THE EFFECT OF A TAX ON COAL IN SOUTH AFRICA: A CGE ANALYSIS

by

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The Effect of a Tax on Coal in South Africa: A CGE Analysis

Probably the biggest concern for South African policy makers is the high level of unemployment that persists in the economy. There is thus an urgent need for policies that could increase employment growth. Any policy that could address these issues, would undoubtedly find favour with policy makers.

Despite high levels of unemployment and social imbalances, there are also concerns about South Africa's environmental management. It seems as if the debate of sustainable development, that has held the attention of policy makers in developed regions of the world for the past decade, has finally caught up with South Africa. One of the concerns that needs to be addressed is the relatively high level of CO_2 emissions created by economic activity in South Africa.

Given the issues discussed above, the purpose of this study is to determine whether policy makers in South Africa could introduce environmental taxation in the form of an intermediate tax on coal, without aggravating the problems of unemployment and the skew welfare distribution. The literature pertaining to the "double dividend" and the "Porter Hypothesis" motivates the possibility of achieving this result.

The results from this study indicate that South African policy makers should approach the problem of controlling the demand for coal with caution. It is shown that any policy that attempts to increase the price of coal would achieve very little environmental benefit. Although such a tax could serve as an attractive source of revenue for the government, the socio-economic benefits achieved through recycling of the tax would also be small and it is debatable whether they would warrant the administration and political debate that would accompany them.

It is therefore evident that policy makers will have to invest in research and development programs that will result in a reduction in the use of coal within the production process. Results from policy simulations have indicated that successful implementation of such an investment would not only reduce CO_2 emissions significantly, but could also increase economic growth, welfare and employment.

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CHAPTER 1

INTRODUCTION AND BACKGROUND

1.1 INTRODUCTION

There is a global trend towards sustainable environmental management and it is hard to imagine that the South African society will not be affected by this. In fact, statements by Government Departments, such as the Department of Minerals and Energy and the Department of Environmental Affairs and Tourism, indicate that the South African government is actively investigating the possibilities and consequences of South Africa's environmental responsibilities.

It would not be far-fetched to state that South African macro economic policy makers have established international recognition for the prudent manner in which they have approached South Africa's macroeconomic challenges since the landmark elections held in 1994. However, despite the successes that have been achieved, a number of concerns remain, of which sustainable development, the high level of unemployment and social imbalances are major aspects.

In the first instance, South African policy makers have to consider the objective of increasing future economic growth within a framework that ensures that current economic achievements are sustainable. Sound management of natural resources is therefore becoming an integral part of South African policy makers' responsibilities. Due to the fact that South Africa is relatively energy intensive, authorities have started to examine different approaches for managing its extensive resource base. One of the main concerns with regard to sustainable development is South Africa's current level of carbon dioxide (CO_2) pollution.

The use of coal is the major contributor towards the high level of CO_2 pollution in South Africa. The country is endowed with a significant portion of the world's coal reserves and as a result, coal is used relatively cheaply to fulfil more than 75 percent of energy needs. The largest consumer of coal in South Africa is the electricity supply industry, which uses coal as its primary input. Coal accounts for about 93 percent of electricity generating capacity in South Africa (http://wwwfe.doe.gov/international/safrover.html, p15). This results in severe pollution and electricity generation from coal is the single largest source of CO_2 emissions, with a contribution of more than 53 percent towards aggregate national CO_2 emissions. Apart from this, the use of coal-derived petroleum products contributes a further 14 percent to national CO_2 emission levels. It is therefore not surprising that South Africa is the biggest contributor towards CO_2 pollution on the African continent (http://wwwfe.doe.gov/international/safrover.html, p19).

South African policy makers have a number of possible policy instruments at their disposal for addressing the environmental problem. A system of national environmental taxes would be a definite consideration in this regard. Taxes, however, distort economic behaviour and environmental taxation has several drawbacks. Besides popular criticism that refers to the loss of competitiveness that arises in countries that unilaterally adopt this type of taxation, more recent criticism has emerged. This criticism is directed towards subjects such as loss of efficiency and the complex nature of environmental taxation when more than one externality is present. These externalities include positive spillovers such as research and development. Also more importantly, it is generally accepted in economic literature that the benefit provided by environmental taxation is too costly in terms of the resultant lower economic growth because regulations imposed on firms can reduce the overall level of employment and investment in the economy (Carraro and Soubeyeran, 1996, p73).

Concerns regarding the negative effects of environmental taxation are further highlighted by the fact that South Africa cannot afford to implement policies that could have negative consequences for economic growth and employment. It is well known that South Africa struggles with one of the highest levels of unemployment in the world and that current levels of economic growth are not sufficient to address this issue. It is also well known that a reduction in the unemployment rate is foremost on the agenda of policy makers in South Africa. It is almost certain that any policy that could decrease economic growth or employment will not find support from policy makers or in broader South African society, regardless of the consequences of pollution for sustainable development.

1.2 OBJECTIVE OF THE STUDY

It is within the above-mentioned context that this study tests whether it is possible for policy makers to design an environmental policy that could achieve a simultaneous reduction in CO_2 pollution and increase economic growth and employment. Although the design of such a policy could seem ambitious, economic and environmental literature proposes two hypotheses that suggest that it is possible. These are the “double dividend hypothesis” and the “Porter hypothesis” (Goulder, 1994 and Jaffe, 1997).

The "double dividend hypothesis" suggests that switching the burden of taxation from labour to pollution could reform the South African fiscal system in a way that would reduce unemployment and increase economic growth. The "Porter hypothesis" suggests that environmental taxation could induce technological innovation in industries that are affected by environmental policies. This technological innovation could reduce pollution and unemployment while also contributing to economic growth.

These hypotheses are, however, controversial in many respects and have gained a significant amount of international interest from economists, environmentalists and policy makers. Much theoretical and practical research has been performed on the question of whether it is possible to obtain benefits simultaneously in both the non-economic and economic domains by internalising pollution externalities. If the answer is positive, one could infer that such a "no-regrets" environmental policy would correct market imperfections and contribute to economic growth and the reduction of unemployment in South Africa.

For illustrative purposes a policy that introduces a tax that increases the cost of coal by 50 percent (in the production processes of South African industries) is implemented. The use of coal as the object of taxation is chosen because of the importance of this resource in satisfying South Africa's energy needs, and because of the positive relationship between the use of coal and CO_2 emissions.

The methodology of the study is comprised of:

i. An investigation and description of the two economic problems that are addressed in this study. The first problem that will be investigated is the contribution of consumption of coal towards South African CO_2 pollution. The second is the problem of unemployment in the South African economy.

ii. Descriptions of these economic problems are followed by an investigation and review of the double dividend and the Porter hypotheses. This review consists of an overview of the economic literature that concerns itself with both the theoretical and practical sides of the two theories.

iii. Investigation of the economic theories is followed by a description of a Computable General Equilibrium model (CGE model) that is used to test different environmental policy proposals.

iv. Finally, results from the different policy proposals are reported and recommendations are made towards the design of an environmental policy that could address environmental concerns without harmful consequences for the economy.

1.3 OUTLINE OF THE STUDY

This thesis can be divided into four sections. The first section can be described as "The Problems" (consisting of Chapter 2 and Chapter 3). Chapter 2 describes the South African coal sector, the use of coal in South Africa and the pollution problem that is associated with this resource. Chapter 3 describes South Africa's problem of unemployment and how it seems to be limited to the unskilled and informal sector labour force.

The second section can be described as "The Literature Review" and consists of Chapters 4, 5 and 6. Chapter 4 describes the literature and theory behind the double dividend hypothesis, while Chapter 5 describes some empirical findings from studies that have been performed to test this hypothesis. Chapter 6 describes the literature and theory behind the Porter hypothesis and highlights the potential role that technological change plays in obtaining the dual objective of economic growth and an improved environment over the long term.

The third section consists of "The Model" (Chapters 7, 8 and 9). Chapter 7 briefly describes the concept of a general equilibrium- and computable general equilibrium (CGE) model. This chapter is included for the benefit of "non-economic/non-modeller" readers. Chapter 8 describes the structure of the CGE model that is used in this study, while Chapter 9 describes the database and the derivation of the various elasticities that are used within the model.

"The Results" make up the fourth and last section (Chapters 10, 11 and 12). The model closures are described in Chapter 10, while the results of the short-run simulations are reported in Chapter 11. These short-run simulations are proposed to test whether some form of double dividend is possible in the South African economy over a short time period. It is shown that certain applications of tax revenue would achieve positive welfare and economic benefits in the short run. In spite of this, the short run simulation results indicate that without technological innovation, the environmental benefit from environmental taxation would insignificant. Chapter 12 builds on the results of the short-run simulations in Chapter 11 – the scenario of whether technological innovation could result in positive benefits for the environment and the South African economy is tested.

A summary follows in which the results of the study are summarised. Recommendations towards further study and policy objectives are made.

CHAPTER 2

THE USE OF COAL AND CARBON POLLUTION

2.1 INTRODUCTION

South Africa is an energy and carbon intensive country in comparison to other African countries and developed nations. The country is ranked 16th in the world in terms of the total amount of primary energy consumption, and depends mainly on fossil fuel to supply its energy needs. Coal provides approximately 75 percent of the required fuel, while the remaining 25 percent of primary fuel supply comes from crude oil (10.1 percent) and renewable resources such as wood and bagasse (9.8 percent). The contribution of nuclear energy in South Africa is small compared to the importance it has in energy supply in some European countries, with only about 3 percent of the country's primary energy taken from nuclear sources (http://www.environment.gov.za/soer/nsoer/drivers/general/energy.doc).

The aim of the research in this study is to analyse the economy-wide effects of a revenue neutral tax on coal, and it is therefore important to describe the country's dependence on this resource for its energy needs. It is also necessary to analyse the structure of the South African coal sector and its economic linkages. This will provide insight into the possible effects that the proposed tax would have on the South African economy.

Below is an introduction to the South African coal industry. The introduction is followed by an analysis of the structure of the coal sector and its economy-wide linkages. Finally, the environmental consequences of CO_2 pollution are briefly described and a motivation is given for the use of environmental taxes.

2.2 AN INTRODUCTION TO THE SOUTH AFRICAN COAL INDUSTRY

Coal has played an important role in the South African economy from as early as 1880, when coal from the Vereeniging area was supplied to the Kimberley diamond fields. The subsequent discovery of gold in the Witwatersrand region, and the growing rail infrastructure across the sub-continent assured an ever-increasing demand for South Africa's coal deposits. This trend continued, and as South Africa's economy became more dependent on the mining sector, coal was increasingly used to generate steam, compressed air and electricity (http://www.eskom.co.za/about/companyinformation/factsheets).

At present, the use of coal is more diversified and this natural resource mainly serves the primary energy needs of the electricity, petro-chemicals and steel industries. Other industries have also become dependent on the use of coal. These include the brick-making, cement and lime industries. Apart from being a significant source of energy, the coal industry has also evolved into one of the sectors that contributes significantly towards South Africa's foreign exchange earnings, and South Africa has become one of the world's largest exporters of coal (http://www.eskom.co.za/about/companyinformation/factsheets). This is not surprising if one considers that South Africa is one of the world's leading producers of coal. Table 2.1 summarises the production statistics of the world's main coal producing countries in 2000. It is interesting to note that South Africa is ranked sixth among these coal producers.

Table 2.1: Production statistics for the world's coal producing countries 2000

	Production		
Country	**Million tonnes**	**% Of total**	**World Ranking**
China	1171.1	32.2	1
USA	899.1	24.7	2
Former Soviet Union	321.6	8.8	3
India	309.9	8.5	4
Australia	238.1	6.5	5
South Africa	224.1	6.2	6
Poland	102.2	2.8	7
Indonesia	78.6	1.9	8
Canada	59	2.2	9
Germany	37.4	1.0	10
Colombia	37.1	1.0	11
UK	32	0.9	12
Other	153.7	4.2	13
Total	3663.9	100	14

Source: International Energy Agency, 2001

2.3 THE STRUCTURE OF THE COAL INDUSTRY

2.3.1 Coal Production

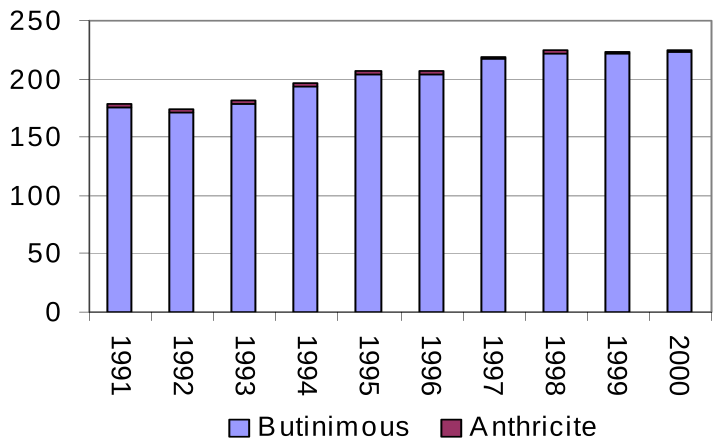
South Africa's coal deposits are located in 19 different coal fields situated in the North–Eastern region of the country, with 80 percent of total coal extraction taking place in Mpumalanga, 10 percent in Limpopo Province and the remaining 10 percent in the Free-State and KwaZulu-Natal. The three largest mining groups (Ingwe, Anglo Coal and Sasol) are responsible for 80 percent of total extraction in these provinces. The coal extracted in Mpumalanga and Limpopo Province is classified as bituminous, while the coal that is mined in KwaZulu-Natal consists of anthracite. The recoverable coal reserves in South Africa amount to approximately 55 billion tonnes, which is equivalent to nearly 11 percent of the world's total coal reserves.

During 2000, opencast mines provided 57.3 percent of the run-off mine coal production. The seven largest collieries were responsible for 57 percent of total output. Five large mines produced 16 percent, nine medium sized mines produced 15 percent and forty-one small mines produced the remaining 12 percent.

2.3.2 Coal consumption and forward linkages

South Africa's total coal production increased over time and stabilised during the late 1990's at levels of around 220 million tonnes per annum. Figure 2.1 reflects South Africa's coal production during the 1990's.

Figure 2.1: South African coal production (millions of tonnes) 1990 - 2000



Source: Digest of South African Energy Statistics, 2001

During 2000 the coal industry in South Africa produced 224.2 million tonnes of coal. Approximately 70 percent of total production was used domestically in either the energy transformation sector or as an important input in specialised industries. The remaining 30 percent that was not domestically consumed, was exported to over 41 countries of which Spain, the Netherlands, France, Israel, India, Germany, Italy, Great Britain, Portugal, Korea and Taiwan were, in order of importance, the largest customers, receiving nearly 90 percent of South Africa's coal exports. The diversified export base that the coal sector enjoys is also reflected in the ever-increasing amount of coal that is exported. It is therefore not surprising that the 68.2 million tonnes exported from South Africa in 2000 had more than double from the 31.1 million tonnes exported in 1980 (Prevost, 2001, p47).

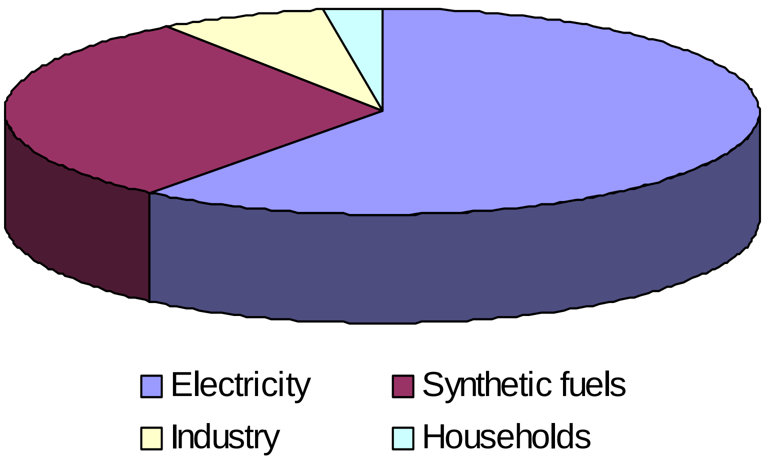
Within the energy transformation sector, electricity plants and the fuel transformation sector are the main users of coal. The high dependence of the energy sector on coal is not surprising if one considers the abundance of coal in South Africa and the historical support that the electricity and synthetic fuel industries have enjoyed from the government.

A case in point is South Africa's main electricity provider, Eskom, which has managed to extend access to electricity at low prices to more than 2.5 million households. This performance has been made possible by low coal prices, utilising power station technologies that maximise economies of scale and exploit the lowest cost of coal, exemption from taxation and dividends, financing subsidies and over–capacity. It seems as if investments in Eskom power plants have effectively been subsidised using public funds. Examples of this subsidisation are the forward cover protection that Eskom enjoyed to protect it against changes in exchange rates and exemptions from having to pay taxes and dividends even after investments have been paid off. This has resulted in the current situation where consumers are only paying for energy costs, because capital costs have been paid off. The overall effect of this situation is that the price of electricity does not reflect its true costs; full capital costs are not reflected, nor are externalities priced. The low price of electricity has, however, resulted in an increase in electricity provision and a subsequent increase in the use of coal, which does not reflect opportunity costs to South Africa as a whole (Winkler et al, 2001, p2).

Apart from Eskom, South Africa's largest synthetic fuel producer, Sasol has also benefited from generous government subsidies in order to allow the industry to develop the technology and infrastructure for converting coal into liquid fuels. These subsidies have taken the form of schemes such as protection against low oil prices. Although levels of protection have decreased significantly, interventions have enabled Sasol to provide synthetic fuels to the South African market by making use of low cost coal inputs.

