are also ways to quantify these interactions and this valuation is already taking place, although on a small scale. The problem, and major cause for concern, however, is that these options and valuation techniques and processes are not perceived yet to be widely applied across the country in either macro- or microeconomic decision-making.[1] A huge gap is discernable, therefore, between what is possible and appropriate, on the one hand, and what is required for prudent resource management, on the other. There are arguably five major steps towards closing this gap, namely:

- The general acknowledgment by both the public and the private sectors that the country is on an unsustainable path (discussed in Part A).
- The application of ERE tools to value the 'unpriced scarcity' of natural and environmental resources, which shows that there are sustainable options and also what the social and environmental opportunity cost is of not internalising these externalities (see the selection of case studies in Part B).
- The design of appropriate policy instruments (instruments that internalise social and environmental externalities, both positive and negative) that can be used to set the country on a path of sustainability (discussed throughout Parts A and B).
- An understanding of the importance of the policy-making process and how suggestions regarding sustainable options should be presented to be acknowledged (Chapter 17).
- The challenge of a more just and sustainable society, concentrating not on the efficiency criteria only, but focusing on justice and prudent management as parameters for decision-making (Chapter 18).

Figure 19.1 highlights these few, simple, steps, which in fact signal the intention of the book. Although simplicity may buy an increased understanding, this understanding might come at the expense of an appreciation of the complexity of reality. This has always been the trade-off in the pursuit of knowledge, and especially so when large-scale, random and complex issues are addressed.[2] Be that as it may, the steps highlighted here do indicate a path towards the realisation of a just outcome. The analysis transcends beyond a mere analysis of environmental, economic and poverty issues, though important they might be, as discussed in the introductory chapters. These steps have the intention also to be action-oriented.

Viewed from an action-oriented perspective, the questions that jump to mind are: What are the sustainable options that can be implemented? What steps have to be taken? Who are the role players and relevant stakeholders? What type of action is required? How could externalities be internalised? And, what policies are required to give effect to the internalisation of externalities? It is necessary to

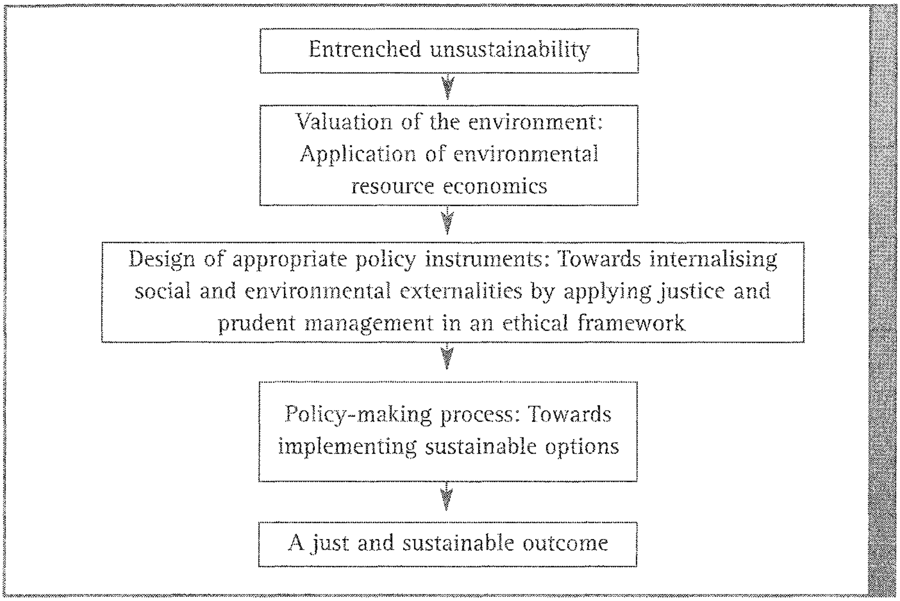

Figure 19.1: Towards a just and sustainable economy: Applying sustainable options

address these questions so that existing sustainable options will be implemented, leading to an increased quality of life, improved human dignity and the improved management of natural resources. If these tough questions are not addressed in one way or another, the application of environmental resource economics (ERE) will simply be an academic pursuit. Therefore, the arguments and developments put forward in this book have been placed in a framework of *action towards sustainability*, conceived with the following questions, urgently requiring answers, in mind: How can ERE help? Where are the gaps in the understanding of the economy-environment interaction and the application of existing knowledge? How can these gaps be closed? To address these questions, a SWOT analysis (an interrogation of Strengths, Weaknesses, Opportunities and Threats) is used to assess progress towards a more just and sustainable economy for South Africa.

Conventionally, a SWOT analysis is used to identify and then promote an organisation's strengths, while eliminating inherent weaknesses and exploiting the identified opportunities and dealing with, planning for or hedging against, the threats.[3] In this case, a SWOT analysis is conducted, not on a well-defined organisation, but on elements concerning the implementation of sustainable options (see Table 19.1). Hence it is done on two levels, first on the theories, tools and techniques to analyse economy-environment related problems and provide decision support, and secondly on the policies and institutions needed to define and implement the practical implementation of such options. The first level of analysis is focused on providing the required information to 'getting the prices right', i.e. the application of ERE, while the second goes much further towards using and implementing a mix of policy instruments and institution building.

With regard to the strengths, it is evident that there is a growing application of ERE, due to an increase in demand thereof. This implies that there is an increasing number of ERE practitioners and a growing understanding of the subject matter. In addition, this understanding is supported by a growing number of policy-related documents in support of the application of ERE.[4] Furthermore, South African environmental legislation ranks among the best in the world. It embodies the fact that all citizens have the right to a clean and healthy environment according to the Constitution.[5] A weakness is that despite the demand-driven application of ERE, and that ERE is at times included in the environmental impact assessment process (see Chapter 16), a concerted focus still lacks in the valuation studies undertaken. Furthermore, a comprehensive economy-environment database does not exist yet, such as economy-environment wide natural resource accounts (see Chapter 15). Likewise, an integrated environmental policy-making process or strategy among government departments seemingly does not exist. Indications are that various governmental departments actually operate in silos apart from one another when considering environmental issues.

The opportunity for broadening the scope as well as depth of the application of ERE across a wide spectrum of activities is therefore (almost) boundless, while, theoretically at least, the necessary environmental legislation is in place to enact economic approaches to environmental management and poverty alleviation. There is, however, a significant threat that, whatever is happening in the policy and/or scientific and research realms will have little impact on the other. The reason for this could be the financial and influential power of interest groups, especially in the private sector, which currently enjoys the utilisation of 'free' environmental goods and services.