Outside of the energy transformation sector, the steel and the non-ferrous metals industry is highly dependent on the use of coal for its smelting ovens, while individual households use less than one percent of South Africa's coal production (Prevost, 2001, p49). Figure 2.2 reflects the broad breakdown of domestic coal consumption during 2000.

Figure 2.2: South African coal consumption during 2000



Source: Digest of South Africa Energy Statistics, 2001

It is apparent that the electricity, synthetic fuels and iron and steel industries would be adversely affected by the introduction of a policy that taxes the intermediate use of coal. Apart from making intensive use of coal, these industries employ 1.60 percent of South Africa's labour force and 11.35 percent of the country's capital stock (Social Accounting Matrix of South Africa, 2001). This implies that the aforementioned industries are relatively capital intensive and that the burden of the tax policy would primarily fall on capital.

Although environmental taxation could have a negative effect on the aforementioned industries, these industries contribute significantly towards South Africa's pollution problems and it is increasingly clear that measures need to be implemented to address this environmental concern.

2.4 COAL CONSUMPTION AND THE ENVIRONMENT

Concerns about the consequences of environmental exploitation have been raised for decades. A quote by Schumacher in 1970 summarises the concerns of environmental economists more than three decades ago.

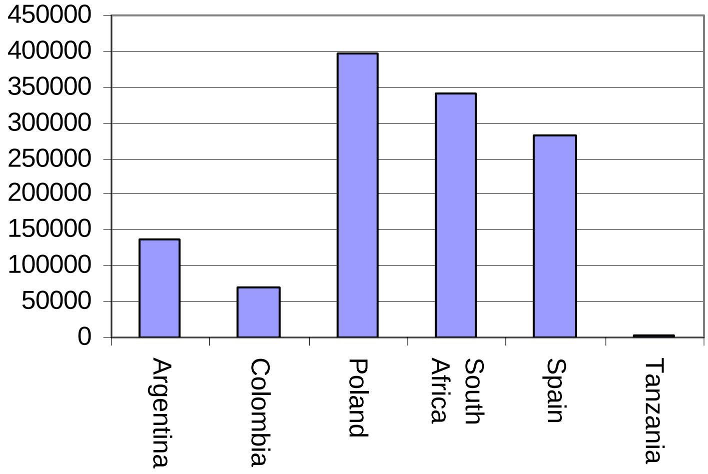
"Modern man does not experience himself as a part of nature but as an outside force destined to dominate and conquer it. He even talks of a battle with nature, forgetting that, if he won the battle, he would find himself on the losing side ………..many people, albeit a minority, are beginning to realise what this means for the continued existence of humanity" (Schumacher, 1973, p13)

Although these concerns had been raised for decades, it was only during the 1990's that the threat of environmental degradation increasingly came to the fore. It became evident that excess greenhouse gas emissions (especially carbon dioxide (CO_2) and sulphur dioxide (SO_2)) were increasing temperatures on earth. This increase in the earth's temperature is referred to as global warming and holds significant economic and health costs. It is therefore not surprising that a number of international policies and agreements have been put in place to address the issue. One such agreement is the Kyoto protocol of 1997 in which 160 nations decided to reduce the emissions of CO_2 and other greenhouse gases to an average of five percent below the levels experienced in 1990.

Although South Africa as a developing country is not bound by the targets set out by the Kyoto protocol, it does support the agreement in principal, and policy makers are investigating methods of reducing South Africa's greenhouse emissions.

With regards to global air pollution, South Africa contributes significantly to this problem on the African continent. Given the dependence of the South African energy industry on coal burning, it is not surprising that the energy sector is the single largest source of CO_2 and SO_2 pollution in the country. South Africa is among the top ten countries contributing to the global greenhouse gas effect, making up 1.2 percent of the total contribution in 1990 (van Tienhoven, 1999, p1). South Africa also accounts for 15 percent of the greenhouse gas emissions on the African continent and it should be no surprise that South Africa's carbon dioxide equivalent emission rate per person is 10 tonnes of CO_2 per year. This is well above the global average of 7 tonnes of CO_2 per person per year. It is also twice as much as that of other developing countries such as Mexico, Argentina, Zimbabwe and Algeria. In spite of this, it is also important to note that South Africa's emission rates are considerably below those of countries such as the U.S., which has emission rates above 20 tonnes per person per year (http://www.environment.gov.za/soer/nsoer/drivers/general/energy.doc). Figure 2.3 compares the World Bank's projected South African CO_2 emissions with countries that have a population size that is comparable to South Africa's. Countries with a population of between 35 and 45 million people are included. The figures indicate that South Africa's CO_2 emissions are indeed relatively higher than those of its peers.

Figure 2.3: A comparison of total CO_2 emissions (million tonnes) 2002



Source: World Bank World Development Indicators

The high level of CO_2 emissions has negative externalities, not only for the global environment but also domestically. Terblanche (1993) indicates that warmer temperatures in South Africa may result in a significant number of health related problems. A few of the problems that he highlights are listed below.

i. More heat related deaths, especially among the elderly.
ii. Increased risk of epidemic and infectious illnesses, such as Malaria, which have been positively linked to both temperature and rainfall increases in South Africa. It seems as if the incidence of Malaria epidemics has slowly increased since 1993.
iii. Increased ozone levels in the lower atmosphere, which could have an effect on respiratory health.
iv. Depletion of upper atmosphere stratospheric ozone, which results in more of the harmful ultra-violet B radiation reaching ground level. This could lead to an increase in the incidence of skin cancer and cataracts. It could also result in a reduction in the effectiveness of the immune system.
v. Although most people associate air pollution with urban outdoor environments, some of the highest pollution concentrations are found in rural, indoor environments. About 2.8 million people die each year in developing countries due to indoor exposure to particulate matter and 0.2 million due to outdoor exposure to suspended particulate matter. In South Africa

this problem is particularly evident among children of low-income families who live mainly in rural areas and in inadequate housing.

Despite these negative health effects, Terblanche (1993) also lists the possible negative externalities that increased CO_2 emissions hold for the ecosystem.

i. Increased ultra-violet B radiation could cause damage to the photosynthetic pathways and the genetic structures of plants.

ii. Rising carbon dioxide levels generally have a stimulatory effect on plant growth, and especially on water use efficiency which results in higher ocean water levels. Although it is difficult to predict, continued rapid rise of the oceans above levels that have been experienced over the past million years could have a negative impact on the climate (Terblanche, 1993).

It is evident that South Africa's contribution towards the world's carbon emissions is significant and that this issue needs to be addressed. The high level of carbon emissions is a direct result of the high level of coal consumption in the country and measures need to be taken in order to reduce the high level of pollution.

It is against this background that the South African government is suggesting the introduction of environmental measures to address high levels of pollution. Table 2.2 below compares the status quo with regard to the management of South Africa's environmental resources and the proposed future management thereof.

Table: 2.2: Accounting for the Natural Environment

Status Quo	Future Outcomes
Some macroeconomic policies (e.g. subsidies) encouraging the depletion of natural resources and the degradation of the environment.	Optimal use of exhaustible resources and mechanisms for saving and investment in future times of depletion.
Market prices reflect low costs of energy, water, air and other environmental media.	Market prices need to reflect true cost of energy, air and other environmental media.
Fiscal base on income and labour taxing.	Fiscal base on taxing of pollution.

Source: Department of Environmental Affairs and Tourism, 1999

2.5 ECONOMIC INCENTIVES FOR REDUCTION OF CARBON POLLUTION

As stated in Chapter 1, environmental taxes are one of the measures that the South African government can implement to address environmental management in South Africa. Blackman *et al* (1999, p3), state that indirect instruments, such as environmental taxes may stand a better chance of being effective in developing nations (than command and control measures), because they are less demanding of regulators than direct measures of pollution control. They come to this conclusion, by evaluating the performance of tradable permits, emissions fee programs and environmental taxes in developing economies that have instituted some (or all) of these measures in order to address environmental concerns. Blackman *et al* (1999) distinguish between three types of environmental taxes:

i. taxes on final products associated with pollution (such as motor vehicles);
ii. taxes on goods which are generally used as inputs into a polluting activity (such as coal); and
iii. taxes on polluting substances contained in inputs (such as sulphur contained in coal).

According to Blackman *et al* (1999) these taxes can have two types of advantageous impacts, these being, fiscal and environmental impacts. These impacts are, however, inversely related and depend on the elasticity of demand for the taxed good. If demand for the taxed good is highly inelastic, taxes will generate significant revenue, but would not have significant environmental effects. If the demand for the taxed good is highly elastic, taxes will have significant environmental effects but will not generate significant revenue. Because demand elasticities are usually more elastic in the long run, the impact of environmental taxes will usually be fiscal in the short run and environmental in the long run (Blackman *et al*, 1999, p4).

Apart from being a tool to raise revenue, environmental taxes are also relatively easy to administer. The reasons for this include the fact that quantities of goods are usually much easier to monitor than quantities of emissions; and environmental taxes operate through government tax collection institutions rather than environmental regulatory institutions, the former being more established and effective than the latter in most developing countries (Blackman *et al*, 1999, p4)

Environmental taxes, however, also have a number of disadvantages. Firstly, they do not create incentives to abate emissions per se, only to limit purchases of goods linked with emissions. Environmental taxes may also affect non-targeted activities. An example would be a tax on coal that would affect chemical manufacturers who use coal as a feedstock, not as a fuel. Environmental taxes may also be less politically acceptable than other regulatory instruments because the costs associated with them are highly visible. Finally, environmental taxes may have distributional impacts in that they could have a more severe impact on poor households than on rich ones. These distributional impacts may be redressed by using tax revenue to finance new expenditures that benefits poorer households (Blackman *et al*, 1999, p4).

Despite of the abovementioned disadvantages of environmental taxation, Blackman *et al* (1999), conclude that a comparison with other incentive measures such as tradable permits and emission fees indicates that environmental taxes would provide the most efficient way to overcome financial and institutional constraints on direct regulation (Blackman *et al,* 1999, p29).

2.6 CONCLUSION

The low cost of coal in South Africa has resulted in the development of an energy sector that has become highly dependent on the use of coal. Due to coal dependence, energy sector industries contribute significantly towards South Africa's levels of CO_2 pollution and make South Africa a major contributor towards CO_2 pollution on the African continent. Because higher levels of CO_2 pollution have negative health and ecological consequences, the global drive towards an improved environment is forcing South African policy makers to re-evaluate their environmental policies. Although a number of measures are available to policy makers, it seems as if environmental taxation would be the option that would be the least challenging with regard to environmental and regulatory requirements.

CHAPTER 3

THE SOUTH AFRICAN LABOUR MARKET

3.1 INTRODUCTION

The unemployment rate in South Africa is exceptionally high and arguably the most pressing concern that faces policy makers. According to the conventional (narrow) definition of unemployment, which applies a job search test, one in every four adults in South Africa who wants work and is actively looking for work, is unemployed. Apart from this, there are also extreme wage inequalities and disparities in the incidence of unemployment between different race groups.

Given the importance of employment income in total household income, the varying incidence of unemployment across different groups has important implications for the distribution of income and for the incidence of poverty (Kingdon *et al*, 2001 (a), p1). Apart from this, high unemployment seems to coexist with comparatively low levels of labour force participation with the result that an even smaller proportion of the working age population is actually working (Klasen *et al,* 2000, p1).

There are therefore two major labour market issues that need to be addressed, these being how to create more jobs and thereby reduce unemployment in South Africa, and how to remove or at least reduce labor market inequalities. In this chapter the unemployment problem in South Africa is described and analysed. The analysis is done to determine the extent of South Africa's unemployment problem, and whether it is possible to design an environmental policy that will have the desired effect on the level of employment in South Africa.

Subsequent chapters that analyse the theory behind obtaining a double dividend will indicate that it is important to determine whether the unemployment problem is a labour demand-side, or a labour supply-side problem. Evidence from European markets indicates that the wage elasticities of both labour supply and demand play an important role in the possible attainment of a double dividend. If the wage elasticity of supply were relatively low (inelastic), an increase in the demand for labour could result in an increase in wages, which would not have the desired effect on unemployment. In the event that the wage elasticity of supply were relatively high, an increase in the demand for labour would actually result in an increase in employment.

The South African labour market is analysed by reporting the results of previous studies that address the unemployment problem. The aim is to determine whether the current literature concerning the South African labour market indicates whether policies that address the demand for labour would result in a decrease in the unemployment rate. This is done by:

i. describing the labour market by referring to the state of employment and unemployment in the country;
ii. giving a review of some findings that argue that the unemployment problem in South Africa is involuntarily;
iii. discussing reasons for the high rate of unemployment; and
iv. reviewing solutions that have been suggested for solving the unemployment problem.

3.2 SOUTH AFRICAN UNEMPLOYMENT: A DESCRIPTION OF THE MARKET

According to Fallon *et al* (1998) there are a number of features of the South African labour market that stand out as being rather unusual for a country at South Africa's present stage of development:

i. The level of urbanisation is relatively high and agriculture accounts for a low share of the labour force;
ii. Formal wage employment is by far the largest source of productive labour absorption;
iii. The urban informal sector is a relatively small employer; and
iv. Unemployment is extremely high.

Contrary to evidence for other developing countries, South Africa's labour force is mostly employed in urban areas, as only 38.5 percent of the labour force is found in rural areas. Apart from this, only 10.7 percent of the labour force is employed in the agriculture sector. This relatively low level of employment in agriculture is not surprising given the systematic encouragement of capital-intensive agriculture by previous governments and the eradication of subsistence farming in much of the country in earlier decades by policies such as the various Land Acts. These factors had a detrimental effect on the absorption capacity of the labour market, because agriculture acts as a valuable buffer in most developing countries as it absorbs what would otherwise be excess labour supply (Fallon *et al*, 1998, p3).

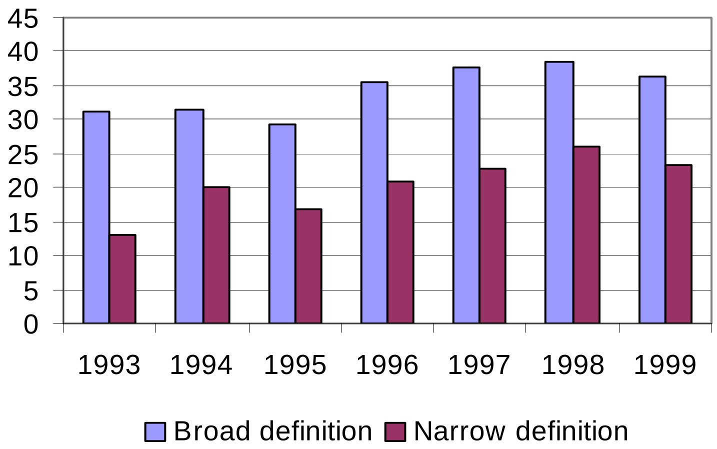
In contrast to the minimal role that the agricultural sector plays in the South African economy, the formal sector is the largest employer of South African labour. Estimates of the labour force in 1995 suggest that approximately 49.9 percent of the labour force in South Africa holds formal jobs, and although the proportion varies across racial groups, it remains true that the formal sector generates the most employment for every racial group. The formal employment sector is highly unionised with 35.1 percent of the formal workforce affiliated to a trade union. Despite the significant amount that this sector contributes towards total employment in South Africa, the employment performance of the formal sector has been disappointing. Formal employment growth peaked in the 1960s at an annual rate of 2.9 percent per year. This declined to 1.9 percent in the 1970s, and dropped further to 0.7 percent in the 1980s. The situation reached a critical stage in the 1990's and average employment growth during this period was negative and reached an all time low in 1996 at 6.9 percent below its average level of the 1990's. Within the formal sector the government has been the only consistent employer over the past 20 years, with a yearly employment growth rate of 4.5 percent in the 1970s and 3.4 percent in the 1980s. If not for the government, employment growth would have been negative in the period 1976-1990 (Fallon *et al*, 1998, p7).

Informal sector employment such as casual work, and self-employment in agriculture and other activities, comprises only a minor part of the labour market and absorbs only 14.6 percent of the labour force. Urban informal activities are heavily based upon trade, while the rise of black taxi services in the 1980s is estimated to have employed nearly 300 000 workers by the end of the decade (Fallon *et al*, 1998, p5).

The slowdown in employment over the past three decades was not matched by a reduction in labour supply growth. This caused an increasing imbalance in recent years between levels of labour supply and formal sector employment. Labour supply estimates indicate that African labour force growth increased from about 2.5 percent per year in the early 1960s to about 2.8 percent in the 1980s, while growth of other Black groups declined from 2.8 percent to 2.6 percent. The imbalance between black labour supply and formal sector demand grew substantially in 1970-1994, and now stands at over 50 percent. In contrast to this, the proportion of Whites without formal jobs remained reasonably constant in the 1970's and the 1980's, although it increased significantly in the 1990's (Fallon *et al*, 1998, p8).

A distinction must be made between the two definitions of unemployment that are commonly utilized, these being the broad and the narrow definitions. The narrowly defined unemployed are those individuals who are currently not employed, but who have looked for work in the past four weeks. The broadly defined unemployed consist of the narrow unemployed plus those who say they want to work but have not looked for work in the past four weeks (Kingdon *et al*, 2001 (a), p4). South Africa had a narrow unemployment rate of 24 percent and a broad-based rate of 38 percent in 1999 (Klasen et al, 2000, p1). Although some improvement in employment is evident due to a broad-based expansion in employment in the private sector, unemployment remains very high, and the lack of job creation in the formal sector continues to be a major concern for the government. The significant difference between the broad and narrow unemployment rates indicates that there is a large proportion of jobless people who say they want to work, but are not actively looking for work. The reason for this discrepancy is a topic of some controversy as some analysts argue that many of these unemployed are not labour force participants. However, others have persuasively argued that the broad definition is the more relevant, because tests suggests that non-searching people are discouraged workers who have given up on the search for employment opportunities (Kingdon *et al*, 2001 (a), p4).

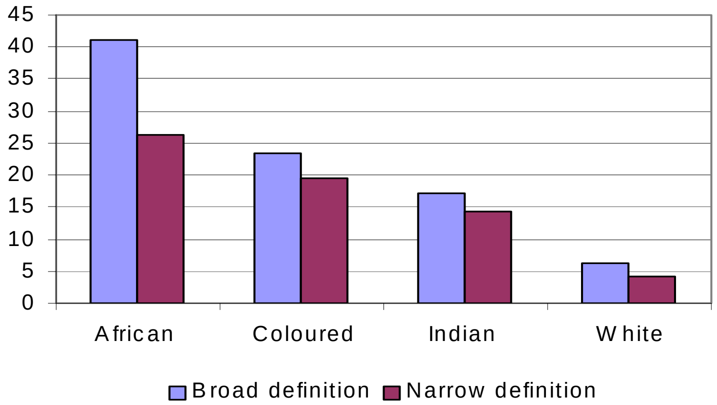
Figure 3.1: Unemployment rates in South Africa: 1993-1999



Source: Kingdon *et al*, 2001 (a)

Apart from the high differential between the broad and narrow unemployed, there is a significant difference in the incidence of unemployment between different race groups, regions, and based on gender and levels of education in the country. While Africans face unemployment rates of 41 percent (broad definition), the rate for whites is only 6 percent. The high level of unemployment among Africans is one of the highest in the world, and could be the highest if compared with rates of countries of similar, or larger, population size. In general, women are more susceptible to unemployment than men. This is a common phenomenon in developing countries, as women are often more restricted to work at or near their homes and may face negative discrimination when looking for work (Fallon *et al*, 1998, p5-6).

Figure 3.2: Unemployment rates by race in South Africa 1994



Source: Kingdon *et al*, 2001(a)

People with higher education face an unemployment rate of 6 percent, but those with primary education or less suffer a rate close to 40 percent. This could partially explain the labour allocation by race, because there is a big gap between education and level of skills between racial groups, with whites having much greater education and skills than other groups, and Africans lagging well behind Asians and Coloureds (Kingdon *et al*, 2001 (a), p5).

As discussed above, rural unemployment rates are higher than unemployment rates in urban areas. This regional discrepancy seems to be the result of the segregation policies of the apartheid era in which millions of Africans were consigned to live in rural areas of poor land quality and with few employment opportunities. The result of this policy was that much of the unemployment in rural South Africa took the form of people waiting in the homelands for a formal sector job opportunity (Kingdon *et al*, 2001 (a), p5).

3.3 SOUTH AFRICAN UNEMPLOYMENT: VOLUNTARY OR INVOLUNTARY?

The chapters that describe the theory behind the double dividend hypothesis indicate that the construction of a policy that addresses both environmental, as well unemployment problems will depend, among other factors, on whether the unemployed are voluntarily or involuntarily unemployed. If the unemployed prefer to be unemployed because of a high premium attached to leisure, the unemployment problem will have to be approached in a different way than it would be if there were barriers to entry into the labour market. It is therefore necessary to determine whether unemployment can be attributed to the supply side or to the demand side of the labour market. Although a considerable amount of research has been performed on the reasons for unemployment, little attention has been directed towards determining whether unemployment in South Africa is voluntary or involuntary. For this reason much importance is attached to a paper by Geeta Kingdon and John Knight (2001 (a)) in which an attempt is made to answer the latter question.

In their research Kingdon and Knight (2001 (a)) distinguish between two broad questions:

i. Why do the unemployed not enter into self-employment (informal sector); and

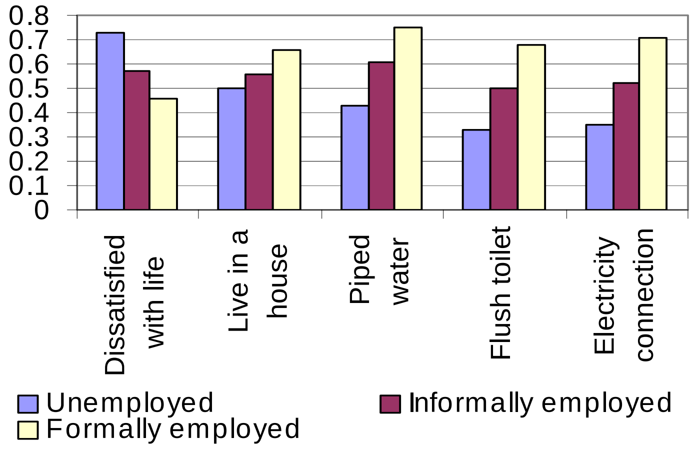
ii. Why do the unemployed not enter into wage-employment (formal sector)?

(Kingdon *et al*, 2001 (b), p5)

In answering the first question they distinguish between the supply and demand functions of labour. If it can be shown that the unemployed do not enter the labour market, because they prefer leisure and can afford it, the unemployment problem is one of voluntary unemployment and should be a labour supply-side problem. If, however, barriers to entry into the labour market exist, then the problem is a demand-side problem.

Informal workers are those workers that are not in regular employment but engage themselves in casual wage employment, domestic services or agricultural/non-agricultural self-employment. Based on surveys conducted by the South African Labour Research Unit and Statistics South Africa, the research conducted by Kingdon *et al* (2001 (b)) indicates that the unemployed are substantially worse-off than the informally employed, when measured by virtually every indicator of well-being. This includes indicators such as per capita income, living space, access to drinking water and the availability of sanitation and electricity. The surveys also show that the predicted earnings of informally employed are 1.44–2.35 times higher than those of the unemployed (Kingdon *et al*, 2001 (b), p11).

Figure 3.3: Measures of well-being of the unemployed, informally and formally employed (% of each sector).



Source: Kingdon *et al*, 2001(b)

The hypothesis of voluntary unemployment was further tested by the question: "Are unemployed people any happier than informally employed people?" If they are, it might be possible to argue that their unemployment is the result of choice and therefore voluntary rather than being the result of limited opportunities for informal sector work. The research tests this hypothesis by using an ordered probit model by means of which it is shown that happiness increases with income and education and that the unemployed are substantially disadvantaged in terms of happiness. This indicates that the unemployed do not "voluntarily" remain unemployed and that the informal sector is not necessarily a free-entry sector in South Africa (Kingdon *et al*, 2001, p11).

With regards to barriers of entry into the formal sector work force, Kingdon *et al* (2001 (b)) test whether the wage expectations of the unemployed are too high by making use of the voluntary wage aspiration hypothesis. This hypothesis indicates that persons whose reservation wages are greater than their predicted wages may be considered to be voluntarily unemployed. Interestingly, the research indicates that more than 50 percent of the unemployed have higher reservation wages than their predicted wages. A closer look at the formation of reservation wages indicates that these figures are, however, not very reliable. Reasons for this include:

i. labour market ignorance to such an extent that the unemployed in rural areas do not know current labour market conditions;

ii. workers may actually be reporting their expected wages, rather than their reservation wages;

iii. workers may actually be taking a bargaining stance when they report their reservation wage;

iv. the participants could be reporting a reservation wage for work in a certain geographical area, other than the one that they live in.

(Kingdon *et al*, 2001 (b), p15–17)

The research concludes that the need for policies that would reduce unemployment in South Africa is compelling, as it is very likely that most of the currently unemployed workers are involuntarily unemployed in the sense that they would accept formal sector jobs at the going wages. For as long as barriers to entry continue to restrict opportunities in much of the informal sector, this sector will be unable to significantly absorb those currently jobless. It would also be remarkable if the unemployed in South Africa chose to remain deprived and it appears as if limited opportunities for entering the informal sector provide no real alternative but high levels of unemployment (Kingdon *et al*, 2001 (b), p20).

3.4 SOUTH AFRICAN UNEMPLOYMENT: THE REASONS

Given South Africa's high unemployment rate, it seems as if some labour market rigidities exist which do not allow the market to clear. Although Fallon *et al* (1998) state that most of the decline in employment growth can be attributed to factors other than wage growth, they analyse its contribution towards unemployment in some detail, because the sensitivity of employment to wages is a very important issue. Its importance is due to it being central to virtually every question regarding wage policies. In their study, Fallon *et al* (1998) make the assumption that Black employment represents the unskilled labour force, while White employed represents the skilled employment force in South Africa. Despite the growing problem of unemployment among black workers, average real wages rose considerably in the 1970s and the 1980s, which means that real wages paid by employers also increased. This increase can be contributed to an improvement in earnings-related characteristics of Blacks such as educational and occupational attainment. However, factors such as reduced discrimination, the abolition of influx control and pressures of growing African trade unionism also contributed to this increase. According to Fallon *et al* (1998) the most striking feature of real wage behaviour since 1970 was that White wages were near stationary while Black wages grew in a somewhat erratic manner which caused wage differentials between White workers and other groups to narrow considerably.

Based on an examination of the relationship between wages and employment at the sectoral level, Fallon *et al* (1998) conclude that employment is more sensitive to wages than previously believed. By fitting labour demand equations to time series data of all the sectors of the economy, they obtained an average long-run wage elasticity of –0.71, which is in line with estimates obtained from other countries. A sectoral analysis indicates that mining has a rather low elasticity of –0.15, while the elasticity of the services sector is much higher at –0.95. Another interesting result from this study is that employment takes a significant period of time to adjust to wage changes and that the impact elasticities are mostly much lower in the short run than in the long run. This means that the employment gains from real wage reductions would take a number of years to be realized fully (Fallon *et al*, 1998, p11).

Although Kingdon *et al* (2001 (c)) do not state that the high unemployment rate is the direct result of high real wages in the South African economy, they do mention some wage-related issues that keep unemployment at high levels. These include labour market institutions such as Industrial Councils (Bargaining Councils) and Wage Boards. These institutions set sectoral minimum wages and stipulate working conditions in many industries. These minimum wages are then applied to all firms in the industry and region, irrespective of the size of the firm. Such provisions impose a burden of high labour costs on small firms and it is likely that it seriously inhibits the entry and growth of such firms into the formal economy (Kingdon *et al* (2001 (c), p7). These sentiments are shared by Black *et al* (1998), who use a labour demand and supply schedule to show that the "new" labour laws, passed in 1995 to reduce social imbalances, give rise to higher unemployment. They argue that the laws result in a loss of productivity, an increase in shirking (from both the employer as well as the employee) and an increase in wages and other costs attached to employment. This will either cause a movement upward along, or a shift leftward of, the labour demand schedule and subsequently cause a higher unemployment rate (Black *et al*, 1998, p460).

Jackson (2001) investigates the role that the unemployed are allowed to play in finding a solution to their plight. He mentions that unemployment is mostly the result of labour market rigidities. These rigidities include the high transaction costs for hiring and firing workers, downwardly sticky wages and institutional wage setting arrangements across industries. The aforementioned factors can be blamed on organized labour, South Africa's apartheid past and the current labour-friendly legislation. Apart from labour market rigidities, mechanization due to labour unrest and access to cheap capital in the past has also had a negative impact on employment. Although capital is far more expensive today, there are still a number of firms that prefer to invest in "non-unionised" machinery instead of a vast workforce. South Africa also suffers from a lack of sufficient skilled labour and the current educational system provides matriculants with few marketable and relevant skills. Jackson (2001) also refers to high real wages, which have not reflected the decrease in the demand for labour or a declining economy. The increases were mostly the result of institutional arrangements. Jackson concludes his section on the causes of unemployment by referring to the "insider-outsider" phenomenon. The labour market segmentation of the 1970s and 1980s has resulted in a sector of "insiders" and "outsiders". The "insiders" in formal sector employment have tended to exert upward pressure on wages and greatly influenced employment practice. The result has been increasing numbers of people who are willing to work at reduced wages or the "outsiders", who have been prevented from doing so by those already in employment.

In summary, factors that have been identified as contributing towards the unemployment rate are:

i. Rising capital-intensity linked to major parastatal investments (Fallon *et al*, 1998 and Jackson, 2001).
ii. Increasing real wages that do not reflect the decrease in demand for labour (Fallon *et al*, 1998, Kingdon *et al*, 2001, and Jackson, 2001).

iii. Insufficient skill acquisition by the work force that acts as a constraint on growth and employment (Fallon *et al*, 1998, and Jackson, 2001).

iv. Declining private investment that leads to slow growth in the non-governmental capital stock (Fallon *et al*, 1998).

v. The apartheid system that repressed the informal sector activities of black South Africans through licensing and zoning regulations (Kingdon *et al*, 2001).

3.5 SOUTH AFRICAN UNEMPLOYMENT: SUGGESTED SOLUTIONS

Fallon *et al* (1998) suggest the following policy initiatives to decrease unemployment:

i. Increasing human capital. Expansion of the skills base would increase growth, and would result in welfare redistribution. This is reflected in the high returns to education received by all racial groups at almost all levels of education. By concentrating government efforts on basic education, a solid base is laid for the whole of the system. This means that access to primary and secondary education must be extended along with an improvement in the quality of instruction. The planning and management capacity of the education sector will also have to be strengthened (Fallon *et al*, 1998, p29).

ii. Creation of a more competitive environment. A more competitive environment would serve to lessen labor market discrimination, as discrimination against workers with non-productive characteristics tends to decrease in a strongly competitive industry, as employers who discriminate less, gain an advantage over those who do (Fallon *et al*, 1998, p30).

iii. Encouragement of the positive aspects of trade unions. The positive aspects of trade unions should be allowed to develop fully. These aspects include their ability to raise productivity by countering arbitrary and unwise employer decisions, and their provision of an information channel through which employers learn of production floor problems. Unions also reduce costs by limiting voluntary worker turnover through increased job satisfaction (Fallon *et al*, 1998, p31).

iv. Creation of public works programs and labour-intensive construction. By creating productive jobs in the form of public works programs, or the

v. adoption of more labour-intensive methods in the construction of public infrastructure, the government can increase employment. It is, however, important that such schemes be located in areas where there are substantial concentrations of surplus labour, otherwise local wage rates may be bid up, to the detriment of employment outside the schemes. Care should also be taken to ensure that the burden on public expenditure is eased by paying wages below prevailing levels. As unskilled labour is in excess supply in South Africa, it is appropriate that such labour is valued at its social opportunity cost. The informal sector wage may be taken as a rough guide (Fallon *et al*, 1998, p32).

vi. Facilitation of national agreement. Given the current labour environment, it would be difficult for unions and employers to agree on a national social pact in which unions forego their power to increase wages in return for job-creating investment and training supplied by employers (Fallon *et al*, 1998, p32).

vii. Avoidance of excessive wage increases. Further high wage increases would have a serious dampening effect on formal employment in the country. However, the government only has a few policy instruments with which to intervene directly in wage setting. Current structures would have to take responsibility for not merely setting minimum wages and other labor standards to protect existing workers, but would also have to ensure that wage increases do not increase unemployment. Under the present circumstances of high unemployment, protection against increases in unemployment would suggest that real wages should be allowed to fall. If this option seems politically unfeasible, labour costs should not rise more quickly than national productivity (Fallon *et al*, 1998, p30).

viii. There are two concerns with regard to the wages that government employees receive. On the one hand, it is important that the government pay its skilled employees similar wages to those received by employees in competing sectors, because other sectors are already starting to attract skilled labour. On the other hand, unskilled labour is in excess supply in South Africa and there is little doubt that the government is actually paying wages well above the supply price (Fallon *et al*, 1998, p31).

3.6 CONCLUSION

The current literature that describes the South African labour market seems to indicate that the unemployment problem definitely stems from the demand side of the labour market in that there are structural restraints that inhibit an increase in the demand for labour. Apart from these structural problems, high real wages also seem to contribute to the unemployment problem, especially for the unskilled labour force.

A very important result that arose from analysing the supply side of the South African labour force is that most of the unemployed are not voluntarily employed and do not obtain a higher level of utility because less labour is supplied. In fact, most studies indicate that the unemployed will be willing to work at real wages that are lower than the current wages within the labour market.

Because unemployment seems to be a phenomenon that is prevalent among the unskilled labour force, it seems plausible to assume that the elasticity of labour supply for unskilled labour is very elastic, and could verge on perfect elasticity. The studies undertaken by Kingdon *et al* (2001) also indicate that unemployment in the skilled labour force is low and it is therefore plausible to assume that the wage elasticity of demand for the skilled labour force is inelastic.

CHAPTER 4

THE DOUBLE DIVIDEND HYPOTHESIS

4.1 INTRODUCTION

Although they are not a favourite among policy makers, environmental taxes have rested on an academic pedestal since they were first proposed by Arthur Pigou in his Economics of Welfare (1920). Pigou argued that taxing polluting emissions would reduce pollution in the most efficient manner possible. Neither Pigou nor anyone else ever seriously considered the possibility that such taxes would introduce new distortions into the economy. Recent research indicates, however, that the distortions associated with environmental taxes could be quite significant. It is also possible that traditional environmental policy instruments, such as tradable permits, could introduce similar distortions.