Table 19.1: SWOT analysis regarding the application of sustainable options in South Africa

Strengths	Weaknesses
Theory	**Theory**
Growing application of South Africa-specific environmental valuation studies	Lack of focused strategy for valuation studies
Growing pool of knowledge	Partial application of valuation studies
Increased interest in subject matter	No official database on natural and environmental resources, e.g., natural resource accounts (NRAs)
ERE taught at many tertiary institutions	Lack of generally accepted decision-support systems on integration of economy and environment
	Data transfer from international experience to South Africa case studies; more primary research necessary
Policy	**Policy**
Constitutional rights	Silos in government; no transparent interaction in economic, social and environmental policy-making processes
Good environmental legislation	Little understanding from elements in civil society (including science practitioners) on how to interact effectively in the policy-making process
	Small-scale and often ineffective institutions bridging the gap between analysis and active decision support
	Weak application of policy

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Opportunities	Threats
Theory	**Theory**
Scope for further development of valuation studies	Non-agreement on valuation methodologies
Many issues still not researched; wide and open research agenda	Ignorance on the use of valuation studies in decision support
Policy	**Policy**
Legislation in place to implement economic approaches to environmental management and poverty alleviation	Overburdened government if only legal and regulatory policy instruments (i.e. not market-based instruments) become entrenched
	Unbalanced power relationships and vested interests working against prudent management of natural resources

19.2 Sustainable options: An assessment of the lessons learnt

It has been argued in this book that South Africa indeed has implementable sustainable options and possesses the capacity to conduct intricate valuation studies. It has also been argued that ERE plays an important role in highlighting these sustainable options, but that there are various weaknesses and threats hampering the process to realise the latent potential of these sustainable options. According to the steps put forward to achieve the implementation of sustainable options (see Figure 19.1) it is clear that South Africa has made some progress with regard to the initial two steps, namely the realisation that it is currently on an unsustainable path, and of the use of ERE. This is evident from the bulk of good environmental legislation promulgated in South Africa, the demand for ERE and the growing pool of knowledge about the use of ERE. With regard to the latter three steps, namely the design of market-based policy instruments, the policy-making process and the application of a normative framework to evaluate development, very little progress has been made. A more detailed assessment of the lessons learnt follows.

19.2.1 Economy-environment context

In Chapter 1, an overview was given on the South African economy: one of relatively stable macroeconomic performance, but coupled with increasing levels of inequality between rich and poor and a deterioration of much of the country's natural and environmental resources; the so-called 'double-decker' phenomenon. Historical evidence indicates that more economic growth will lead to higher levels of human health (at least in the short to medium term) and that cleaner future growth is feasible, owing to technological progress. However, more growth will almost invariably lead to an increase both in material consumption and the use of fossil fuels, and thus the emission of greenhouse gases. Apart from such biophysical constraints to growth, social and ethical limits are also becoming paramount. An increase in welfare cannot be attained by a single-minded pursuit of self-interest; higher sets of normative principles such as justice and prudent management are crucial to the sustainable interaction between economics and the environment. Although the debate on an ethical framework for development has been touched upon (Chapter 18), it is certainly necessary to invoke a societal debate on the juxtaposition between the neo-liberal framework, often uncritically accepted on the wave of globalisation, and a set of ethical principles against which development should be tested. It was indicated that South Africa is in no position to postpone social and environmental concerns in its development path; there is no political, nor ecological space for the country to outgrow these problems. They are persistent and entrenched in the fabric of the economy and society and have to be addressed through a more holistic perspective on development.

19.2.2 Valuing the environment

Several case studies were described in Chapters 5 to 14, providing an insight into the economic value through the internalisation of externalities and the changing quantity and quality of natural and environmental resources. These studies are valuable in highlighting the 'unpriced scarcity' of natural and environmental resources in a South African context, an issue that was only addressed during the last few years. When these values are internalised in private and public decision-making, market prices will at least better reflect the trade-offs between further development and eroding natural capital on which such developments are often based. In all the cases reported, the studies made use of tools available in the subject field of environmental and resource economics. Despite good progress, a definite need exists to find agreement on the methodologies that will be used to value changes in the availability of natural resources and in environmental quality. The contingent valuation method, for instance, is, theoretically, the best approach to quantify total economic value, but its use is often avoided because of either resource constraints or a lack of uniformly accepted principles for developing countries such as South Africa. Nevertheless, other valuation techniques, such as the travel-cost method and hedonic pricing studies, have been applied fruitfully to demonstrate that natural and environmental resources do constitute economic value, often at surprisingly high levels. Documentation of all these case studies according to certain categories,[6] incorporated in a spatially sensitive database, will be of great value. For the public good, such a database should be developed and maintained in such a way that all practitioners working in the field can easily access and update its content. Furthermore, a clear need exists to produce authoritative manuals on the method and expedient time of use of valuation techniques in the evaluation of projects, plans and programmes. It is suggested that the various government departments tasked with the management of natural and environmental resources, produce such manuals or endorse international ones, to start with. This should not require an immense effort, especially when ERE approaches are integrated into existing evaluation optimum practices such as the family of cost-benefit analysis approaches (including cost-effective analysis, multicriteria analysis and decision analysis).[7]

In a developing country such as South Africa, richly endowed with natural resources, but with acute socio-economic disparities between rich and poor, the importance of managing towards a just and sustainable outcome is even greater (and more difficult) than would have been the case otherwise. Therefore, a broad-scale application of ERE to inform decision-making regarding the management of natural and environmental resources is required. In so doing, an integrated socio-economic-environment policy package is to be prepared. Such a package might include environmental taxes, but these taxes then become only one of the instruments within a broader context of policy reform.[8] Also, this tax reform should be part of a process of tax reform in itself, lest much needed development is unnecessarily constrained.

An academic debate on the value principles underlying various theories about the interaction between the economy and the environment is at this stage non-existent in South Africa. Environmental and resource economics accepts the neo-classical economic framework, although providing a critique on the exclusion of natural resources in the model. This debate, and the results of ERE applications, can be further enriched by being placed in the context of the ecological economic concept of biophysical limits, the neo-institutional concept of transaction costs and the dynamics of evolutionary economic theory. Such a pluralistic approach emphasises cautiousness when valuing environmental resources and when making use of such results.

19.2.3 Tools for decision support

In the field of applied environmental and resource economics, valuation is a means to an end, namely the better management of resources. Two different means of decision support were discussed, namely natural resource accounts (NRAs), in Chapter 15, and environmental assessment (EA), in Chapter 16. Seen from an economic perspective, NRAs are a vital link between valuing natural and environmental resources and making decisions on a macroeconomic level, and informing development strategy and policy. Reasonable success has been achieved in compiling NRAs in recent years, indicating, amongst others, the declining contribution of gold mining to the South African economy, the increased importance of prudent water management and the significant, but unvalued, contribution of natural woodland and forestry products to the gross geographic product (GGP) in three of South Africa's poorer provinces. It is clear that more accounts are needed to reflect both the quantity and quality of all of South Africa's most important natural and environmental resources, and the obvious fact that these and further accounts should be made official and mainstreamed into national accounting frameworks and ensuing economic development planning. Value-adding tools, such as integrated economy-wide models, can only be developed much more effectively for official planning when such NRAs have been developed and maintained properly. Further work on economy-wide and sectoral models that are sensitive to changes in the availability and value of natural and environmental resources is crucial to effective planning. Further sectoral work is needed on those sectors that are sensitive to changes in the availability of natural resources and those that produce high levels of pollution and waste.

It was also argued that the process of including economics in environmental assessments is plagued by a lack of consistent standards. A full quantification of opportunity costs, whether including environmental impacts or not, is not always necessary – this again will be guided by the need to inform decision-making. It must be mentioned that a full project cycle can benefit from an economic analysis of opportunity costs by including better shadow prices (including environmental damage costs and control costs) in pre-feasibility and feasibility studies. Again agreement on the types and levels of environmental costs that have to be included should be a priority in further applications of ERE in project evaluation.

A topic that was not touched upon in this book, but one that will also become increasingly important in future, is how to account for the environment on a business level.[9] The triple-bottom line concept, for example, should be developed further into one that measures welfare changes, rather then highlighting the trends of certain selected indicators.