Along with new research on the distortions of environmental taxation, a new body of economic research has come to the fore, which is based on the fact that environmental taxes provide revenues. It is argued that revenue from environmental taxes can be used to reduce existing market distortions that are caused by an inefficient tax system. This argument has resulted in a policy debate that focuses on the potential "double dividend" that can be reaped from an environmental taxation policy. David Pearce (1991) is among the early proponents of the double dividend hypothesis, which proposes that the introduction of an environmental tax should be accompanied by a revenue-neutral decrease in a pre-existing distortionary tax. In his seminal article published in 1991 Pearce argues:

"*While most taxes distort incentives, an environmental tax corrects distortion, namely the externalities arising from the excessive use of environmental services. A carbon tax would be set on the basis of the carbon content of fossil fuels. Given the widespread use of fossil fuels, any tax would inevitably be revenue raising, even though the tax works best if it is avoided through the introduction of low or zero carbon technologies. Governments may then adopt a fiscally neutral stance on the carbon tax, using revenues to finance reductions in incentive–distorting taxes such as income tax, or corporation tax. This "double dividend" feature of a pollution tax is of critical importance in the political debate about the means of securing a "carbon convention"*"
(Pearce, 1991, p940).

Pearce (1991) proposes that the revenue that is raised from an environmental tax should be returned to the economy by decreasing a pre-existing distortionary tax. The benefits of such a policy would result in a double dividend, namely:

i. *The environmental dividend*: a reduction in the environmental damage caused by pollution externalities.

ii. *The tax dividend*: a reduction in the distortion of the overall tax system due to the reduction in a specific distortionary tax.

Although there is widespread agreement on the benefits that accrue to an improvement in the environment (first dividend), the magnitude of these benefits in terms of the welfare of society are uncertain and difficult to quantify. Attention has therefore been directed towards proving the existence of the second dividend. If it can be shown that the implementation of an environmental tax will result in a positive tax benefit (or at least a zero tax cost), then a policy that introduces an environmental tax should appeal to policy makers, as the net result of both dividends will be positive. However, the opposite also holds. If the benefits of the second dividend are shown to be negative, it will be difficult to propose an environmental tax policy, given the uncertainties regarding the magnitude of the first dividend. It is therefore not surprising that the notion of a double dividend has become increasingly popular with environmental groups, which argue strongly in favour of a positive second dividend. Apart from its appeal to policy makers, Pearce (1991) also argues that the notion of a double dividend could serve as a mechanism to persuade the developing world to sign up for international agreements to reduce CO_2 emissions. The importance of this mechanism is highlighted by the fact that fossil fuels contribute significantly towards the development process and that few developing countries would agree to reductions if a positive benefit could not be attained, regardless of the environmental concern (Pearce, 1991, p941).

Because of its appeal to policy makers, several papers have explored the possible existence of the double dividend. Most of the theoretical work has been unable to achieve clear-cut conclusions. Papers have often emphasised the restrictive conditions that need to be satisfied within a particular market for the double dividend to be attained (Carraro *et al*, 1995, p74). The reason for this ambiguity stems from the well-known economic principle that taxes distort economic behaviour. Environmental taxation is no exception.

4.2 DEFINING A DOUBLE DIVIDEND

In order to obtain a thorough understanding of the literature concerning the double dividend hypothesis it is necessary to clarify and define this notion properly.

Goulder (1994) essentially identifies three forms of the double dividend. These three forms are briefly described below.

4.2.1 The weak form of the double dividend

A weak form of the double dividend hypothesis postulates that by using revenues from an environmental tax to finance reductions in marginal tax rates of an existing distortionary tax, the economy will achieve cost savings relative to the case where the tax revenues are returned to taxpayers in lump-sum fashion. According to Goulder (1994), this form of the double dividend has been uncontroversial and should hold, given that a lump-sum redistribution of tax revenue will be inefficient relative to a distribution of tax revenue through a reduction of existing (inefficient) marginal tax rates. The only exception to this would be where the existing marginal tax rate is already negative. In this case, a further reduction of the tax rate would actually increase the inefficiency (Goulder, 1994, p4).

According to Miller (2001, p2), the weak form of the double dividend is nearly unambiguous, but does not have much power. A net negative benefit to the economy, which could arise from the market distortions (caused by the implementation of an environmental tax), is still possible. Apart from the above description of the weak form of the double dividend, Hansen (1999, p5) confirms the above description by stating that the allocation of revenue from environmental taxes towards the reduction of other distorting fiscal taxes will be a welfare improvement above returning revenues to tax payers in a lump-sum fashion. This argument implies that there is a welfare gain if revenue from those environmental taxes that are imposed is allocated towards general expenditures or tax cuts, rather than earmarked for recycling by polluters or for environmental expenditures.

Although the weak form of the double dividend hypothesis seems uncontroversial, it does not give much power to motivating the introduction of an environmental tax and only concerns itself with the manner in which the revenue that is raised from such a tax is redistributed. The “strong forms” of the double dividend definition is more controversial and defines a more narrow benefit that can be attained from environmental taxation.

4.2.2 The intermediate and the strong forms of the double dividend

According to Goulder (1994), the strong forms of the double dividend hypothesis postulate that by swapping an environmental tax for an existing distortionary tax, the economy will reap positive benefits (negative costs) through the increase in social welfare. These results are usually obtained, because inefficiencies of the existing tax system are reduced by the recycling of revenue from the new (more efficient) tax. A distinction is made between two forms of this double dividend, namely:

i. The "intermediate form" of the double dividend postulates that there exists at least one tax for which the strong form of the double dividend hypothesis applies.

ii. The "strong form" of the double dividend implies that the double dividend hypothesis holds for typical taxes.

The stronger form differs from the intermediate form only in that the stronger form is postulated for a representative distortionary tax, while the intermediate form is postulated for some distortionary tax. Both these forms claim that the gross costs of the tax reform are negative. The gross costs can be separated into the cost of the environmental tax and the cost of an equal-revenue change in the distortionary tax. Both the intermediate and the strong forms claim that the first cost is always smaller than the second (Goulder, 1994, p7).

Hansen (1999, p5) adds to the definition of the strong form of the double dividend by postulating that environmental taxes carry a strong double dividend (in addition to gains from Pigouvian price signal corrections) because the implied broadening of the tax base in itself is welfare improving. Therefore, under this form of the double dividend hypothesis, the introduction of environmental taxes will be welfare improving even if the environmental effect is negligible. As the following sections will illustrate, Hansen's argument in favour of the strong form does not seem to hold, as an environmental tax usually results in a decrease in the tax base of a country, especially where it is used to finance decreases in distortionary taxes such as the tax on labour.

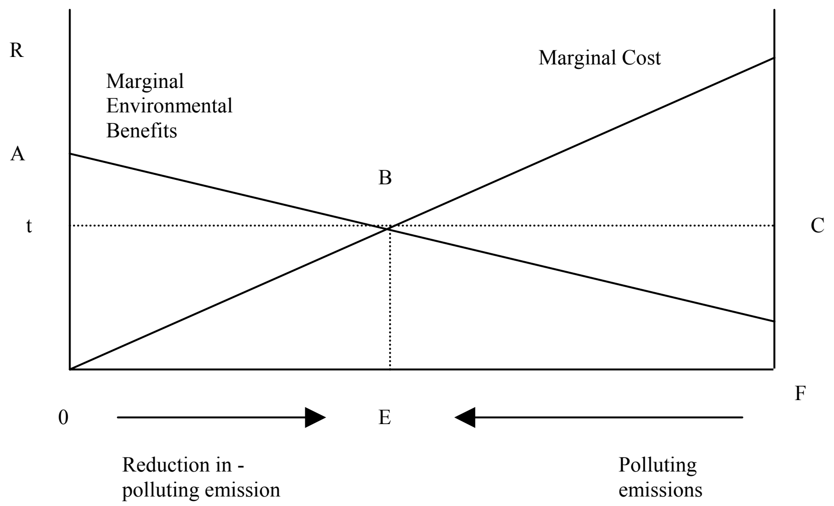
Because the strong forms of the double dividend entails a positive benefit that arises from the reduction in the marginal tax rate on other factors of production, focus has shifted towards determining the conditions under which such a dividend will exist. As already noted, the existence of a strong form of the double dividend hypothesis will increase the popularity of an environmental policy with policy makers, as it will only be necessary to make the very plausible assumption that an improved environment will have a positive welfare effect on a society. The magnitude of this effect is, however, of no relevance once the existence of a second dividend can be proven.

The above definitions of the different forms of the double dividend indicate why the existence of a double dividend can be so appealing to environmental groups and policy makers. Even though the existence of a double dividend is easy to prove within a partial equilibrium framework, subsequent general equilibrium analysis has resulted in a much broader debate around this topic. Although still not clear-cut, recent research has shown that the strong form of the double dividend can only be obtained under very specific circumstances.

4.3 THE DOUBLE DIVIDEND UNDER PARTIAL EQUILIBRIUM ANALYSIS

Within a partial equilibrium framework, analysis of the effect of an environmental tax on the economy indicates a net welfare gain for society if the revenue is returned to the economy by reducing marginal taxes on factors of production. The following analysis provides an example of a partial equilibrium approach to the double dividend hypothesis.

Figure 4.1: Partial equilibrium analysis of the effect of an environmental tax on the welfare of society.



Source: Parry *et al*, 1995

The first welfare gain that society obtains from an environmental tax is the triangle OAB that results from internalising the external effect (or social cost) of polluting emissions. In this case is due to a unit tax of 0t on emissions. According to Parry *et al* (1998), in an analysis where environmental revenues are returned to economic agents in a lump sum, this environmental benefit is the only concern of policy makers. However, in the presence of pre-existing tax distortions, an additional concern can be addressed. In this case, the revenues that are raised by the environmental tax (EBCF in the figure) can be used to reduce the rates on existing distorting taxes. This should result in a second welfare gain, which is popularly known as the revenue recycling effect. In the case where the distorting tax is a tax on labour, the welfare gain should arise from the reduction of the difference between the gross and net wage, which should result in an increase in employment. The combination of the first and second gains in welfare is equal to the existence of a double dividend (Parry *et al*, 1998, p9).

Although the results of a partial equilibrium analysis seem positive for the attainment of a double dividend, such analysis seems inadequate. Pearce (1991) refers to the need for a general equilibrium analysis of the double dividend hypothesis because carbon taxes themselves will impose a deadweight loss, which has to be set against the gain from the reduced externality of global warming. A partial equilibrium approach can therefore, at best, indicate the effect of “small” carbon taxes on economic welfare (Pearce, 1991, p943).

This “concern” with partial equilibrium analysis became apparent in 1994 when Lans Bovenberg and Ruud De Mooij published a paper in which they made use of a general equilibrium approach to indicate that a simple partial equilibrium analysis of the double dividend hypothesis omits significant second order effects that pertain to the consequences of the interaction between the new environmental tax and existing distortionary taxes. Since this paper, numerous studies have been performed that made use of general equilibrium analysis to indicate that the introduction of an environmental tax brings about a tax interaction effect that could aggravate existing tax distortions. This tax interaction effect could be larger than the positive effect that arises from the revenue recycling effect. If this is the case, the tax interaction effect will render the second dividend from an environmental tax negative.

4.4 THE DOUBLE DIVIDEND UNDER GENERAL EQUILIBRIUM ANALYSIS

As indicated above, the first influential researchers that made use of a general equilibrium analysis to evaluate the double dividend hypothesis were Bovenberg and de Mooij (1994). They analysed the existence of the strong form of the double dividend within a general equilibrium model. Subsequent research on the topic of the attainment of the double dividend focused on the relaxation of some of the assumptions of their model. The theoretical model that Bovenberg and De Mooij utilised is based on the following simplifying assumptions:

i. A closed economy in which two goods are produced: a "clean" product and a "dirty" product. The consumption and production of the "dirty" product result in an increase in pollution.
ii. Labour is the only factor of production and labour pays an income tax.
iii. Utility is obtained by consumption of both the "clean" and the "dirty" products and the enjoyment of leisure. An increase in the utility of a household postulates an increase in welfare.
iv. The production function exhibits constant returns to scale.

Within this model the introduction of an environmental tax and the subsequent reduction of marginal tax rates on labour did not result in a double dividend (positive welfare benefit). In fact it was found that the introduction of an environmental tax could actually increase the inefficiency associated with existing distortionary taxes. The intuition behind the finding is that the general equilibrium effects associated with the introduction of an environmental tax introduces tax interaction effects that negate the benefit from the revenue recycling effect. These affects have been disregarded by partial equilibrium models. In a general equilibrium setting the effect of an environmental tax is to increase the cost of production. To the extent that this cost is passed on to consumers, it will reduce the real wage that is received by households. As a result of the decline in the real wage, the return to work effort declines and less labour is supplied. This results in a fall in employment and a reduction in overall welfare. Furthermore, the tax also distorts the choice among consumption goods, which adds to the gross cost of the environmental tax. It can therefore be deduced that environmental tax swaps will increase rather than decrease the efficiency cost of pre-existing tax distortions (Goulder, 1994, p10).

Apart from serving as an additional tax on factors of production, Bovenberg and de Mooij (1994) found that by recycling environmental taxes (revenue recycling effect) the tax base is eroded, as taxation is shifted from the broader based labour income tax to selective environmental taxes. This reduces the tax base, and if the government wishes to maintain unchanged tax revenues it will be unable to cut labour taxes to the extent that it compensates workers for the erosion of their after-tax real wage stemming from higher environmental taxes. As a result, employment decreases (rather than increases) as a consequence of environmental tax reform.

Subsequently these findings have been confirmed by other studies which used general equilibrium analysis to test for the existence of a strong form of the double dividend. These studies have indicated that by introducing an environmental tax into a system in which distortionary taxes already exist, three effects need to be considered to evaluate the existence of a positive second dividend. These are:

i. *The primary cost of the environmental tax*: this is the direct cost to the regulated sector's need to reduce pollution through changes in production methods or installation.

ii. *Revenue recycling effect*: this effect requires a general equilibrium analysis but should, in general, serve to lower the cost of tax reform.

iii. *Tax interaction effect*: this effect also requires a general equilibrium analysis and usually counters the revenue recycling effect. Generally it shows how the new tax increases producer costs, which implies higher prices for commodities, and reduces the real income of factors of production. The tax interaction effect usually implies that the environmental tax functions like an increase in factor taxes, adding to the distortion in factor markets arising from existing taxes (Goulder, 1994, p11).

With few exceptions, most studies find that the costs from this interaction effect dominated any efficiency benefits from recycling environmental tax revenues by reducing other distortionary taxes.

From the above it is clear that the theoretical requirement for obtaining a double dividend from an environmental tax is that the revenue recycling effect should outweigh both the primary cost and the tax-interaction effect of the environmental tax. However, there is strong evidence that the revenue recycling effect is not strong enough to outweigh the other two costs, and in some cases, the revenue recycling effect is weaker than the tax interaction effect alone. In these cases the gross cost of the environmental tax not only fails to be negative, but turns out to be higher than it would be in a world without prior distorting taxes where the revenue recycling and tax interaction effects are absent. This attests that environmental taxes are actually implicit factor taxes that compound existing factor market distortions.

Carraro *et al* (1995) complement the above findings by identifying three main mechanisms that frustrate attempts to increase employment within a double dividend setting. According to the authors, these three mechanisms have become prominent from applied work on the double dividend hypothesis. The mechanisms are:

i. The effects of energy taxes on the tax base. If the substitution effects induced by the tax (factor substitution, product substitution, technical progress) are such that they shrink the tax base, the revenue to be recycled may be very low (substitution effect). According to Carraro *et al* (1995), the revenue may be even lower if the tax induces a contraction of economic activity (income effect).

ii. The second effect relates to the expenditure side of the government budget. If the tax has an impact on product prices, the increased inflation rate increases nominal interest rates, which worsens the debt burden of the government (debt effect). In countries where the public debt is high, the increased expenditure for interest payments may significantly reduce environmental tax revenue.

iii. The third mechanism is directly linked to the functioning of the labour market. In particular, this mechanism is concerned with the possibility that tax revenue, whenever it exists, may not reach the desired objective. This will particularly be the case in a labour market where wages are dependent on bargaining between unions and employers. The experience in Europe has been that a reduction in payroll taxes would increase the net wage and reduce the gross wage. In the long-run, all changes of the fiscal wedge are exactly off-set by changes in the net wage. This will leave employment unchanged. On the other hand, if the elasticity of the net wage with respect to the fiscal wedge is low, employment increases and the net wage increases, thus increasing consumption and, more generally, aggregate economic activity. This effect brings about an increase of energy consumption and emissions. Therefore, whenever the employment objective is achieved, the environmental one may be lost (Carraro *et al*, 1996, p74).

Based on the above, existing research indicates that the existence of a double dividend is questionable once the general equilibrium effects of the proposed environmental tax are considered. There are, however, some cases in which the revenue recycling effect could outweigh the tax interaction effect. These cases appear more plausible when some of the simplifying assumptions from the Bovenberg and De Mooij (1994) model are relaxed.

4.5 REQUIREMENTS FOR ATTAINING THE SECOND DIVIDEND

Although the Bovenberg and de Mooij (1994) model indicates that the existence of a double dividend could be difficult to obtain, Goulder (1994) and Goulder *et al* (2000) summarise a few conditions under which the Bovenberg and de Mooij results could be altered to obtain a double dividend. Goulder (1994) analysed possible extensions to the simple Bovenberg and De Mooij

(1994) model and showed that different extensions could alter the evidence with regard to the strong form of the double dividend. The extensions that Goulder examined are briefly discussed below.

i. The inclusion of intermediate inputs in the production function

According to Goulder (1994) the inclusion of intermediate inputs in the production function should not result in a strong form of the double dividend. The argument in this regard is the same as with a tax on the production of a polluting product. An environmental tax on intermediate inputs, which result in pollution, will also cause producer costs to rise. This increase in producer costs will be passed on to the consumer, which should result in a decrease in real income and reduce the incentive to provide labour. The net effect is a welfare loss to households and society (Goulder, 1994, p12).

ii. The inclusion of capital in the production function

According to Goulder (1994), two considerations are important when assessing the importance of including capital in the analysis:

- The extent to which the marginal efficiency costs of capital taxation differs from those of labour taxation before the introduction of an environmental tax. Here the factors on, which these marginal efficiency costs depend, need to be taken into consideration. Labour taxes distort the labour-leisure margin (therefore a function of labour elasticity of supply and marginal tax rate), while capital taxes distort the margin of choice between consuming today and consuming in the future (therefore a function of the intertemporal elasticity of substitution in consumption and marginal capital tax).
- Whether the burden or incidence of the environmental tax falls largely on labour or capital. An example would be an environmental tax that falls mainly on consumption commodities. The burden of such a tax will mainly fall on labour. However, the burden of an environmental tax that affects the production of investment commodities will fall mainly on capital (Goulder, 1994, p14).