19.2.4 Public policy-making

The design of environmental economic policies and understanding of the process of policy-making in the country is one area that has not received much attention yet in South Africa (see Chapter 17). The best results from environmental valuation studies, the best set of NRAs, and an official set of sectoral and economy-wide assessment models and tools can all be available, but if there is no understanding of policy design and implementation, this effort will only be of academic interest. A real change towards sustainability can only be achieved by designing the best mix of incentives and disincentives within the context of a dynamic policy design process. The design of policy is not simply to make a choice between quantity-based (for example, command and control instruments) or price-based approaches (such as market-based instruments), or even hybrids of these approaches (for instance, cap and trade systems) to environmental policy-making, as is often suggested in environmental economics textbooks. An analysis of the real-world policy process itself cannot be ignored. A better understanding of such processes can, for example, explain why many governments are still choosing command and control mechanisms despite the obvious economic inefficiencies and often impracticality of such systems in already overloaded governments.

Gunningham and Grabosky[10] argued that the challenge is to regulate smartly: 'to design the best possible environmental policy ... using a broader combination of instruments and actors'. The interests of actors, and their relationships, however, change over time. Smart regulation in one political context might not be so smart in another. Policy-making is subject to a multiplicity of sources of change and adjustments, and is open-ended.[11] The challenge is to find an environmental policy that produces continuous incentives that will encourage adaptation to changing economy-environment interactions.[12] This does not mean that policy can be changed at every whim of the socio-political system; these incentives have to be tested to a higher set of ethical norms such as justice and prudent management.

The important implication is that the internalisation of externalities, whether attempted through a Pigouvian or Coasian strategy or the setting of standards, is a necessary, but not adequate, condition towards a sustainable interaction between the economy and the environment.[13] At least two other conditions apply, first, that policy instruments adhere to certain ethical norms and second, designing an adaptive and flexible environmental policy accounting for changing realities. The achievement of these conditions can at this stage best be described as a fertile future research agenda for environmentalists, economists, political scientists and scholars in environmental law.

19.2.5 Summary

Recent legal developments in South Africa have opened the door for a more holistic approach to environmental management,[14] which provides many options towards the implementation of sustainable options. Some pressure points for future research and applications are highlighted below:

- First, this does provide the option to include user costs in the calculation of prices for natural resources such as water and minerals, and to start including the otherwise externalised costs of energy generation, manufacturing, mining, transport, agriculture, forestry and domestic activities. Internalising these costs is an important option towards achieving longer-term economic sustainability. Much work has been done in this respect, but future work is required on standardisation of valuation techniques and efforts in making such values part of the official statistics.

- Second, entrenching the economic value of natural and environmental resources in policy-making by developing tools for decision support. Promising work has been done on NRAs, but more is required on such accounts as well as on the development of models and tools informing national, sectoral and business level decision-making.
- Third, to identify a best mix of incentives and disincentives for environmental management. Here one should take cognisance of the fact that policy-making is a very sensitive, yet dynamic, process. In this regard very little work has been done.

19.3 Towards *JustAfrica*

The term *JustAfrica* encapsulates many stories and dreams. Although this book has focused on South Africa, capturing the entrenched unsustainability of the country's current development path as well as some of the ongoing responses to this problem, the fundamental application thereof is much wider. All developing countries that have to rely on natural resources and cope with high levels of poverty are implied. The term *JustAfrica* suggests at least four different aspects. First, and most evident, a dream of more *justice* in Africa. Most of Africa's inhabitants have been excluded from national and international economies for a long time, as was accurately depicted by the term 'double-decker' economies,[15] implying multi-layered income distribution (see Chapter 1). Second, it is also *true* that natural resources will continue to play an important role in Africa's development path for the future. It is the platform of economic development, but also portrays the harsh day-to-day reality for a large part of Africa's population. Third, it sends out the message that Africa *barely* can continue on the current (under)development path. It is time to focus on weeding out the exploitation by nationally and internationally vested interests of both the people of Africa and the environment. Lastly, solutions to Africa's problems will have to be *custom made* for African realities.

Steps were suggested towards the realisation of sustainable options (Figure 19.1), a precondition for a just Africa. Some of these aspects were dealt with in this book with much scientific vigour, others are broad indicators of envisaged directions, others are even less; only dreams. What binds them together is a vision of a cleaner and greener economy that is sensitive to all of those participating. It is a reaction to the relentless and unfettered pursuit of material goods, consumerism, commercial indicators of success and welfare, and the rational, calculating and ethically neutral *homo oikonomos* in pursuit of self-interest. People, *homines sapientes*, however, are guided by a much broader set of ethical choices, of which justice and prudent management have been highlighted as key guiding principles (in this regard see also the work by the 2002 Economics Nobel Laureate, Daniel Kahneman[16]). To achieve this higher goal a few clusters of activities are essential, namely:

- Valuing the environment's contribution to the economy and to society:
  - The 'unpriced scarcity' of natural and environmental resources should be quantified further. Valuation studies are necessary where the highest return in terms of just and sustainable change can be yielded.
  - An official database on the state of natural and environmental resources should be maintained and developed according to a methodology that measures changes in welfare, not only indicating changes in income. Natural resource accounts for all key resources are required.
  - Further investment is essential for the application of the results of valuation studies and such official databases towards providing effective decision support. This can be done first through using equilibrium-based integrated economic-environmental modelling (input-output, social accounting matrices and computable general equilibrium modelling), but has to be taken further to account for complex and novel feedback mechanisms in these socio-economic and environmental systems.

- Institution building:
  - Establish sustainable institutions required to bridge the gap between theories, techniques and tools for analysis and effective decision support. This should happen at the macro-, meso- and micro-levels: for example, on the levels of public policy-making, influencing business decisions and household choice.
  - Effective institutions are essential to facilitate negotiation and interaction between representatives of economic, environmental and societal interests

on the highest levels. This will not only include government departments who are the custodians of these interests, but also other actors such as business, labour, non-governmental organisations and civil society – including voices for the poor and science. This implies the internalisation of the dream of *JustAfrica*, i.e. all for a prosperous clean and green economy in which everyone participates.

- Structural reform:
  - Structural changes may be necessary in some sectors or for some activities in society. This moves beyond 'getting the prices right', but may make use of this strategy to start changing behaviour gradually when the stakes are very high. A practical example in the South African setting is a development strategy that includes the same levels of fossil fuels, especially coal, in meeting the country's energy needs. With South Africa already having a carbon-intensive economy and the threats of accountability on the post-2012 period of commitment to the Kyoto Protocol, choices that have to be made are highlighted.

- Monitoring and evaluation:
  - Societal objectives, the principles derived from them, and the instruments used to achieve them, have to be monitored and evaluated for their contribution towards a more just and sustainable economy.
  - Perhaps an environmental agency should be considered. Such an agency would then become the implementing agency of all environmental legislation across all the line departments. That would necessitate the alignment of all environmental policies. Also, such an agency could be tasked to monitor and audit compliance.

19.4 Conclusion

Some aspects of the suggestions above are already in operation, some not. The important point is that options towards sustainability can only be effective in the longer run if they are well informed, are accepted and implemented, are supported by long-lived institutions and are evaluated for performance and, if necessary, agreements are in place that corrective managerial actions can be undertaken.

Most important of all, however, is the set of ethics that guides these activities. It suggests a holistic approach in designing and executing a full-scale programme for development.

It definitely excludes any national programme following the credo of unfettered neo-liberalism, as this will inevitably lead to much hardship to the increasing number of poor and a degradation of the country's natural capital. The design of such a programme in itself needs a powerful institutional home, but should be flexible enough to facilitate the inevitable trade-offs that will have to be made.

Endnotes and References

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5 RSA. 1996. Constitution of the Republic of South Africa. Act no. 108 of 1996. *Government Gazette* 378(17678). (18 December). Pretoria: Government Printer. Clause 24 states:
Everyone has the right:
(a) to an environment that is not harmful to their health or well-being; and
(b) to have the environment protected for the benefit of present and future generations,
 (i) through reasonable legislative and other measures that prevent pollution and ecological degradation;
 (ii) promote conservation; and
 (iii) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.

6. An example is the Economic Valuation Reference Inventory (EVRI) database (www.evri.ca/english/eng_m.htm), expanded for a spatial representation to account for South Africa's varying natural and social diversity. Such a database on valuation studies

will support policy-making by providing the means for a proper use of the benefit transfer technique.

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Glossary

$2xCO_2$: Doubling of the level of carbon dioxide concentration in the atmosphere from pre-industrial levels, predicted to occur between 2030 and 2050.

Abatement: The reduction of the degree or intensity of emissions.

Abiotic: Refers to all non-living elements of an ecosystem, including, for example, climate, soil, water, geology, physiography, ice, and non-living organic matter like peat.

Absorption: The uptake of a solid body, liquid or gas.

Acid rain: This is the combination of dry deposition of acidic substances and precipitation. The acidic deposition is normally the result of fossil-fuel combustion which releases sulphur dioxide and nitrogen oxide into the atmosphere. Acidic aerosols in the atmosphere are deposited via rain, snow, fog or dry particles.

Ad valorem: A type of levy expressed in terms of the percentage of the price of a good or service.

Adaptability: Refers to the degree to which adjustments are possible in practices, processes, or structures of systems, to projected or actual changes of climate. Adaptation can be spontaneous or planned and can be carried out in response to, or in anticipation of, changes in conditions.

Additionality: In the greenhouse gas programme, reductions are considered additional if they represent reductions that would not have occurred without the credit-producing project.

Administrative costs: All agency personnel and non-personnel costs associated with implementing a regulation, including technical and legal costs and management oversight and enforcement. These costs should include all agencies involved at state and local levels, where applicable. Indirect costs should be included but estimated separately from direct costs.

Affected parties: All entities that are directly subject to the proposed regulation and who, therefore, are likely to incur compliance costs, and all parties who will receive direct benefits (economic, social, environmental, etc.) as a result of the regulation being implemented.

Afforestation: Establishment of new forests and trees on unforested land.

Aggregate demand curve: In macroeconomic theory, the aggregate demand curve relates the level of real national income (GDP) demanded (the total quantity of goods and services demanded) to the price level (as measured by the GDP deflator).

Aggregate expenditure: In macroeconomic theory, aggregate expenditure is the total amount of desired spending by consumers, governments, private investors and foreign buyers (net of spending on imports) at each level of real national income (GDP).

Aggregate supply curve: In macroeconomic theory, the short-run aggregate supply curve relates the total quantity of goods and services supplied to the price level (as measured by the GDP deflator) *ceteris paribus*. The long-run aggregate supply curve is a vertical line at the full employment (capacity output) level of real national income (GDP).

Annex 1 parties: In climate change negotiations referring to industrialised countries that have a commitment according to the Kyoto Protocol to reduce their greenhouse gas emissions to approximately 5.2 per cent below the 1990 level during the first commitment period, 2008 to 2012.

Anthropogenic: Caused or created by human beings.

Assumption: A statement accepted or supposed true without proof or demonstration. For example, if data are unavailable to complete a step in a cost-benefit or risk assessment, they may have to be estimated or assumed to complete the analysis. In some situations, formal policy guidelines may direct the use of preferred assumptions.

Average fixed costs: In the theory of the firm, fixed costs are costs of production, being constant whatever the level of output. Average fixed costs are total fixed costs divided by the number of units of output, that is, fixed cost per unit of output.

Average revenue product: In the theory of factor pricing, the average revenue product is the total revenue divided by the number of units of the factor employed.

Average variable costs: In the theory of the firm, the total variable cost divided by the number of units of output.

Avoidance cost: Actual or imputed costs for preventing environmental deterioration by using alternative production and consumption processes, or by reducing of, or abstaining from, those economic activities causing environmental deterioration.

Balance of payments accounts: A record of all transactions involving a country's exports and imports of goods and services, borrowing and lending.

Balance of trade: A record of a country's exports and imports of goods and services.

Benefit-cost analysis: An economic technique applied to public decision-making that attempts to quantify in dollar terms the advantages (benefits) and disadvantages (costs) associated with a particular policy.

Biome: Ecological region determined by complex interactions of climate, geology, soil type, water resources and latitude.

Biotic: Refers to the living elements of an ecosystem, such as plants and animals.

Biochemical oxygen demand (BOD): The extent of biochemical degradable substances in water and considered as an indicator of water pollution.

Biodiversity: The number of different kinds of plant and animal species that live in a region and their interaction with one another.

Biomass energy: Energy produced by combustion biomass, i.e. living matter, such as wood.

Carbon dioxide (CO_2): Colourless, odourless and non-poisonous gas that results from fossil fuel combustion, and is normally a part of ambient air. It is also produced in the respiration of living organisms (plants and animals), and is considered to be the main greenhouse gas, contributing to climate change.

Carbon monoxide (CO): Colourless, odourless and non-poisonous gas that results from incomplete fossil fuel combustion. Carbon monoxide combines with the haemoglobin of human beings, reducing its oxygen-carrying capacity, with effects harmful to human beings.

Carbon sequestration: In the greenhouse gas programme, a concept that refers to capturing carbon and keeping it from entering the atmosphere for some period. Carbon is sequestered in carbon sinks, such as forests, soils or oceans.

Carbon sink: Pool (reservoir) that absorbs or takes up released carbon from another part of the carbon cycle. For example, if the net exchange between the biosphere and the atmosphere tends towards the atmosphere, the biosphere is the source and the atmosphere is the sink.

Carbon taxes: Discourage the use of fossil fuels and aim to reduce carbon dioxide emissions by placing a surcharge on the carbon content of oil, coal and gas.

Certified emission reductions (CERs): In the greenhouse gas programme, CERs are verified and authenticated reductions of greenhouse gas from the abatement or sequestration project that are certified by the Clean Development Mechanism.

CGE: An occasional abbreviation for 'computable general equilibrium' models.

Classical economics: The economics of Adam Smith, David Ricardo, Thomas Malthus and later followers, such as John Stuart Mill. The theory concentrated on the functioning of a market economy, spelling out a rudimentary explanation of consumer-and-producer behaviour in particular markets and postulating that in the long term the economy would tend to operate at full employment because increases in supply would create corresponding increases in demand.

Clean development mechanism (CDM): In the greenhouse gas programme, the CDM is a mechanism established by Article 12.2 of the Kyoto Protocol for project-based emission reduction activities in developing countries.

Climate: The prevalent pattern of long-term weather conditions.

Coase theorem: In the presence of complete competitive markets and, simultaneously, in the absence of transactions costs, market agents will select an efficient set of inputs to production and outputs from production regardless of how property rights over the inputs were assigned to the agents. Private property rights are, however, a precondition for the application of the Coase theorem.

Command-and-control regulations: Regulations dictating specific pollution and/or technology standards which have to be met (usually by individual polluters).