These two considerations will cause the costs of the environmental tax to be lower if:

- The difference in the marginal excess burdens of the initial tax systems is large.

- The burden of the environmental tax falls primarily on the factor with relatively low marginal efficiency cost.
- The base of the environmental tax is relatively broad, so that the distortions it generates in the intermediate good and consumer markets are small.
- Revenues from the tax are devoted to reducing tax rates on the factor with relatively high marginal efficiency cost (Goulder, 1994, p15).

Goulder (1994) also states that if the above considerations do in fact exist within an economy, the environmental taxation could result in an intermediate or strong double dividend. An example of these conditions is in the USA where the marginal excess burden on capital is much higher than the excess burden on labour. Therefore, if a tax on consumption of fuel was to be introduced, it should result in a relative increase in the tax burden on labour if the revenue is used to decrease the burden on capital. The results are, however, reversed if the tax were to be introduced on intermediate inputs, as this would ultimately be borne by capital and increase the excess burden relative to labour (Goulder, 1994, p16). Therefore, it seems that introducing capital into the model could only result in a strong form of the double dividend if inefficiencies exist within the existing tax system (Goulder, 1994, p17).

iii. The existence of subsidies on the production of a polluting good

From economic theory it is known that subsidies on the production and consumption of goods introduce inefficiencies and welfare costs into an economy. If subsidies on the production or consumption of polluting goods exist, an environmental tax could be used to eradicate the effects of the subsidy and subsequently result in a strong form double dividend. It can, however, be argued that the eradication of the subsidy could be achieved without the environmental tax, which should result in efficiency gains for the economy, independent of an environmental tax (Goulder, 1994, p17).

iv. Introducing an argument of exhaustible resources and decreasing returns

According to standard economics on natural resource taxation, an environmental tax should not result in an alteration of the intertemporal allocation of these resources, nor should it have any efficiency cost because natural resources are an exhaustible input or commodity. However, according to Goulder this would not necessarily result in the existence of a double dividend, as an environmental tax is usually not raised on scarcity rents, but rather on the quantity produced, and therefore introduces an efficiency cost (affects intertemporal choice). The reason is that the quantity of the resource that is used is the result of a combination of labour, capital and natural resource inputs. Therefore, although the environmental tax will not have an efficiency cost on the natural resource input, it will have an effect on the efficiency of labour and capital. Distinguishing the efficiency cost to each of these factors is, however, a difficult exercise, and the efficiency cost on capital and labour should still have a considerable tax interaction effect (Goulder, 1994, p18).

v. Introducing involuntary unemployment into the model

A general assumption in general equilibrium models is that all markets clear and unemployment should therefore not exist. However, introducing a fixed wage above the market-clearing wage does not result in a strong form of the double dividend. The reason is that the introduction of an environmental tax decreases labour productivity and shifts the labour demand curve to the left. This result should hold, regardless of the existence of a fixed wage (Goulder, 1994, p19).

Bovenberg and van der Ploeg (1996) indicate, however, that in the case where there is involuntary unemployment while capital remains fixed, an environmental tax results in a tax shift from labour towards the immobile factor of production. This can result in a double dividend if labour is already inefficiently taxed (Bovenberg et al, 1996, p79).

vi. Introducing the environment as a capital good

Most models only include the environment as a consumption good. However, environmental quality could be included as a capital good within the production function. This allows a cleaner environment to contribute positively to production, if all other factors are held constant. The problem with this approach is the separation of the costs and benefits of tax policies towards welfare, once the environment is included within the production function. The distinction between the costs (benefits) of a cleaner environment and the costs that arise from the tax revenue effect is important in proving the double dividend hypothesis (Goulder, 1994, 20).

vii. Introducing an open economy and the terms of trade effect

An environmental tax on a polluting good could result in an improvement in the terms of trade if the country which raises the tax is a net importer of the good and has enough market power to change the world price of the good. By taxing the imported good the economy reduces national (and therefore global) demand for the good and reduces the good's price before taxes in the world market. This shifts some of the burden of the environmental tax onto foreigners if the revenues from the tax are devoted to cutting taxes paid by domestic consumers or domestically owned firms. According to Ethier (1995) such an argument is strictly a nationalistic one, and with such a policy the domestic economy imposes a loss on the rest of the world that exceeds the domestic economy's gain (Ethier 1995, p224).

By allowing for the above extensions to the Bovenberg and De Mooij model of 1994, Goulder (1994) indicates that in most cases inefficiencies within the tax system should already exist before the existence of the strong form of the double dividend can be obtained. The only exception is where a country can obtain terms of trade benefits by implementing the environmental tax.

Goulder *et al* (2000) adds to the above by showing that more complex general equilibrium models, as well as larger numerical models, offer scope for the existence of the strong form of the double dividend by allowing additional potential channels for beneficial efficiency impacts. These channels include:

i. A model, which allows the polluting good to be a weak substitute for leisure

A strong double dividend could arise if the polluting good is a weak substitute for leisure. The efficiency loss from the tax interaction effect will be smaller. In fact, when the polluting good and leisure are complements, the efficiency of the tax interaction effect should increase. That is, by making the polluting good more expensive, less leisure will be enjoyed and more labour supplied. This could, however bring about a decrease in utility if leisure is inductive to an increase in utility. On the other hand, taxing goods that are relatively strong substitutes for leisure would increase efficiency costs. In such a case, instead of enjoying more of the polluting good, the higher price of the polluting good should induce labour to substitute it for leisure. This will result in a decrease in labour supply and a reduction in welfare. Furthermore, pollutants associated with energy production are effectively inputs into a wider range of consumption goods.

ii. Inefficient relative taxation of multiple factors of production

This argument follows the above arguments of including intermediate factors of production and capital within the production function. It is concluded once again that if models that test for the existence of a double dividend are extended to consider more than one factor of production, a double dividend can occur if one factor is initially over-taxed relative to the other and the environmental tax improves the relative taxation of the factors.

The relatively high taxation of capital relative to labour in the US serves as an example of such a case. If the "tax shifting" from an environmental tax takes place in favour of capital rather than labour, the new environmental tax could cause relative taxation to improve. However, in the USA polluting industries are capital intensive and tax shifting is not enough to create a double dividend.

iii. Environmental feedbacks

Environmental improvements from an environmental tax could feed back on the functioning of labour and capital markets through possible effects on the improvement of the efficiency of these factors of production. An example would be an improvement in human capital through health improvements. Williams (2000) explored this productivity issue, but found that it is not large enough to result in a double dividend.

iv. Tax deductible expenditure

Most models that test for a double dividend neglect the fact that certain expenditures (such as mortgage interest) are deductible from income taxes. This distorts the choice between tax-favoured spending and ordinary spending, which means that the recycling of tax revenues through income tax cuts can yield an even larger revenue recycling effect, since cutting the income tax rate lowers the effective subsidy for tax-favoured spending.

It is clear from the economic literature that the attainment of the double dividend is only possible under certain "restrictive" conditions and that the introduction of an environmental tax could actually amplify distortions caused by existing taxes. A review of some empirical studies provides valuable insight into the various approaches that have been used to test for the double dividend hypothesis in various economies. Most of the studies performed on this topic are applied to the US and European economies and therefore distinction is made between these two economic regions, as the features of these economies differ. While most of the studies in the US focus on the double dividend as a mechanism through which tax distortions can be addressed, the studies on the European economies focus on the possible gains to employment. The results of two policy studies on the US economy are analysed. This is followed by the examination of a study that analyses the Swedish economy, and a study that analyses the Spanish economy.

In each case the background of the study is described, followed by an explanation of the major defining characteristics of each model used in the analysis. Finally the results of each analysis are discussed. The model "characteristics" are included as it is evident that they can have a significant impact on the results of a study. The aim of this empirical review is to describe different approaches and results that have been used to analyse the double dividend hypothesis. Exhaustive detail is therefore avoided and can be obtained from the relevant literature.

4.6 THE DOUBLE DIVIDEND HYPOTHESIS: EMPIRICAL FINDINGS

4.6.1 Results from the US economy

The two studies that are discussed were part of an exercise of the Energy Modelling Forum at Stanford University (EMF) in the 1990s, in which a number of different economic models were used to assess the impact of carbon emission reductions on the US economy. The broad result from this exercise was a paper that compared a number of carbon-tax-with-revenue-recycling scenarios across four models. These models include two macro-econometric and two CGE models. The former are referred to as the DRI and LINK models, while the CGE models are referred to as the Jorgenson-Wilcoxen Model and the Goulder Model respectively. In the paper, Gross National Product (GNP), consumption and consumer utility were used as measures of welfare. The results from most of these simulations were that the revenue neutral environmental tax swap involved a reduction in welfare. The only exception was the results from the Jorgenson-Wilcoxen model that supported the notion of a strong double dividend. Closer examination of the difference between the Jorgenson-Wilcoxen result and that of the Goulder Model indicates that the elasticities of capital supply and capital demand are higher in the Jorgenson-Wilcoxen model. This difference resulted in a higher marginal excess burden of capital taxation in the Jorgenson-Wilcoxen model than that which prevailed in the Goulder model (Goulder, 1994, p24).

The Goulder and Wilcoxen models are both computable general equilibrium models, but they produce opposite results. A comparison of these models should provide valuable insight into conditions that will result in the attainment of a double dividend.

4.6.1.1 Effects of carbon taxes in an economy with prior tax distortion: an intertemporal general equilibrium analysis by Lawrence Goulder, 1995

i. Background to the analysis

In his research Goulder investigates how the use of carbon tax revenues and the nature of pre-existing taxes affect the cost of a carbon tax. Goulder addresses these issues by employing an intertemporal general equilibrium model of the US economy. This framework is useful for addressing interactions among energy (fossil fuel) industries as well as between energy industries and other sectors of the economy. The intertemporal focus shows how the effects of taxes change over time as households and firms alter saving and investment decisions.

ii. The model

The model that Goulder employs has three important features. Firstly, the model contains a detailed treatment of US taxes, which enables the model to account for pre-existing tax distortions, and to examine various options for using carbon tax revenues to finance reductions in distortionary taxes. Secondly, the model incorporates non-renewable resource supply dynamics and transitions from conventional to synthetic fuels. This facilitates the understanding of the effects of a carbon tax, since there are significant differences in the carbon content of conventional fuels and synfuels. Thirdly, the model incorporates capital adjustment dynamics. Because producer investment decisions take account of adjustment costs associated with the introduction of new capital, capital is rendered perfectly immobile.

iii. Production

Production within the model is represented by a nested production structure that accounts for potential substitutions between different forms of energy and other inputs. Each industry produces a distinct output, which is a function of capital, labour, energy, composite materials and current levels of investment. Capital and labour as well as energy and materials are aggregated within a CES technology. Capital adjustment costs are also included in the production function and they affect output negatively, as installing new capital necessitates the use of inputs which could otherwise be used to produce output.

Firms in each industry are assumed to be price takers and to maximise value by choosing in each period the optimal levels of labour and intermediate inputs and investment, given personal tax rates on dividend income, capital gains and interest income.

The production structure of the oil and gas industry is different from the other industries in that it includes a resource stock effect that takes into account that these industries' stocks will deplete over time and that capital will eventually move to other industries.

All domestic prices in the model are endogenous except for domestic oil and gas prices, for which the world price is taken.

iv. Households

The decisions surrounding consumption, labour and savings are the result of the maximisation of the utility of an infinitely lived representative household. The household maximises an intertemporal utility function where consumption is a CES composite of goods, services and leisure. The household is subject to an intertemporal budget constraint. In each period, overall consumption of goods and services is allocated across the 17 specific consumption categories according to fixed expenditure shares.

v. Government sector

The government collects taxes, distributes transfers, and purchases goods and services, while government expenditure is exogenous and grows at a constant rate equal to the steady state growth of the economy.

vi. Foreign trade

Except for oil and trade, imported intermediate and consumer goods are imperfect substitutes for their domestic counterparts. Export demands are functions of the foreign price of US exports and the level of foreign income.

vii. Equilibrium

In equilibrium the aggregate demand for labour equals the aggregate supply, while the demand for each industry's output equals its supply. Aggregate demand by firms for loanable funds equals the aggregate supply of these funds by households. The government's tax revenues are equal to the difference between government spending and the government deficit.

viii. Results from the simulation

The first policy shock that Goulder tests within this framework is a carbon tax of 25, 50 and 100 1990 US dollars per ton of carbon where the tax applies on a consumption basis in the sense that it is applied to domestically produced and imported fossil fuels but exempts exported fuels. Revenue neutrality is assumed through reductions in either the marginal taxes on labour or capital at the personal level. This simulation is then compared with a situation in which revenues are returned in lump-sum to the economy.

Goulder finds that the costs of a carbon tax for GDP are significantly reduced when distortionary taxes are reduced relative to the case where revenue is returned to the economy in a lump-sum manner. The reason for this reduction is that, over time, the cuts in distortionary taxes allow for the improvement in intertemporal and inter-sectoral resource allocation. In terms of the welfare effects (as measured by the equivalent variation per dollar of revenue earned), the welfare loss is approximately 36 percent smaller when marginal taxes are reduced at personal level, 37 percent smaller when marginal taxes are reduced at payroll level and 42 percent when marginal taxes are reduced on all levels. However, cuts in distortionary taxes do not entirely eliminate welfare costs of the revenue neutral policy and it appears that, at the margin, a carbon tax generates larger gross distortionary costs than are produced by the major types of income taxes it might partially replace.

By performing different "base-case" scenarios where the type of taxation is changed from a pure carbon tax to that of a broad income tax, Goulder shows that the positive cost that arises from the carbon tax can be ascribed to the narrowness of a carbon tax base. Apart from the narrowness of the tax base, Goulder also shows that the existence of pre-existing distortions aggravates the costs of an environmental tax because it raises the pure cost of the tax. These findings are also in the line with the theoretical findings of Bovenberg and De Mooij (1995).

4.6.1.2 Reducing U.S. carbon emissions: An econometric general equilibrium assessment by Dale Jorgenson and Peter Wilcoxen, 1994

i. Background to the analysis

The research performed by Jorgenson and Wilcoxen aims to establish the effects of a carbon emissions tax on the US economy. According to Jorgenson and Wilcoxen, the model that they employ has three features that set it apart from other studies that test for a possible double dividend. The first feature is that their model is a highly disaggregated model of the US economy that allows them to examine the effects of carbon taxes on narrow segments of the economy, such as particular industries or types of households. Secondly, they obtain all the parameters of their model by econometric estimation that allows their results to be consistent with historical trends. Thirdly, productivity growth is modelled at the industry level which allows it to be an endogenous function of relative prices.

These features of the model enabled the researchers to reach several important conclusions that can be briefly summarised as follows:

- In the USA the effect of a carbon tax will be very similar to the effects of a tax placed solely on the use of coal. Of all the fossil fuels, coal is the least expensive per unit of energy and produces the most carbon dioxide when burned. A tax on carbon emissions will raise the cost of coal-based energy more in percentage terms than the price of energy derived from oil or natural gas. This will result in a substantial decrease in the demand for coal.
- Because most of the coal that is consumed in the USA is used to generate electric power, electric utilities will convert some generating capacity to other fuels, although substitution possibilities are rather limited so that the tax will raise the cost of electricity significantly.
- Higher energy prices will lead to slow productivity growth, reduced capital formation and a reallocation of labour to lower-wage industries that will cause GDP to be lower than it would be in the absence of the tax.
- A carbon tax that is large enough to have a big effect on carbon emissions will raise tens to hundreds of billions of dollars annually. How this revenue is used will affect the overall burden of the tax.

ii. Production

Production is disaggregated into thirty-five industries. Each of the industries produces a primary product and may produce one or more secondary products. The behaviour of each industry is derived from a hierarchical tier-structured transcendental logarithmic cost function. At the highest level the cost of each industry's output is assumed to be a function of the prices of energy, materials, capital and labour. At the second level the price of energy is a function of the prices of coal, crude petroleum, refined petroleum, electricity and natural gas, while the price of materials is a function of all other intermediate goods. The parameters of each industry are estimated econometrically. An unusual feature of the model is that productivity growth is determined endogenously as a function of input prices.

iii. Consumption

Consumption behaviour is represented by assuming that households follow a three-stage optimisation process. At the first stage each household allocates full wealth (the sum of financial wealth plus the imputed value of leisure time) across different periods of time. That is, the household maximises an additive intertemporal utility function subject to a budget constraint. At the second stage households allocate full consumption to goods and leisure in order to maximise an indirect utility function. The demand for leisure implicitly determines labour supply, while the difference between current income and consumption of goods implicitly determines savings. The third stage of the household optimisation problem is the allocation of total expenditure among capital services, labour services and thirty-five commodities. At this stage distinction is made between 1344 household types according to demographic characteristics.

iv. Investment and capital formation

It is assumed that there is a single stock of capital in the economy of which the supply is fixed in the short run. However, it is also assumed that capital is malleable and can be reallocated among industries and also between industries and final demand, at zero cost. The price of a unit of capital is therefore equal in every industry and there will be a single, economy-wide rate of return on capital.

v. Government

Government behaviour in the model is specified by computing total government spending on goods and services. Exogenous tax rates are applied to taxable transactions in the economy, to which capital income and non-tax receipts are added to obtain total government revenue. It is further assumed that the government deficit can be specified exogenously. This is then added to total revenue to obtain total government spending. Government spending is allocated among commodity groups according to fixed shares constructed from historical data.

vi. Foreign sector

It is assumed that imports are imperfect substitutes for similar domestic commodities and the mix of goods purchased by households and firms reflects substitution between domestic and imported products. Exports are determined by a set of export demand functions that depend on the foreign income and foreign prices of US exports.

vii. Results from the simulation

In calculating the amount of carbon dioxide emissions in the economy, it is assumed that carbon dioxide is produced in fixed proportions to fossil fuel use. The carbon content of each fuel used is then calculated by multiplying the amount of fuel used by the amount of carbon emitted per billion of BTU produced from each fuel. A carbon tax is introduced on both the domestic and imported sources of carbon emissions. The level is chosen to be exactly enough to hold US carbon dioxide emissions at their 1990 value of 1576 million tonnes. Although Jorgenson and Wilcoxen run simulations where the tax revenue is returned in a lump-sum fashion to households, the result of interest is where the tax revenues are used to reduce a distortionary tax. That is, lowering either taxes on labour or capital. The result of these simulations shows that when the revenue is returned by lowering the tax on labour, the loss of gross national product (GNP) is only 0.69 percent, which is half the decrease when the revenue is returned lump-sum. However, when the revenue is used to lower taxes on capital, the level of GNP actually increases. Because the marginal excess burden of taxation in the US is higher on capital than on labour, the revenue neutral tax allows some correction for this inefficiency.

4.6.2 Results from the European economies

As mentioned in the introduction, the studies that have been performed on the European economies differ in their approach to that of the studies that were performed on the USA economy, in that it tries to address the problem of unemployment. To this regard the emphasis is placed on the use of the carbon tax revenue to lower the cost of labour. The success of these policies is therefore dependent on the reaction of the labour market to these cost lowering incentives. Given this approach, the European experience seems to be more in line with the South African situation.

4.6.2.1 General equilibrium effects of increasing carbon taxes in Sweden by Glen Harison and Bengt Kristrom, 1997

i. Background to the analysis

Sweden signed the Rio declaration on the reduction of greenhouse gas emissions, which states that the current environmental goal is to stabilise CO_2 emissions to levels that pertained in 1990. In 1995 the Swedish government launched a commission to provide an analysis of a tax system intended to have a stronger environmental profile. The commission was asked to evaluate prevailing environmental taxes and to scrutinize the potential for a "double dividend" that could arise from new carbon taxes. The goal was to look at the impact of new taxes on the labour market, the government budget, competitiveness, dynamic impacts, distributional impacts and environmental aspects. Because Sweden is a small open economy it is also important to look at the impact of a revenue neutral tax-swap on international competitiveness.

ii. Production

The model used in this analysis identifies 87 sectors of production. Each sector in the model produces output by using inputs and a value added composite of the primary factors. These are combined through a CES technology with a low elasticity of substitution across all sectors. The value added is a CES composite of the labour composite and capital, while the labour is a CES combination of the different labour skill types. The model also allows for the specification of sector specific capital types in any set of sectors. This allows for the identification of sectors that employ a significant amount of primary factor that can be interpreted as specific to that sector. This could be interpreted as referring to a "short-run" in which capital is applied to sectors in a manner that does not permit it to be readily moved to other sectors. According to Harison and Kristrom (1997) it is intuitively clear that as the relative demand of output for a specific industry falls, *ceteris paribus* all input prices, the factor that is specific to this industry cannot escape to other industries. It must therefore experience a larger drop in real return than when it is inter-sectorally mobile. This relatively sharp decline in factor input cost results in a larger drop in the supply price in that specific industry than when the factor is assumed mobile.

iii. Households

Distinction is made between 30 households. The households are differentiated by family status and income. Final demand by households arises from a nested constant elasticity of substitution utility function. This allows consumer decision making to occur in the form of multi-stage budgeting. At the top-level goods from different sectors compete subject to the budget constraint of the consumer, and all income elasticities are equal to one. In the second stage the consumer decides how much to spend on domestic or imported goods in each sector, subject to the income allocated to spending on that sector in the first stage. Each allocation decision is modelled as a CES technology.

iv. Government expenditures and investment demand

Government expenditures and investment demand are exogenous and tax revenues and tariff revenues provide funding for government expenditures. The government also derives revenues from indirect taxes. Any lost revenues are recovered by increasing taxes on labour that are collected at the enterprise levels. Similarly, labour taxes are reduced for any increase in revenue.

v. Trade

Because the Swedish economy is a small open economy, trade is modelled as occurring at fixed world prices, although Swedish importers may substitute between alternative import sources and domestic production and the import composite. Similar assumptions apply on the export side, where Swedish producers have a constant elasticity of transformation between the sale to domestic markets and a composite foreign market, and sales of the composite to any of several foreign trading partners.

Because the specification of energy and carbon taxes is central to the model, taxes are modelled as falling on trade in intermediate inputs. This allows flexibility to calibrate the model to capture distortionary effects of existing taxes at the correct margin.

vi. Results from the simulation

Estimates of carbon emissions in each sector were derived on the basis of information on physical usage of primary energy inputs. This data can be used to infer the amount of CO_2 emissions generated by each sector, since emissions are a reliable multiple of the physical amount of energy used.

The core simulation based on this model is one of a 100 percent increase in existing carbon taxes in Sweden. By default labour taxes are lowered to ensure equal government revenue after the carbon tax policy. The results indicate that all household groups lose from the doubling of the existing carbon tax, with richer households bearing a higher cost, which reflects the greater carbon intensity of their expenditure patterns. On the other hand, the policy shock results in a reduction of 52 Kilotons of CO_2 in the economy, even though some sectors experience an expansion in CO_2 emissions and others experience a contraction. This is what one would expect in a general equilibrium analysis when relative prices change.

4.6.2.2 Implementing a double dividend: recycling ecotaxes towards lower labour taxes by Antonio Manresa and Ferran Sancho, 2002

i. Background to the analysis

The authors attempt to provide an answer to the possibility of attaining a double dividend by making use of a large size numerical model where general economic interdependence is fully taken into account. They feel that most contributions to the testing of the double dividend hypothesis are essentially analytical and deal with small size economic models. The model that is implemented in this study therefore uses the rich data set contained within a Social Accounting Matrix of Spain. The authors find that, under certain plausible conditions on the structure of the economy, it is indeed possible to obtain a double dividend. A budget neutral tax reform can yield a better environment and, at the same time, improve the employment levels while it also improves the efficiency of the Spanish tax system. The policy shock to the economy is one where an environmental tax (*ad-valorem* tax on all energy goods) is introduced, while payroll taxes are lowered across all production sectors under a budget neutral restriction.

The authors claim that the reason for the attainment of a double dividend rests in the inefficiency of taxation over primary factors (labour and capital) in the Spanish fiscal system, where there is a relatively high tax on labour use compared to taxes levied on capital which are inelastically applied in the model.

ii. Production

Production takes place under constant returns to scale where maximum profits are zero and a firm's behaviour is reduced to cost minimisation. The production side of the model used in this study distinguishes between 22 industries of which 10 correspond to energy production activities. Domestic output is obtained by using a fixed coefficient technology that combines intermediate inputs and value added. Value added is a composite primary factor that is generated by combining capital and labour services with a Cobb-Douglas technology.

iii. Households

Households maximise a utility function that combines different types of consumption and savings in a Cobb-Douglas technology. The budget constraint is a function of the direct income tax rate, consumer prices, the price of capital and the price of labour respectively. Consumption demand depends upon goods' prices and disposable income, which in turn depends on factor prices and the unemployment rate.

iv. Government

The government collects tax income that is spent to provide public consumption, public investment and government transfers to the private sector. The model distinguishes between the following tax categories: aggregate income tax, production indirect tax, value-added tax, payroll tax, tariffs and an environmental tax.

By adding all income tax sources, total tax collection is obtained, which depends on the applicable tax base.

v. Trade

The foreign sector plays a residual but nonetheless important role in the model. Distinction is made between two foreign sub-sectors; the European Union and the rest of the world. Imports are demanded by domestic industries and are used along with domestic output to provide the total supply of goods.

vi. Equilibrium

The model's equilibrium is essentially Walrasian, but also includes a macro rule that affects the labour market by including a relationship that reflects the sensitivity of the unemployment rate to the wage rate. In equilibrium, markets for goods clear, market for factors of production clear, total tax collections are equal to total tax payments and total investment is equal to total savings.

vii. Results from the simulation

In evaluating the results from the policy shock, Manresa and Sancho state that CO_2 emissions are a natural by-product of economic activities and that there is a direct link between the level of economic activity and the level of emissions. The evaluation of CO_2 emissions must therefore take into account, on the production and final demand sides, only those emissions that effectively take place on national territory and should therefore only count emissions generated in domestic production activities and in domestic final demand, ruling out any exported emissions.

The policy simulation performed encompasses the adoption of an environmental tax on the use of energy products and maintains the level of government tax collections by way of a compensating decrease in social security contributions by employers. The result of the policy shock is that the reduction in the social security contributions of the employer yields a positive impetus to the Spanish economy, as the distinct reduction in the relative cost of using labour proves to be a sufficient stimulant to substitute capital for labour and reduce unemployment, along with a 2.8 percent reduction in CO_2 emissions, which corresponds to the strongest form of the double dividend hypothesis.

4.7 CONCLUSION

The discussions on the existence of the double dividend illustrate that a double dividend could arise if three conditions hold:

i. The initial tax system is inefficient along some non-environmental dimension.
ii. The revenue-neutral environmental tax reduces this inefficiency.
iii. The efficiency improvement along this dimension more than compensates for the environmental tax's inherent efficiency disadvantage that is brought about by the narrow base of environmental taxes.

The discussion on the double dividend hypothesis also indicates that the existence of the strong form of the double dividend hypothesis in an economy will allow policy makers to introduce an environmental tax without having to prove the benefits of a cleaner environment to society.

Although partial equilibrium analysis indicates that the benefit of such an environmental tax will be positive, subsequent general equilibrium analysis, on balance, indicates the opposite. The reason for the latter result is that, apart from a few cases, environmental taxes usually increase the distortions caused by existing distortionary taxes. This increase in inefficiency is usually bigger than the decrease obtained by reducing the distortionary tax with revenue obtained from the environmental tax. However, there seems to be circumstances in which an environmental tax could indeed be used to reduce distortionary taxes and obtain a positive welfare benefit to society.

The brief analysis of a few empirical findings on the double dividend hypothesis confirms that the attainment of a double dividend in an economy is ambiguous, and that much depends on the structure of the economy and the model used to analyse such a policy. The studies that have been performed on the US economy indicate that a double dividend can be obtained if the marginal excess burden from taxation is relatively high on one factor of production. Because the USA does not have a significant unemployment problem, these studies seem to focus on an increase in the use and efficiency of capital as a factor of production.

In contrast to the US findings, the studies performed on European economies focus more on unemployment and indicate that a double dividend could be obtained if the supply of labour does not react negatively to lower real wages. A relatively low wage elasticity of supply could result in an increase in unemployment because the increase in the demand for labour will result in an increase in real wages (not necessarily in an increase in employment). This will ultimately result in increased inflation and a decrease in economy-wide welfare. The opposite, however, is also true, as a high wage elasticity of supply would result in a relatively small decrease of labour supply that will be offset by an increase in labour demand.

Because of South Africa's problem of high unemployment, the results from the European studies seem more applicable to the South African situation. The review of the South African labour market in Chapter 3 indicated that the South African unemployment problem is not a labour supply problem, but rather a labour demand problem, and that it is possible that a double dividend could be obtained.

CHAPTER 5

TECHNOLOGICAL INNOVATION, THE ENVIRONMENT AND ECONOMIC GROWTH

5.1 INTRODUCTION

Although the notion of obtaining a double dividend seems appealing and could hold significant positive consequences for the South African economy, it is widely recognised that energy efficient innovations not only reduce emissions of greenhouse gases, but also reduce production costs (Blackman, 1999, p1). Therefore, one cannot ignore the need for technological innovation, nor the opportunities that it offers to the country. The need for technological innovation in energy generation in South Africa is apparent from the fact that the South African economy relies almost solely on the use of coal to satisfy its energy needs. The results of the short-run simulations (which will be discussed in later chapters) also indicates that, although some positive welfare effects can be obtained from the use of environmental tax revenue, technological innovation is a necessary condition if South Africa wants to address the pollution problems that arises from the use of coal in the production process.

Apart from the consequences for the environment, technological innovation could also support higher economic growth rates. The aim of this chapter is to provide insight into current economic thought about technological change. This overview is important because it provides the motivation behind the use of tax revenue to fund research and development to reduce South Africa's dependence on coal for energy provision.

Section 5.2 looks at a description of technological change and thoughts about the role it plays in economic growth and sustainable development. Section 5.3 briefly describes the theories about the factors that drive technological change, while section 5.4 describes the opportunities that these theories provide to induce technological change. Section 5.5 discusses the current research and development (R&D) activities of the three South African industries that rely the most on coal in their production processes.

5.2 TECHNOLOGICAL INNOVATION AND SUSTAINABLE ECONOMIC GROWTH

The roots of modern theories of the process of technological change can largely be traced to the ideas of Josef Schumpeter (1942). Schumpeter distinguished between three steps in the process of technological innovation. The first step is invention. Invention constitutes the development of a scientifically/technically new product or process. The second step is innovation. Innovation encompasses the process of commercialising a new product or process. The invention and innovation stages are usually carried out in private firms through a process that is broadly characterised as "research and development" (R&D). According to Schumpeter, successful innovation will prompt firms and individuals to use the invention in relevant applications. The application constitutes the third stage of technological change and is known as diffusion. The cumulative economic impact of new technology results from all three stages, which are commonly referred to as the process of technological change (Jaffe *et al*, 2000, p4).

The importance of technological change is well known and widely recognised in economic growth literature. Solow (1956) was one of the first to show that the "effectiveness of labour" is a very important component that explains differences in growth between countries with roughly the same amount of capital stock, and that countries with more effective labour will attain higher levels of economic growth. What Solow implies with the notion of the "effectiveness of labour" has since been a subject of debate, although many economists reason that it is a catchall for factors other than labour and capital that affect output (technological change). Solow's growth theory spurred interest in research that became known as "new growth theories". These theories explain economic growth by incorporating a variable that represents technological progress. Despite the "new growth theories", the concept of technological progress remains vague.

The mystery that surrounds technological innovation is emphasised by Beltratti (2001) who reviews a number of articles that try to explain sustainable development/economic growth. Beltratti (2001) comes to the conclusion that there is a real need for a better theory of technological innovation. He states that technological innovation is a key parameter, which is often taken as exogenous to the growth theory and, although endogenous growth models try to push the explanation of technological innovation a little further, the economic variables that affect technological innovation need to be cast in more precise terms. He further concludes that there is a need to understand more about the origin of technological progress, and how to effectively increase the productivity of the resources spent on research and development. This conclusion seems to be relevant to both general economic growth theories as well as environmental economics (Beltratti, 2001).

As hinted by Beltratti (2001), technological innovation can also contribute significantly towards the improvement of the environment. This suggestion is well-known among environmental economists. The attractiveness of technological innovation in environmental management is emphasised by Opschoor (2001), who suggests one of four methods that can be used to obtain a sustainable level of economic growth (or a combination of these methods). He suggests that methods should be devised that:

i. raise ecosystems' carrying capacities for economic activity, and/or
ii. reduce the population size, and/or
iii. reduce income or production per capita, and/or
iv. change the environmental impact of production technology.

Not surprisingly, Opschoor (2001) finds the first and the last strategies attractive. He states that both these strategies could be achieved through improved knowledge, technology and management. The achievement of the relevant knowledge and technological change remains a challenge to both policy makers and economists alike (Opschoor, 2001, p32).

5.3 THE DETERMINANTS OF TECHNOLOGICAL INNOVATION

Despite the apparent difficulties, there is a line of research that has attempted to discern the determinants of technological change. Jaffe et al (2000) identifies two major strands of thought regarding the determinants of innovative activity. The first category is called the "investment subject to market failure" approach and the second category the "evolutionary" approach.

The "investment subject to market failure" approach explains the determinants of technological innovation by assuming that firms undertake an investment activity such as R&D with the intention of producing a profitable new product, or to engage in profitable new processes. The investment decision that surrounds R&D has important characteristics that distinguish it from investment in equipment or other tangible assets (Jaffe et al, 2000, p10).

The first characteristic is that the outcome of investment in R&D is much more uncertain than that of average investment undertakings. The second characteristic is that the assets that are produced by the R&D process are specialised and intangible. The costs of the investment are sunk, and R&D can therefore not be used for collateral. These two characteristics of R&D make the financing of research activity through capital market instruments more difficult than would be the case for other investments. This could result in under-investment in research (Jaffe *et al*, 2000, p11).

Apart from the problem of financing investment in R&D, the returns to R&D activities are difficult to keep from other parties that have not invested in the development (the so-called appropriability problem). It seems as if a significant portion of the social return to investment will accrue as "spillovers" to competing firms or to downstream firms that purchase the innovator's products, or to consumers (Jaffe *et al*, 2000, p11).