Comparative advantage: The ability to produce a tradable good or service at a lower opportunity cost than when produced in another country.

Constant values (real value): Monetary values that remove the effect of inflation from statistical data reported for different years. To obtain constant monetary data a base year is selected and a pre-selected price index or deflator adjusts all other monetary observations for years before and after that base year. The consumer price index (CPI) is the most commonly used constant deflator. There are other indexes that may be more appropriate to the subject matter, however, such as an index for construction costs of purchasing equipment.

Consumer surplus: The net benefit realised by consumers when they are able to buy a good at the prevailing market price. It is equivalent to the difference between the maximum price consumers would be willing to pay and that which they actually pay for the units of the good purchased. Graphically, it is the triangle above the market price and below the demand curve.

Consumption function: Generally, the relationship between consumer expenditures and all the influences by which they are determined. More specifically, the relationship between consumers' disposable incomes (personal income less taxes) and the amount they wish to spend on consumer goods and services.

Consumption: Spending to acquire consumer goods and services, or using up those goods and services to satisfy wants.

Contingent valuation: The use of questionnaires about valuation to estimate the willingness of respondents to pay for public projects or programmes. Often the question is framed, 'Would you accept a tax of x to pay for the programme?' Or, alternatively, 'Would you be willing to accept x as due compensation for the loss suffered?'

Control cost: Costs incurred by government, individuals, industries or infrastructure providers, to control or improve the condition of the natural resource.

Current account: That part of a country's balance of payment accounts that records the value of goods and services exported minus the value of goods and services imported.

Current account balance: The difference between a country's savings and its investment. If positive, it measures the portion of a country's saving invested abroad; if negative, the portion of domestic investment financed by foreigners' savings. It is defined by the sum of the value of imports of goods and services plus net returns on investments abroad, minus the value of exports of goods and services, where all these elements are measured in the domestic currency.

Damage cost: Costs incurred by industries, infrastructure providers or households, because of the degradation of natural resources. These costs are divided into:

- recurrent damage costs in the form of loss of income from impaired economic activity;
- additional repair or maintenance expenditure;
- reduced service life of capital items; and
- non-recurrent investment costs on such items as additional water treatment plants or provision of replacement reservoir capacity.

DDT (Dichlorodiphenyltrichloroethane): A chlorinated hydrocarbon insecticide with extremely toxic features.

Defensive expenditures: Expenditures incurred to mitigate or avoid the external cost of the general growth process of production and consumption. Defensive environmental costs are expenditures for preventing or neutralising a decrease in environmental quality, as well as for compensating for, or repairing, negative effects (e.g., human health and welfare) of environmental deterioration.

Deflation: A fall in the general level of all prices; it is the opposite of inflation.

Depreciation (consumption of fixed capital): The using up or wearing out of capital goods.

Diminishing returns: The tendency for additional units of a productive factor to add less and less to total output when combined with other inputs that are to some degree fixed in quantity. Combining more of a variable input, such as labour, with a given amount of some other input, such as capital in the form of a machine, will eventually result in the marginal product for labour declining.

Discount rate: The interest rate at which an agent discounts future events in preferences in a multi-period model. Often denoted r. A present-oriented agent discounts the future heavily, yielding a high discount rate.

Discounting: A method used by economists to determine the monetary value today of a project's future costs and benefits. This is done by weighting money values that occur in the future by a value less than 1, or 'discounting' them.

Because environmental decision makers are increasingly forced to evaluate policies with costs and benefits that will be spread out over tens – perhaps hundreds – of years, discounting is used to help evaluate the value of measures that deal with problems such as stratospheric ozone depletion, global climate change and the disposal of low- and high-level radioactive wastes.

Disposable income: The income a person or household has left to dispose of after income tax has been deducted from personal income. Disposable income may either be spent on consumption, or saved.

Double dividend: Refers to the notion that environmental taxes can both reduce pollution (the first dividend) and reduce the overall economic costs associated with the tax system by using the revenue generated to displace other more distortionary taxes that slow economic growth at the same time (the second dividend).

Dynamic incentives: Incentives to alter behaviour over time through adjustments such as changes in technology, technique, etc.

Earmarking: Where the revenue raised through a levy is used exclusively to finance a specific activity or programme.

Economic growth: The percentage change in the gross domestic product, resulting from four basic causes:

- investment, meaning increases in the capital stock (Solovian growth);
- increases in trade (Smithian growth);
- size or scale effects, e.g., by overcoming fixed costs or achieving specialisation; and
- increases in knowledge, most of which are called technological progress (Schumpeterian growth).

Economic rent (resource rent): Any return a factor of production receives in excess of its opportunity cost (what it would have received in its next best use).

Economies of scale: If all the inputs in a production process are increased and the output increases by proportionately more than the inputs were increased, economies of scale are being realised.

Ecology: The study of the interaction of organisms with their physical environment and with other organisms associated with it.

Ecosystem: The complex of plant, animal, fungal and micro-organism communities and their associated non-living environment interacting as an ecological unit. Ecosystems have no fixed boundaries; instead, their parameters are set according to the scientific, management, or policy question being examined. Depending on the purpose of analysis, a single lake, a watershed, or an entire region may be considered an ecosystem.

Elasticity: A measure of responsiveness. The responsiveness of behaviour measured by variable Z to a change in variable Y is the change in Z observed in response to a change in Y. Specifically, this approximation is common: elasticity = (percentage change in Z) / (percentage change in Y).

Emission taxes: Taxes levied on air or water emissions, usually on a per ton basis. Emission taxes provide incentives for firms and households to reduce their emissions and therefore are a means by which pollution can be controlled. The greater the level of the emissions tax, the greater the incentive to reduce emissions.

Emissions trading: A regulatory programme that allows firms the flexibility to select cost-effective solutions to achieve established environmental goals. With emissions trading, firms can meet established emissions goals by reducing emissions from a discrete emissions unit, reducing emissions from another place within the facility, or securing emission reductions from another facility.

Emissions trading encourages compliance and financial managers to pursue cost-effective emission reduction strategies and incentivises emitting entrepreneurs to develop the means by which emissions can inexpensively be reduced.

Emissions: Pollutants released into the air or waterways from industrial processes, households or transportation vehicles. Air emissions pertain to atmospheric air pollution; water emissions refer to pollutants released into waterways.

Endemic: A species native to a specific location, occurring naturally in a specific region of a characterisation of biogeophysical features; a species or a race native to a particular region.

Endogenous: A variable is endogenous in a model if it is at least partly a function of other parameters and variables in a model.

Energy intensity: Energy consumption relative to total output (GDP or GNP).

Environmental equity or environmental justice: Refers to the environmental protection for all citizens so that no segment of the population, regardless of race, ethnicity, culture or income, bears a disproportionate burden of the consequences of environmental pollution.

Environmental impact assessment (EIA): Analytical process that examines systematically the possible environmental consequences of the implementation of projects, programmes and policies.

Environmental valuation: Procedures for valuing changes in environmental goods and services, whether or not they are traded in markets, by measuring the changes in the producer and consumer surpluses associated with these environmental goods.

Evapotranspiration: The loss of water from the soil both by evaporation and by transpiration from the plants growing in the soil. Increases with air temperature increase.

Ex ante: Latin for 'beforehand'. In models where there is uncertainty that is resolved during the course of events, the *ex ante* values (e.g., of expected gain) are those that are calculated in advance of the resolution of uncertainty.