Both the problems of financing and appropriability raise the cost of R&D activities. Because the "investment subject to market failure approach" assumes that firms undertake R&D activity to maximise profits, these costs could reduce expected profits. It also implies, however, that the rate and direction of R&D activities should respond to changes in the relative prices that affect the profitability of firms. This holds important consequences for the effect that environmental policies could have on technological innovation. Since environmental policies implicitly or explicitly make environmental inputs more expensive, the hypothesis suggests an important pathway for the interaction of environmental policy and technology (Jaffe *et al*, 2000, p12).

The second school of thought explains R&D activities of firms as an investment decision that takes place in reaction to an external event. The so-called "evolutionary" approach assumes that firms are "satisfying" rather than "optimising" and approach their strategy with regard to R&D in a way that is not pre-determinable, but rather event-driven. This approach towards R&D development also holds intriguing opportunities for environmental policies. In as far as a new environmental policy is seen as an "external event" that could provide new profit (or loss) opportunities, it should move firms to re-evaluate their current R&D activities (Jaffe *et al*, 2000, p12).

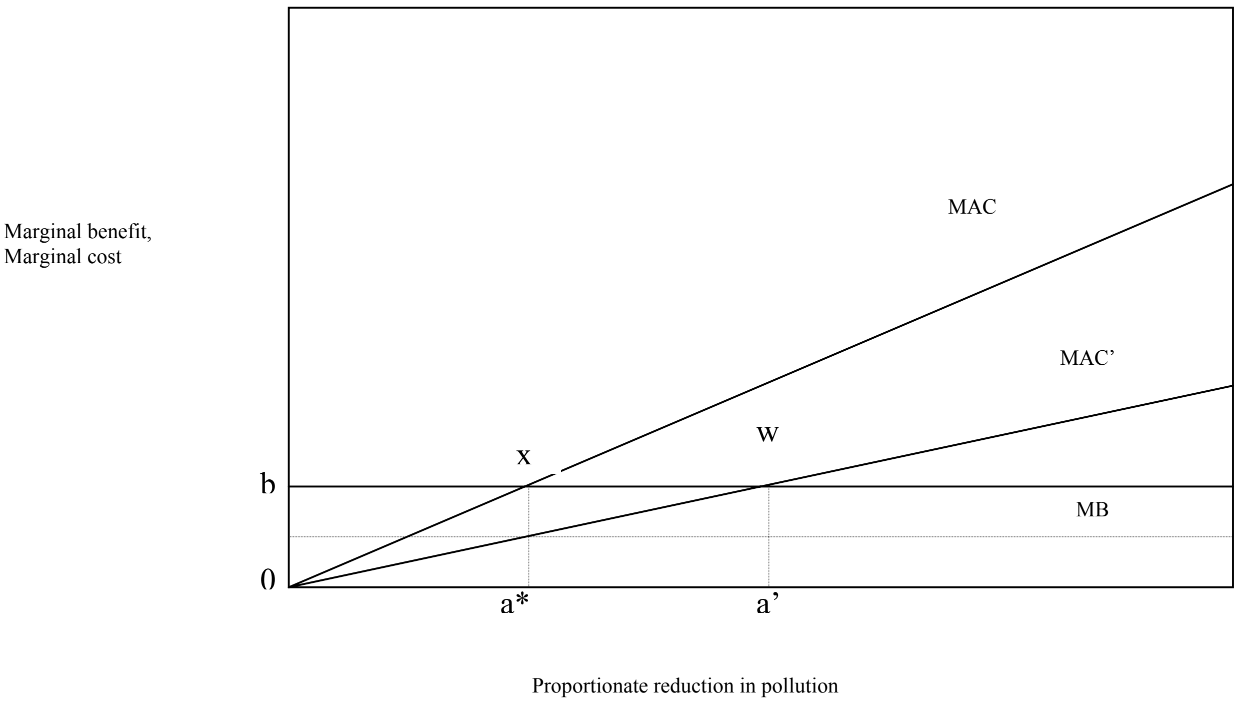
As hinted in the above discussion, the two approaches that are used to explain R&D development also suggest measures that can be implemented to induce technological innovation.

5.4 INDUCING TECHNOLOGICAL INNOVATION

Given the above theories, it is not surprising that environmentalists are among the main proponents of new and more stringent environmental regulations. These groups argue that increasing the stringency of environmental regulations provides an incentive for firms to develop new and less costly ways of reducing pollution. Some proponents argue that it could potentially result in entirely new methods of production which eliminate particular types of emissions and reduce the cost of production (Jaffe *et al*, 1997, p610).

Parry (2001) illustrates the benefits of potential technological innovation with a simple static model. In the traditional Pigovian analysis in which the state of technology for reducing pollution is taken as given, there is usually an upward sloping marginal cost curve for abating economy-wide emissions of a particular pollutant. This is shown by MAC in the figure below. The proportionate emissions reductions is denoted by "a" on the horizontal axes. The MAC curve usually reflects some combination of the extra costs to firms from using cleaner but more expensive inputs in the production process, the costs for operating technologies for treating waste emissions, and the efficiency cost of reduced final production. In addition to the MAC curve, there is a marginal benefit curve (MB). This curve reflects the environmental gains from incremental reductions in pollution, such as the health benefits from clearer air. The optimum amount of pollution abatement is a*, where MB and MAC intersect, and the welfare gain achieving this abatement is triangle 0bx.

Figure 5.1: An analysis of welfare benefits of induced technological innovation



Source: Parry, 1999

As stated, the above analysis assumes that the state of technology for pollution control is exogenous, while in reality it is not and will change over time in response to environmental policies (Parry, 1999, p3). If firms are penalised for polluting, they will have an incentive to come up with improved techniques for pollution control, which will lower the future cost of emission mitigation. Therefore, the MAC curve will move down over time in the presence of environmental policies (e.g. towards MAC'). Optimal abatement would now be at a', where MAC' intersects MB, while the maximum welfare gain from pollution control would now be triangle 0bw. There is thus an increase in welfare of triangle 0xw over and above the situation with no technological change.

Supporters of this school of thought have also suggested that if a country adopts stricter environmental regulations than its competitors, the resulting increase in innovation will enable that country to become a net exporter of the newly developed environmental technologies. This view is known as the Porter hypothesis (Jaffe *et al*, 1997, p610). Three different forms of the Porter hypothesis are distinguished.

i. The "narrow version": this version of the "Porter hypothesis" postulates that certain types of environmental regulations stimulate innovation.

ii. The "weak version": this version states that environmental regulation places constraints on the profit opportunities of firms that were not there before, and that firms maximising profits subject to those constraints will do a variety of things differently from what they would have done without the constraints. A likely outcome of the new regulations is that the activity would result in investments that fund R&D projects which find ways to meet the new constraints at lower costs. However, because the addition of constraints to a maximisation problem cannot improve the outcome, the weak version of the Porter hypothesis implies that the additional innovation must come at an opportunity cost that exceeds its benefits.

iii. The "strong version": this form of the hypothesis rejects the narrow profit-maximising paradigm of production behaviour and postulates that firms under normal operating circumstances do not necessarily find or pursue all profitable opportunities for new products or processes. The shock of a new regulation may therefore induce firms to broaden their thinking and to find new products or processes that both comply with the regulation and increase profits. The strong form of the Porter hypothesis has been construed to imply that environmental regulation is a free lunch, because regulation induces innovation of which the benefits exceed the costs, making regulation socially desirable, even ignoring the environmental problem it was designed to solve (Jaffe *et al*, 1997, p610).

A statement by Opschoor (2001) confirms the intuition that prevails behind the Porter hypothesis. He states: "*the changing of the environmental efficiency of production will come about as a consequence of research and development in industry and scientific institutions; these will emerge in response to price changes and changes in profits, and in response to public programmes and* *funding that stimulate innovation where the market fails to produce signals of adequate strength. Growth may generate the private and public funds necessary for financing innovation but here, again, deliberate policies and specific institutions and mechanisms appear as necessary conditions"* (Opschoor, 2001, p32).

Although the theoretical argument behind the Porter hypothesis seems appealing as an argument for environmental regulation, proponents of these theories emphasise that not all environmental regulations will generate significant innovation offsets. For this reason, policy makers should create new regulations carefully to ensure that they encourage innovation. The latter emphasis follows from a large subset of literature that focuses on the incentives of a firm that faces a decision to undertake R&D in order to reduce environmental compliance costs under different approaches to environmental regulation. This literature finds that R&D incentives tend to be stronger under incentive-based environmental policies than under command and control policies (Jaffe *et al*, 1997, p611).

There is also some research that explores the relationship between the stringency of environmental regulation and incentives for R&D and technology diffusion. Oates *et al* (1993) show that increasing the level of a pollution tax rate increases the firm's incentive to adopt a more efficient abatement technology. Schmalensee (1994) suggests that while R&D devoted to environmental compliance may increase with stricter environmental regulation, this increase will likely come at the expense of other research efforts that could have been more profitable.

Although empirical testing of these theories is difficult, the studies that have attempted empirical tests, confirm in general what is postulated by the above theoretical approaches. Examples of empirical research that prove the relationship between relative factor price changes and technological innovation include Lanjouw and Mody (1996) and Jaffe and Palmer (1997). Lanjouw and Mody (1996) have shown that a strong relationship is found between pollution abatement expenditures and the rate of patenting in related technology fields. Joffe and Palmer (1997) have found that there is a significant correlation within industries over time between the rate of expenditure on pollution abatement and the level of R&D spending. Another interesting study that indicates some relationship between changing factor prices and technological change is that of Popp (2001) in which it is found that patenting in the energy-related fields increases in response to increased energy prices. Jaffe *et al* (2000) summarise the main findings of the empirical research in a comparative table. The table is reflected below.

Table 5.1 Overview of conclusions on induced innovation and the "win-win" hypothesis

AREAS OF AGREEMENT	
Historical evidence indicates that a significant but not predominant fraction of innovation in the energy and environment area is induced.	
Environmental regulation is likely to stimulate innovation and technology adoption that will facilitate environmental compliance.	
Firms are boundedly rational so that external constraints can sometimes stimulate innovation that will leave the firm better off.	
First-mover advantages may result from domestic regulation that correctly anticipates world-wide trends	
AREAS OF DISAGREEMENT	
Win-Win theory	**Neoclassical economics**
Widespread case-study evidence indicates significant "innovation offsets" are common.	Case studies are highly selective.
Innovation in response to regulation is evidence of offsets that significantly reduce or eliminate the cost of regulation.	When cost-reducing innovation occurs, the opportunity cost of R&D and management effort makes a true "win-win" outcome unlikely.
Pollution is evidence of waste, suggesting why cost-reducing innovation in response to regulation might be the norm.	Costs are costs; even if firms are not at the frontier, side effects of pollution reduction could just as easily be bad as good.
Existing productivity or cost studies do not capture innovation offsets.	Existing productivity and cost studies suggest that innovation offsets have been very small.
There is much evidence of innovation offsets, even though existing regulations are badly designed. This suggests that offsets from good regulation would be large.	Since there is agreement that bad regulations stifle innovation, the apparent beneficial effects of existing regulation only show that case studies can be very misleading.

Source: Jaffe *et al*, 2000

5.5 FUNDING TECHNOLOGICAL INOVATION IN SOUTH AFRICA

As indicated above, R&D investment can be induced by well-designed regulatory policies. However, investment in research and development programs will require funding. The funds can originate from either the private sector or from the public regulator. As discussed above, the expected returns from investments in R&D activities is highly uncertain at the best of times. Apart from this uncertainty, it seems as if there are additional factors that inhibit investments in R&D activities in developing countries.

Gilles et al (1992) indicates that developing countries have not yet succeeded in making the development of appropriate technology a dynamic force in their economic development processes. According to the researchers, one of the main reasons for the lack of technological improvement is the absence of competitive pressures. This absence reduces the incentives for firms to invest in technological innovation. Another reason for the lack of technological progress is that most governments of developing countries have not yet fully awakened to the need to promote local research and development. It seems further as if universities of developing countries are usually preoccupied with teaching, and official research institutes in various fields are often slow to be set up or these institutions experience severe staffing difficulties once they open their doors. Given this, it seems as if there is scope for policies that will promote investment in R&D in developing countries (Gilles *et al*, 1992, p213).

Analysis of South Africa's Research and Development Strategy (2002) indicates that the country is no exception to the problem of low R&D that seems to plague the developing world. The R&D strategy of the Government mentions that South Africa currently suffers from an "Innovation Chasm" despite high proportions of private sector participation in some tertiary institutions and research councils. The Government is also acutely aware of the fact that technological innovation is needed for long-term economic growth and it states:

"*In many areas where South Africa is currently competitive, we do not have a capacity for local innovation and are dependent on imported know-how. This is not problematic in the short term. However, countries that make strategic innovation investments will inevitably attract new foreign direct investment and will eventually secure or supplant our current productive capacity*" (Department of Science and Technology, 2002, p38).

The Research and Development Strategy (2002) goes further to state that South Africa has a limited capacity at present to respond to new areas of technology that are regarded as critical in the global economy (such as biotechnology) and that there is a particular need to mobilise sciences to develop far more holistic understandings and interventions to increase the rate of innovation in our society (Department of Science and Technology, 2002, p38).

Although the lack of financial support is not the only factor that contributes towards the low levels of technological innovation, it does seem as if the South African economy suffers from low levels of expenditure on R&D activities. South Africa's total (public and private sector) R&D expenditure amounted to approximately 0.7 percent of gross domestic product (approximately R6 billion in 2002), whereas the average OECD country spent approximately 2.15 percent of GDP on R&D activities (in 2002). According to the Government, the R&D undertaken by large South African companies has shown a significant, measurable decline in the past four years, while global statistics show that the real determinants of technology-driven economic development is a sustained high level of research and innovation by the indigenous private sector firms of all sizes (South African Government, 2002, p21). It is against this background that the South African Government has set itself a target to double investment in R&D over the next three years, with a more gradual increase thereafter (Department of Science and Technology, 2002, p17).

Apart from this, the funding of research and development in South Africa, which could result in appropriate technological innovation, (with specific reference to the problem of energy efficiency) seems to be insufficient at present. There is, however, a common understanding of the importance and urgency of sufficient technological innovation.

Eskom, one of the industries that make intensive use of coal in the production of electricity, states in its 2002 Directors Report that it is committed to strive continually towards sound environmental management and performance. According to the report, Eskom allocated expenditure of R489 million during 2002 for environmental purposes. The Resources and Strategy division accounted for 21 percent (R102.69 million) of this expenditure. This division used the funds mainly for research that was related to the pilot wind energy facility (Eskom, 2002 (a)).

Sasol's expenditure on R&D expenditure has also increased from R268 million for the year ending June, 2001, to R359 million for the year ending June 2002 (Sasol, 2002, p109). A significant part of this expenditure is used on projects that focus on the use of natural gas (rather than coal) to serve Sasol's needs for energy transformation. It seems as if Sasol expects that the Natural Gas project will decrease the use of coal by Sasol Chemical Industrial plant from the current six- to seven-million tonnes to some 1.9- to 2 million tonnes as the primary energy source for the factory's power and steam plants (Engineering News, 2003, p30).

5.6 CONCLUSION

Apart from the positive benefits that technological innovation holds for economic growth and environmental management, it is also evident that environmental policy could, in itself, induce technological innovation in those sectors that are affected by relative price changes. The attainment of technological innovation is, however, not unambiguous, as indicated in the review of the economic literature on this topic.

It is also evident that South Africa currently has an "innovation chasm" despite the benefits that innovation holds for an economy. Although not the only reason, it seems as if a lack of funding of R&D activities in both the government, as well as the private sector, contributes towards the lack of innovative capacity. This is also true for technological innovation in environmentally sensitive industries such as the electricity and synthetic fuel industries.

CHAPTER 6

INTRODUCTION TO AN APPLIED GENERAL EQUILIBRIUM MODEL[1]

6.1 INTRODUCTION

The previous chapters have indicated that analysis of the effect of environmental taxation on the South African economy will be best served within a general equilibrium framework. Studies in this regard were analysed in previous chapters and the models briefly described. The purpose of this chapter is therefore to analyse the concept of general equilibrium modelling. The analysis will serve as an introduction to the two chapters that follow this one, which describe a general equilibrium model of the South African economy. This model will eventually be applied to analyse a proposed revenue neutral tax on the use of coal in South Africa.

6.2 INTRODUCTION TO GENERAL EQUILIBRIUM THEORY

The concept of general equilibrium modelling has developed over the past two centuries. Adam Smith's description of the behaviour of capitalists, motivated by considerations of profitability in the selection of economic activities, and John Stuart Mill's treatment of international trade and agents' responses to changes in taxes and import duties, can be viewed as the source of inspiration for this type of modelling framework. However, work by Leon Walras in 1854 allowed general equilibrium modelling to reach a mature form when he provided a general description of the functioning of a complex economic system based on the interaction of a number of interdependent economic units. Walras' work was expanded, and solutions to some of the caveats in his formulations of a general equilibrium were provided by the increase in activity in mathematical economics that took place in the 1940s and 1950s under mathematical economists such as Arrow (1954) and Debreu (1954). The most significant contribution by mathematical economists was in the mathematical confirmation of the consistency of the general equilibrium model (Scarf *et al*, 1984, pix).