Ex post: Latin for 'after the fact'. In models where there is uncertainty that is resolved during the course of events, the *ex post* values (e.g., of expected gain) are those that are calculated after the uncertainty has been resolved.

Exchange rate: The price of the currency of one country in terms of that of another country.

Excise duties: Taxes on the manufacture or sale of certain domestic or imported products. Usually charged on products such as alcoholic beverages, tobacco and petroleum.

Existence value: The value that individuals may attach to the mere knowledge of the existence of something, as opposed to having direct use thereof. Synonymous with non-use value. For example, knowledge of the existence of rare and diverse species and unique natural environments may have value to environmentalists who do not actually see them.

Exogenous: A variable is exogenous in a model if it is not a function of other parameters and variables in a model.

Externalities: A benefit or cost associated with an economic transaction, which accrues to those not directly involved in undertaking the transaction; alternatively, it is a coincidental beneficial or adverse side-effect of production or consumption.

Free-rider: Deriving benefits without having to pay any costs.

Fiscal policy: Policy on tax, spending and borrowing by the government.

Foreign direct investment (FDI): A component of a country's national accounts. Foreign direct investment is investment of foreign assets in domestic structures, equipment and organisations. It does not include foreign investment in the stock markets. Foreign direct investment is thought to be more useful to a country than investments in the equity of its companies, because equity investments are potentially 'hot money' which can leave at the first sign of trouble, whereas FDI is durable and generally useful, irrespective of the state of affairs.

Fossil fuels: Fuels from fossils; includes coal, petroleum and natural gas.

General equilibrium: The condition reached when all markets (for products and productive factors) have cleared, that is, established equilibrium prices and quantities.

Gini coefficient: A number between zero and one that is a measure of inequality. An example is the concentration of suppliers in a market or industry. The Gini coefficient is the ratio of the area under the Lorenz curve to the area under the diagonal on a graph of the Lorenz curve, which is 5 000, if both axes have percentage units. If the suppliers in a market have near-equal market share, the Gini coefficient is near zero. If most of the suppliers have very low market share, with one supplier, or a few, providing most of the market share, the Gini coefficient is near one. In labour economics, inequality of the wage distribution can be discussed in terms of a Gini coefficient, where the wages of subgroups are fractions of the total wage bill.

Global warming potential (GWP): In the greenhouse gas programme, the GWP is an index found in the Kyoto Protocol that allows for the comparison of greenhouse gases with each other in the context of their relative potential to contribute to global warming.

Government failure: A situation, usually discussed in a fictitious model, in which the behaviour of optimising agents in a market with a government would not produce a Pareto optimal allocation. The point is not that a particular government has, or would have, failed at something, but that the problem abstractly put cannot be solved perfectly by the government. The most common source of government failures in models is private information among the agents.

Greenhouse effect: The progressive, gradual warming of the earth's atmospheric temperature, caused by the insulating effect of carbon dioxide and other greenhouse gases that have proportionately increased in the atmosphere. The greenhouse effect disturbs the way in which the Earth's climate maintains the balance between incoming and outgoing energy by allowing short-wave radiation from the sun to penetrate to warm the earth, but preventing the resulting long-wave radiation from escaping back into the atmosphere.

Greenhouse gas reduction: A reduction in emissions that is recognised to contribute to climate change, e.g., carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexofluoride. Greenhouse gas reductions are often measured in tons of carbon dioxide-equivalent. For example, one ton of methane has the same global warming potential as 20.9 tons of carbon dioxide.

Greenhouse gases: Include the common gases of carbon dioxide and water vapour, but also rarer gases such as methane and chlorofluorocarbons (CFCs) whose properties relate to the transmission or reflection of different types of radiation. The increase in such gases in the atmosphere, which contributes to global warming, is a result of the burning of fossil fuels, the emission of pollutants into the atmosphere and deforestation.

Gross capital formation (investment): Total investment during the accounting period. It includes both additions to the capital stock (net investment) and investment to replace worn-out capital (to make up for depreciation).

Gross domestic product (GDP): The value of all the final goods and services produced in an economy during some accounting period, usually a year.

Gross domestic product (GDP) deflator: Nominal GDP divided by real (constant dollar GDP) multiplied by 100. Nominal GDP is the value of output measured in terms of the prices prevailing in the accounting period in question. Real GDP is that output measured in terms of the prices prevailing in some base period. The value of the deflator in the base period is always 100.

Gross national expenditure (GNE): The sum of all spending on consumption and investment plus government spending on goods and services and net exports (total exports minus imports). It is equivalent in value to GDP.

Gross revenue: In general terms, the gross revenue is equal to the price multiplied by quantity of agricultural product sent to market.

Hedonic or relating to utility (Lit.: pleasure-related): A hedonic econometric model is one where the independent variables are related to quality, e.g., the quality of a product that one might buy or the quality of a job one might take up. A hedonic model of wages might correspond to the idea that there are compensating differentials – that workers would get higher wages for jobs that were less pleasing. A product that meets several needs, or has a variety of features, generates a number of hedonic services. Each one of these services can be thought of as generating its own demand, along with a resulting hedonic price. Although each separate component is not observable, the aggregation of all the components results in the observed product demand and equilibrium price. Quality improvements will appear to an observer as an outward shift of the product demand curve, as consumers are willing to purchase more at the prevailing price.

Hedonic pricing models: The method entails collecting large amounts of sample data and using statistical techniques (such as a regression analysis) to measure how one variable affects another. For example, a hedonic pricing model could help to determine how changes in air quality have an effect on property values.

Hicks-Kaldor criterion: Applied to determine whether a cost-benefit analysis supports a public project. The criterion is that the gainers from the project could in principle compensate the losers, i.e. that total gains from the project exceed the losses. The criterion does not go as far as the Pareto criterion, according to which the gainers would in fact have to compensate the losers.

Hotelling rent: Net return realised from the sale of a natural resource under particular conditions of long-term market equilibrium. It is defined as the revenue received minus all costs of resource exploitation, exploration and development, including a normal return to fixed capital employment.

Human capital: The attributes of a person who is productive in some economic context. Often refers to formal educational attainment, with the implication that education is an investment whose returns are in the form of wage, salary, or other compensation. These are normally measured and conceived of as private returns to the individual but can also be social returns. Human capital was invented by the economist Theodore Schultz in 1960 to refer to all those human capacities, developed by education, that can be used productively – the capacity to deal in abstractions, to recognise and adhere to rules and to use language at a high level. Human capital, like other forms of capital, accumulates over generations; it is something that parents 'give' to their children through their upbringing, and that children then successfully deploy in school, allowing them to bequeath more human capital to their own children.

Hypothecation: See Earmarking

Imperfect competition: A market situation where one buyer or more, or sellers, are important enough to have an influence on price.

Income effect: The effect of a change in income on the quantity of a good or service consumed.

Income elasticity of demand: The percentage change in quantity demanded divided by the percentage change in income.

Indifference curve: A curve showing all possible combinations of two goods among which the consumer is indifferent.

Indirect benefits: Secondary gains or improvements from a regulation that are not directly intended as benefits. For example, if an air pollution regulation concerned with motor vehicles results in not only reduced pollutant emissions but energy savings on gasoline consumption as well, the latter would be an indirect benefit. Conversely, added gasoline consumption resulting from a regulation should be treated as an indirect cost. Indirect benefits have to be substantiated and explained, since some indirect benefits may often be included in the direct benefit estimates.

Indirect costs: Costs that cannot easily be segregated or linked to compliance costs. For example, a certain proportion of a firm's administrative expenses is related to compliance costs. It is difficult, however, to determine that proportion, because of complying with a specific regulation. Direct compliance costs should be estimated to the fullest extent possible.

Industry: A group of firms producing similar products, hence the textile industry or the steel industry.

Inferior good: A good for which the demand decreases when income increases. When a household's income goes up, it will buy a smaller quantity of such a good.

Inflation: A general rise in the average level of all prices.

Interest: The payment made for the use of funds with which to create capital goods.

Interest rate: The percentage rate that must be paid for the use of investable funds.

Investment: Any use of resources intended to increase future production output or income.

Joint implementation (JI) or activities implemented jointly (AIJ): A concept indicating industrialised countries meeting their obligations for reducing their greenhouse gas emissions by receiving credits for investing in emissions reductions in developing countries. Proponents of joint implementation argue that such an international trade in emissions credits would achieve greenhouse gas reductions in industrialised countries at much lower costs, while providing foreign investment benefits to developing countries.

Kyoto Protocol: In the greenhouse gas programme, the Kyoto Protocol is an agreement between 159 nations that attended the 3rd Conference of Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC), which was held in Kyoto, Japan, in December 1997. The Kyoto Protocol specifies the deadlines and specific levels of greenhouse gas reductions that signatory countries are to achieve. Overall, developed countries are to reduce greenhouse gas emissions by 5.2 per cent between 2008 and 2012 as measured against 1990 emission levels.

Labour: The economically productive capabilities of humans, their physical and mental talents as applied to the production of goods and services.

Land (as production factor): All natural resources, the 'gifts of nature'.

Levy: A more general term covering both taxes and charges.

Liabilities: In general, debts owed by individuals or firms. In the case of commercial banks, their liabilities are largely in the form of what they owe their customers, that is, the total amount of deposits held.

Long-run average costs: Total costs divided by the number of units of output. The long-run average cost curve plots the relationship between output and the lowest possible average total cost when all inputs can be varied.

Long-run costs: Production costs where the firm is using its economically most efficient size of plant.

Long run: In the context of the theory of the firm, the long run is a period of time long enough for the firm to vary the quantities of all its inputs, including its physical plant.

Lorenz curve: Used to discuss concentration of suppliers (firms) in a market. The horizontal axis is divided into as many pieces as there are suppliers. Often it is given a percentage scale going from 0 to 100. The firms are listed in order of decreasing size. On the vertical axis are the market sales in percentage terms from 0 to 100. The Lorenz curve is a graph of the sales of all the firms to the right of each point on the horizontal axis. So (0.0) and (100.100) are the endpoints on the Lorenz curve and it is weakly convex, and piecewise linear in between. See also Gini coefficient.

Macroeconomics: The branch of economic theory concerned with the economy as a whole. It deals with large aggregates such as total output, rather than with the behaviour of individual consumers and firms.

Marginal analysis: An analytical technique which focuses on incremental changes in total values, such as the last unit of a good consumed, or the increase in total cost.

Marginal benefit: The increase in total benefit consequential to a one-unit increase in the production of a good.

Marginal cost: The increase in total cost consequential to a one-unit increase in the production of a good.

Marginal physical product: The change in total product measured in physical terms caused by a one-unit increase in a variable input.

Marginal propensity to consume: The part of the last dollar of disposable income that would be spent on additional consumption.

Marginal propensity to save: The part of the last dollar of disposable income that would be saved.

Marginal revenue: The addition to total revenue resulting from the sale of one additional unit of output.

Marginal revenue product: The change in total revenue that results from employing one more unit of a factor.

Market failure: A situation, usually discussed in a fictitious model, in which the behaviour of optimising agents in a market would not produce a Pareto optimal allocation. Sources of market failures are, among others, monopolies or oligopolies, producers which have incentives to under-produce and to price above marginal cost, which then provides consumers with incentives to buy less than the Pareto optimal allocation and externalities.

Market valuation: Market price valuation applied to national accounts; imputed value of natural resources and of their depletion and degradation, based on expected market returns. Methods applied, in the absence of market prices of natural assets, include:

- the net present value of the future net returns from the natural asset use;
- the net price method which determines the unit asset value as the difference between the market price of a raw material minus its unit exploitation cost (including a normal return to produced capital invested); and
- the user cost allowance, i.e. the difference between the finite net returns from the sales of an exhaustible asset during the accounting period and the 'true' income remaining after investing the allowance during the lifetime of the asset so as to penetrate a permanent income stream.

Market-based instruments: Measures and regulations that encourage changes in behaviour through market signals rather than through explicit directives regarding pollution control levels or methods.

Markets: Any coming together of buyers and sellers of produced goods and services or the services of productive factors.

Morbidity rate: The number of illnesses or cases of disease in a population in relation to the total population.

Multiplier effect: The tendency towards a change in aggregate spending to cause a more than proportionate change in the level of real national income.

National accounts: A system of macroeconomic categories of production and purchase in a nation. The production categories are usually defined to be output in currency units by various industry categories, plus imports. (Output is usually approximately the same as industry revenue.) The purchase categories are usually government, investment, consumption and exports, or subsets of these. The amount produced is supposed to be approximately equal to the amount purchased. In practice, measures are made by national governments. Alternatively, national accounts are a system of all the income received by economic actors within an economy. It can be measured as expenditure (on investment and consumption), income (wages, salaries, profits and rent) or as the value of output (expenditure of all goods and services). Inevitably these three different methods of estimating national accounts will produce different results, but these discrepancies are usually relatively small.

Net exports: The total value of goods and services exported during the accounting period minus the total value of goods and services imported.

Net present value (NPV): The present value of an investment, found by discounting all current and future income streams of income or expenditure by an appropriate discount rate.

Nitrogen dioxide (NO_2): A form of air pollution, viz. a brownish gas produced when nitric oxide emitted from power plants combines with the oxygen in the atmosphere. It can damage trees and lead to acid rain, which can harm lakes and streams and also corrode exposed materials. In the presence of sunlight and volatile organic compounds, NO_2 can contribute to the formation of ground-level ozone, or smog.

Nitrogen oxides (NOx): Often mentioned in discussions of nitrogen-based air pollution as a reference to both nitric oxide (NO) and nitrogen dioxide (NO_2). In addition to particulates and sulphur dioxide, NOx is one of the major electricity-related pollutants. It can transform to nitrates in the atmosphere (a fine particulate).

Open access resource: A material resource with no property right held by any individual or entity.

Opportunity cost: The best alternative sacrificed to have or to do something else.

Ozone (O_3): A pungent, faintly bluish gas composed of three atoms of the element oxygen. In the lower 10 kilometres of the atmosphere, it occurs as a pollution product formed by combining nitrogen oxides (NOx) and volatile organic compounds (VOCs) in the presence of sunlight. In this portion of the atmosphere, it is also a greenhouse gas. Above 20 kilometres, it is produced naturally and serves to protect life on earth from damaging ultraviolet radiation.

Panel data: Data from a (usually small) number of observations over time on a (usually large) number of cross-sectional units like individuals, households, firms or governments.

Pareto optimality: The condition where it is impossible to make any individual better off without making any other individual worse off.

Pareto optimum: Claimed to have been attained by an economy when resources and output cannot be reallocated in a way that will contribute to the improvement of welfare of some without worsening the welfare of others.

Particulate matter (PM): A form of air pollution that includes soot, dust, dirt and aerosols. It has readily apparent effects on visibility and exposed surfaces and can create or intensify breathing and heart problems and lead to cancer and premature death.

Pigouvian taxes: Taxes of equivalent penalties and charges assessed as required to correct for externalities caused by economic agents or producer-polluters.

Polluter pays principle: In its most basic form, the polluter pays principle requires that those causing (or potentially responsible for) environmental damage bear the financial costs of doing so. In turn, this usually implies that consumers of products and services which generate pollution in their manufacture/delivery 'see' (more or less) the costs of pollution in the price of the goods and services they purchase.

Precautionary principle: In the context of the Framework Convention on Climate Change it refers to the idea that action to forestall large-scale, irreversible damage from climate change is warranted even though the risks of climate change are not yet fully understood. The precautionary principle thus puts a premium on the long-term safeguarding of the world's climate system, even in the face of uncertainty about the impacts and the need to bear near-term costs of mitigation.

Price discrimination: The selling of a good or service at different prices to different buyers or classes of buyers in the absence of differences in the costs of supplying it.

Price elasticity of demand: The percentage change in the quantity of a good demanded by the percentage change in its own price.

Price: The amount (money) that must be paid to acquire the right to possess and use a good or service.

Principle of diminishing marginal utility: The proposition that the satisfaction derived from consuming an additional unit of a good or service declines as additional units are acquired.

Principle of diminishing return: The proposition that the marginal product of the last unit of labour employed declines as additional units of labour are employed.

Private goods: A good that cannot be consumed without having been paid for and the supply of which is reduced when it is consumed by a particular user.

Privatisation: The selling-off of state-owned enterprises to private owners.

Product differentiation: Causing buyers to believe that a particular version of a product is superior to that being offered by competitors.

Production possibilities: Levels of output which are within the range of possibilities for a particular economy.

Production possibility curve: A graphical representation of the boundary between possible and unattainable levels of production in a particular economy.

Profit: When a firm's revenues exceed its costs, profit is the difference between the two.

Provider-gets principle: Financial or in-kind compensation to an individual or an entity for providing environmental goods and services for the collective good. Could be viewed as the opposite of the polluter pays principle or the internalisation of positive externalities.

Public goods: A good that can only be supplied to all if it is supplied to one and the availability of which is not diminished by any one consumer's use thereof.

Renewable energy technology: A technology relying exclusively on an energy source that is naturally regenerated over a short time and is derived either directly or indirectly from the sun, or from moving water or other natural movements and mechanisms of the environment. Renewable energy technologies include those that rely on energy derived directly from the sun, on wind, geothermal, hydroelectric, wave or tidal energy, or on biomass or biomass-based waste products, including landfill gas. A renewable energy technology does not rely on energy resources derived from fossil fuels or waste products from inorganic sources.

Renewable resources: Resources that do not use exhaustible fuels. Sources of renewable energy include water, wind, solar and geothermal energy, as well as some combustible materials, such as landfill gas, biomass and municipal solid waste.

Rent-seeking: The activities of individuals or firms to obtain special privileges, such as monopoly power, which will enable them to increase their incomes. Using of resources to win such privileges from governments or their agencies.

Salinity of water: The salt content of water. Four quality classifications are used:

- fresh (TDS < 500 mg/L)
- marginal (TDS 500 to 1 500 mg/L)
- brackish (TDS 1 500 to 5 000 mg/L)
- saline (TDS > 5 000 mg/L)

Satellite remote sensing: The collection of data on land use, industrial activity, weather, climate, geology and other processes through earth observations from satellites in outer space.

Scarcity: The incidence of human wants exceeding the means of satisfying them.

Shadow price: Shadow prices are opportunity costs where the latter differ from market prices due to some distortion such as indirect taxes or subsidies.

Short run: In the theory of the firm, a period of time that is too short for changes to be made in all inputs. For example, a period not long enough to permit the size of the physical plant to be altered.

Sink: A reservoir of any medium which assimilates or absorbs pollutants and thus contributes to the uptake of a pollutant from a part of the atmospheric cycle.

Smog: Literally a contraction of 'smoke' and 'fog'; smog includes ground-level ozone and numerous other contaminants. It tends to provide a brownish-yellow haze to the atmosphere, especially over urban areas.

Social cost: The real cost to society of having a good or service produced, which may be greater than the private costs incorporated by the producer in its market price.

Substitute goods: Goods that may be used in the place of other goods.

Substitution effect: The change in the quantity of a good demanded resulting from a change in its relative price, leaving aside any change in quantity demanded that can be attributable to the associated change in the consumer's real income. It may also be thought of as a change in the quantity demanded as a result of a movement along a single indifference curve.

Sulphur dioxide (SO_2): Air pollution in the form of a gas, resulting from the combustion of fuels that contain sulphur. SO_2 is most prevalent in the combustion of coal.

Sustainable development: A broad concept referring to the need to balance the satisfaction of near-term interests with the protection of the interests of future generations, including their interests in a safe and healthy environment. As expressed by the 1987 UN World Commission on Environment and Development (the Brundtland Commission), sustainable development '... meets the needs of the present without compromising the ability of future generations to meet their needs'.

Tariff: A tax imposed on an imported good.

Tax: A compulsory, unrequited payment to government where benefit distributions are not proportional to the taxpayer's payment.

Tax base: The aggregate value of income, sales or transactions on which particular taxes are levied.

Tax-GDP ratio: A ratio used to measure a country's tax burden. It is calculated by taking the relative tax payments for a particular fiscal year as a fraction or percentage of the gross domestic product for that year.

Tax incidence: The final distribution of the tax burden. Statutory incidence defines where the law requires a tax to be levied. Economic incidence refers to the way in which the effects of a tax are experienced in market transactions.

TDS: Total dissolved solids in a water sample, measured in mg/L.

Technology transfer: In the context of climate change, technology transfer policy most often refers to the process by which energy-efficient technologies and processes developed by industrialised nations are made available to the less-industrialised nations. These transfers may be conducted solely through the efforts of private parties or may involve governments and international institutions.

Tradable emissions permits: A market-based instrument used in an environmental regulatory scheme where the sources of the pollutant to be regulated (most often an air pollutant) are given permits to release a specified number of tons of the pollutant. The government issues only a limited number of permits consistent with the desired level of emissions. The owners of the permits may keep them and release the pollutants, or reduce their emissions and sell the permits. The fact that the permits have value as an item to be sold gives the owners an incentive to reduce their emissions.

Tragedy of the commons: A metaphor for the public goods problem that it is hard to coordinate, and pay, for public goods. The commons is a pasture held by a group. Each individual owns sheep and has the incentive to put more and more sheep on the pasture – for private gain. The overall effect of many individuals doing this overwhelms the carrying capacity of the pasture and the sheep cannot all survive.

Transaction cost: The totality of cost (not including market prices of the sale/purchase) of exchanging and enforcing property rights or of undertaking market/non-market transactions.

User charge: Compulsory, requited payments from a willing buyer based on the individual benefit principle. Payments are therefore usually made in proportion to the level of benefits derived from the good or service.

Vulnerability: Defines the extent to which climate change may damage or harm a system. It depends not only on the sensitivity of a system but also on its ability to adapt to new climatic conditions.

X-inefficiency: The failure to minimise costs or maximise returns. (Sometimes referred to as X-efficiency, but carrying the same meaning.)

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