In the text describing their general equilibrium model for the US economy, Ballard *et al* (1985) introduce the usefulness of this type of model by stating: "*Many questions of economic policy can be analysed within a partial equilibrium framework. When policy changes being considered are relatively small, it may be appropriate to neglect general equilibrium interactions among many*

[1] This chapter serves as an introduction to general equilibrium modelling for readers that are not familiar with the concept of general equilibrium modelling.

different markets. However, when large policy changes are considered, partial equilibrium analysis becomes painfully inadequate. In recognition of this fact, a vast increase has occurred in the past twenty years in the number of economists who use general equilibrium models" (Ballard *et al*, 1985, p1)

Scarf and Shoven (1984) expand on this description by stating that one of the virtues of the general equilibrium model is its ability to trace the consequences of large changes in a particular sector throughout the entire economy. A general equilibrium model is therefore an expansion of input-output analysis in that it permits a more flexible treatment of the consumer side of the economy and is less rigid in the requirements that it places on the production side. This confirms the statement of Ballard *et al* (1985): "*The consequences of a change in economic policy are frequently analysed by assuming the changes to be small and using local linear approximations based on estimates of the relevant elasticities. If the sectors are small, diagrammatic techniques or explicit analytical results may also be available as in the two-sector models so frequently used in international trade theory. But if the model is disaggregated, and if changes – possibly more than one – are large, there is no recourse other than the construction and explicit solution of a numerical general equilibrium model.*" (Scarf *et al*, 1984, pxi).

Scarf *et al* (1984) also mention the imperfections of a general equilibrium model. General equilibrium models have difficulty in allowing for money and financial institutions, they have difficulty with the incorporation of unemployed resources into their frameworks and are unable to cope with large-scale industrial enterprises that are capable of exerting significant pricing power on an economy. However, there are currently no competing formulations that can avoid these short-comings and until economic theory is capable of providing compelling alternative formulations, general equilibrium modelling will retain its usefulness.

It is therefore hardly surprising that general equilibrium models have been used to analyse policy issues such as:

i. changes in tariffs, exchange rates and other trade;
ii. changes in tax policy;
iii. changes in energy prices or environmental and energy policies, and
iv. changes in the development process.

6.3 A DESCRIPTION OF GENERAL EQUILIBRIUM MODELLING

A general equilibrium model is an economic model, based on the underlying economic theory of general equilibrium. According to Mansfield (1991, p414), a state of general equilibrium is a state in which the following conditions hold:

i. Every consumer chooses a consumer basket subject to a budget constraint, which is determined by the prices of inputs and the prices of products.
ii. Every consumer supplies whatever amount of inputs he or she chooses, given the inputs of product prices that prevail.
iii. Every firm maximises profits subject to a budget constraint imposed by the available technology, the demand for its product, and the supply of inputs in the long run. However, economic profits are zero.
iv. The quantity demanded equals the quantity supplied at the prevailing prices in all product and input markets (Mansfield, 1991, p 414).

Shoven and Whalley (1984, p1009) confirm the above conditions by summarising a general equilibrium as a state in which all markets clear. This is supported by Varian's (1993, p282) comments that, in a general equilibrium, all prices are variable, and equilibrium requires that all markets clear. The existence of such a state in the economy was first proven by Leon Walras.

From Walras' work it has been shown that:

i. an equilibrium set of prices will only exist if there is no good for which there is positive excess demand (Walrasian equilibrium);
ii. for any set of equilibrium prices the value of the excess demand is identically zero (Walras' law);
iii. if demand equals supply in k-1 markets, and the price of the good in the k^{th} market is positive, then demand must equal supply in the k^{th} market;
iv. if a set of prices results in Walrasian equilibrium and some goods are in excess supply at this equilibrium, it must be a free good (Varian, 1993, p493).

From the above it seems as if a feature of a general equilibrium model is that a set of prices, levels of production and consumption exist in each industry and household, so that market demand equals supply for all commodities.

A very descriptive summary of what a general equilibrium model entails is given by Scarf (1984). According to him, the fundamental theme of a general equilibrium model lies within the heart of economic theory. The production side of the economy, engaged in the transformation of certain commodities into other commodities, is distinguished from the consumption side, whose goals are the acquisition and eventual consumption of goods and services. Households' own stocks of commodities, may be consumed directly, maintained as inventories for eventual use, or offered as factors of production in a physical form, or by means of a variety of financial instruments. A consumer's income or wealth is determined by evaluating his stock of commodities in terms of those prices at which the commodities can be sold. Income and knowledge of relative prices permit the consumer to express his demands for goods and services as well as his offerings of labour and other stocks that are made available for the productive side of the economy. The decisions of the production and consumption sides of the economy need not be consistent with each other if they are based on an arbitrary set of prices. If the prices of a desired commodity are too low, consumers may be motivated to demand large quantities of this commodity, and producers may be averse to supplying that commodity, of which sales generate insufficient revenue to cover the costs of manufacturing the commodity. Equilibrium prices are therefore those prices that equate demand and supply in all markets. Once these prices are known, economic decisions are made based on them (Scarf, 1984, p1-3).

6.4 FROM A GENERAL EQUILIBRIUM MODEL TO A COMPUTABLE GENERAL EQUILIBRIUM MODEL

A computable general equilibrium model (CGE) is nothing more than a general equilibrium model that can be used to provide quantitative analysis of economic policy problems. A CGE model therefore also needs, apart from the theoretical structure provided by a general equilibrium model, some data concerning the economy of interest. Once the general equilibrium model and data have been integrated, an actual solution method needs to be determined in order to solve the equilibrium prices and decision variables in the equilibrium system. (Dixon *et al*, 1991).

The development of an applied general equilibrium model typically includes the following steps:

i. Development of the theoretical general equilibrium model which consists of:

- Equations representing household and other final demands for commodities.
- Equations for intermediate and primary factor inputs.

- Pricing equations relating commodity prices to costs.
- Market clearing equations for primary factors and commodities.

ii. Use of input-output data to provide estimates for the relevant cost and sales shares.

6.5 CONCLUSION

From the above description of the nature and use of general equilibrium models, it has been shown that this type of model is based on the underlying assumption of the existence of a set of prices that allows for market clearing. General equilibrium models have widely been used in policy analysis that covers almost every field of economics, ranging from international trade theory to taxation and environmental issues. The advantage of these models lies within their ability to analyse the effect of large policy changes on the economy as a complete system of interdependent variables. However, given the above advantage, general equilibrium models have a number of imperfections. These include difficulty in allowing for unemployed resources and problems with allowing for large-scale enterprises that are capable of exerting significant influence on prices. However, because of the lack of competing formulations that are capable of providing the same amount of analytical power, this type of analysis will retain its usefulness until economic theory provides compelling alternative formulations.

CHAPTER 7

REVIEW OF THE STRUCTURE OF THE ORANI MODEL

7.1 INTRODUCTION

The computable general equilibrium (CGE) model that will be utilised in this analysis is based on the ORANI model of the Australian economy. The ORANI model of Australia is a highly disaggregated applied general equilibrium model of the Australian economy, which was first developed in the 1970s. It uses the Johansen approach of linearisation to find a solution to the set of general equilibrium prices and quantities. Since its development, this model has been used as the launching pad for developing new models in various parts of the world. The group of models is known as the ORANI-G family of CGE models, and has served as the basis for models of countries such as Vietnam, South Korea, Thailand, the Philippines, South Africa and Pakistan (http://www.monash.edu.au/policy/oranig.htm).

Because the CGE model that will be used in this study is based on the ORANI-G methodology, the theoretical structure of the ORANI model will be discussed. The theoretical discussion will be complimented in the next chapter by a discussion of the South African database that will be employed within this study and the derivation of the elasticities of the model.

As already mentioned in Chapter 6, the development of the theoretical framework for a CGE model consists of the following components:

i. Equations for intermediate and primary factor inputs.
ii. Equations representing household and other final demands for commodities.
iii. Pricing equations relating commodity prices to costs.
iv. Market clearing equations for primary factors and commodities.

The ORANI specification as described for each of these components will subsequently be discussed (as described by Dixon *et al* (1980) and Horridge *et al* (2000)). Dixon *et al* (1980) describes the theory and background of the original model in detail, while the layout of Horridge *et al* (2002) encompasses the latest version of the ORANI-G model, which includes changes and adaptations to the original model. The notation that is used in this chapter is derived from the Dixon *et al* (1980) literature and is adapted if applicable.

7.2 THE ORANI-G MODEL AND EQUATIONS FOR INTERMEDIATE AND PRIMARY FACTOR INPUTS

ORANI-G addresses the modelling of the production side of the economy by assuming that the production of commodities in each industry takes place by combining domestic and imported commodities, capital, different types of labour, land and "other costs" as inputs. These inputs are combined by a certain production technology to produce a specified level of output. In the ORANI-G model it is assumed that all factors of production are variable. This means that, with respect to capital and agricultural land, producers act as if they rent both these inputs. It is, however, assumed that both capital and land are not transferable between industries.

As is the case in most CGE models, the production specification is nested. At the top nest of the ORANI-G model, the demand for inputs in each industry (j) is determined by minimising the cost function of the firm subject to a Leontief production function. The inputs entering the production structure at this top nest are composite commodities (i), a primary input (g+1,s) and "other costs" (g+2). The production function in the top nest is therefore given by:

$$Leontief\left\{\frac{X_{ij}^{1}}{A_{ij}^{1}}\right\} = A_{j}^{1} Z_{j}$$

where

X_{ij}^{1} is the effective input of good or factor i into current production in industry j.

Z_{j} is industry j's activity level.

A_{ij}^{1} and A_{j}^{1} is technological coefficients that allows for technological change.

Because the Leontief specification is assumed, the production function exhibits constant returns to scale and there are no substitution possibilities between the inputs in the production function. This assumption, which has been inherited from input-output analysis, has been justified by numerous studies that have failed in attempts to establish whether changes in relative prices result in changes in relative input quantities (Sevaldson, 1976). It must be noted, however, that more recent work by Jorgenson and others has shown that there could be feasibility in estimating material/material and material/primary factor substitution elasticites at a detailed level for the USA. This could be important for general equilibrium analysis of issues that involve sharp changes in the relative prices of competitive inputs (Dixon *et al*, 1992). In the South African context, the assumption of a Leontief technology at the top nest is retained and it is assumed that no substitution possibilities exist between the primary factor composite, the intermediate inputs or the "other cost tickets".

At the second level of the production nest, the composite commodities $X^{1}_{(is)j}$ that are used by each industry consist of a combination of domestically produced (s=1) and imported (s=2) goods, which are combined according to a CES technology. Also on the second level of the production nest, the primary input ($X^{1}_{(g+1,s)j}$) consists of a combination of labour (s=1), capital (s=2) and land (s=3), which is also combined with a CES technology. The second level of the production technology can be expressed as:

$$X^{1}_{ij} = \underset{s=1,2}{CES}\left\{\frac{X^{1}_{(is)j}}{A^{1}_{(is)j}}\right\}$$

and

$$X^{1}_{(g+1,s)j} = \underset{s=1,2,3}{CES}\left\{\frac{X^{1}_{(g+1,s)j}}{A^{1}_{(g+1,s)j}}\right\}$$

where

$i = 1,....,g$ (that is g, different products)

$j = 1,.....h$ (that is h, different industries)

The use of a CES production technology to combine domestically produced and imported commodities indicates that these two sources may not be perfectly substitutable for each other and that the demand for these inputs will change according to relative price changes. This treatment of imported and domestically produced goods follows Armington's (1969 and 1970) treatment of imported and domestically produced goods and is usually adopted in order to accommodate the phenomenon of countries both importing and exporting the same good (cross hauling).

Substitution possibilities are also allowed between the three different primary inputs through the use of the CES technology to combine them. This allows for substitution possibilities between the different primary factor inputs, based on changes in relative prices. If the price of one primary production factor increases relative to the average price of all primary inputs, the demand for the input will decrease relative to the total primary factor input demand.

At the third level of the production nest, the m different types of labour ($X^{1}_{(g+1,1,m)j}$) are also combined by means of a CES production technology to obtain the aggregated labour input, which enters into the primary factor composite. That is:

$$X^{1}_{(g+1,1,m)j} = CES\left\{\frac{X^{1}_{(g+1,1,m)j}}{A^{1}_{(g+1,1,m,j)}}\right\}$$

As is the case for the primary factor composite and intermediate inputs, the CES specification allows for substitution possibilities between different types of labour, based on relative price changes between these different skill types.

In order to solve the above production nest for the input demand functions, the level of output in each industry, as well as the prices of the inputs (except that for the composite labour demand), are treated as exogenous. Therefore, given the above production specifications, the following cost minimisation problem needs to be solved in order to obtain the input demand equations:

Choose:

$X^{1}_{ij}, X^{1}_{(is)j}, X^{1}_{(g+1,s)j}, X^{1}_{(g+1,1,m)j}$

to minimise

$$\sum_{i=1}^{g}\sum_{s=1}^{2} P^{1}_{(is)j} X^{1}_{(is)j} + \sum_{m=1}^{M} P^{1}_{(g+1,1,m)j} X^{1}_{(g+1,1,m)j} + \sum_{s=2}^{3} P^{1}_{(g+1,s)j} X^{1}_{(g+1,1,s)j} + P^{1}_{g+2} X^{1}_{g+2,j}$$

where:

X^{1}_{ij} is the demand for effective intermediate and primary inputs by industry j.

$X^{1}_{(is)j}$ is the demand for imported and domestic intermediate inputs, i, by industry j.

$X^{1}_{(g+1,s)j}$ is the demand for the "composite" primary factor input of industry j, that consists of capital, labour and land.

$X^{1}_{(g+1,1,m)j}$ is the demand for labour of different skill groups by industry j.

$P^{1}_{(is)j}$ is the price of the domestic and imported intermediate input.

$P^{1}_{(g+1,1,m)j}$ is the price of labour of skill group m in industry j.

$P^{1}_{(g+1,s)j}$ is the price primary factor s in industry j.

P^{1}_{g+2} is the price of other cost tickets.

Because the solution of the system of non-linear equations in the ORANI model is based on Johansen's linearisation technique, the solution to the above minimisation problem should therefore enter the ORANI model in the form of percentage change.

The equations below represent the solutions to the above cost minimisation problems in form of percentage change.

i. Intermediate input demand equation:

$$x^1_{(is)j} = z_j - \sigma^1_{ij}(p^1_{(is)j} - \sum_s S^1_{(is)} p^1_{(is)j}) + a^1_j + a^1_{ij} + a^1_{(is)j} - \sum_s S^1_{(is)} a^1_{(is)j}$$

$i = 1,.....g$

$s = 1,2$

$j = 1,....h$

The lower case denotes the percentage change forms of the variables that have been defined above. $S^1_{(is)j}$ is the share of the total cost of good i, from source s, into the inputs of industry j.

$$S^1_{(is)j} = \frac{P^1_{(is)j} X^1_{(is)j}}{\sum_s P^1_{(is)j} X^1_{(is)j}}$$

and σ_{ij} is the elasticity of substitution between imported and domestic goods as inputs into production of industry j. This specification indicates that if the price of one of the sources increases relative to the other, this will result in a decrease in the demand for the input from this source.

ii. Demand functions for primary factors

$$x^1_{(g+1,v)j} = z_j - \sigma^1_{(g+1,v)j}(p^1_{(g+1,v)j} - \sum_s S^1_{(g+1,v)j} p^1_{(g+1,v)j}) + a^1_j + a^1_{g+1,j} + a^1_{(g+1,v)j} - \sum_s S^1_{(g+1,v)} a^1_{(g+1,v)j})$$

$v = 1,2,3$

$j = 1,...g$

$S^1_{(g+1,v)}$ is the share of labour, capital and land in industry j's payments for primary factor inputs and is expressed as:

$$S^1_{(g+1,v)j} = \frac{P^1_{(g+1,v)j} X^1_{(g+1,v)j}}{\sum_{v=1}^{3} P^1_{(g+1,v),j} X^1_{(g+1,v)j}}$$

Once again, increases in the cost of industry j of any particular factor relative to a weighted average of the costs of all three factors leads to substitution away from that factor in favour of the other two factors.

Although the price of capital and land is exogenous to the cost minimisation problem, the price of labour is not exogenous and is a function of the different types of labour included in the model. The cost of labour is therefore defined (in percentage change form) as:

$$p^1_{(g+1,1)j} = \sum_{q=1}^{M} p^1_{(g+1,1,q)j} S^1_{(g+1,1,q)j} + \sum_{q=1}^{M} a^1_{(g+1,1,q)j} S^1_{(g+1,1,q)j}$$
$$j = 1, \ldots . h$$

If the technology coefficient ($a^1_{(g+1,1,q)j}$) is set to zero, then the percentage change in the cost of labour ($p^1_{(g+1,1)j}$) is a weighted average of the percentage changes in the cost to industry j of units of labour from the different skill groups. The weights are the shares of each skill group in j's total labour cost ($S^1_{(g+1,1,q)j}$). Given this cost, the demand for different types of labour can be determined. The percentage change form of this demand equation is shown below.

iii. Demand function for labour of different skill types

$$x^1_{(g+1,1,q)j} = x_{(g+1,1)j} - \sigma^1_{(g+1,1)j}(p^1_{(g+1,1,q)j} - \sum_q S^1_{(g+1,1,q)j} p^1_{(g+1,1,q)j}) + a^1_{(g+1,1,q)j} -$$
$$\sigma^1_{(g+1,1)j}(a^1_{(g+1,1,q)j} - \sum_q S^1_{(g+1,1,q)j} p^1_{(g+1,1,q)j})$$
$$v = 1,2,3$$
$$j = 1, \ldots g$$

$S^1_{(g+1,v)}$ is the labour specific cost share defined by:

$$S^1_{(g+1,1,q)j} = \frac{P^1_{(g+1,1,q)j} X^1_{(g+1,1,q)j}}{\sum_{q=1}^{M} P^1_{(g+1,1,q),j} X^1_{(g+1,1,q)j}}$$

In summary, the demand function for labour of certain skill types relates the demand for labour of a certain skill type to the industry's demand for labour in general, to the costs of the different types of labour and also to various technical change variables. If there is no technical change, an increase in the price of labour of a certain type (for example skilled labour) relative to the price of other types of labour, will cause the use of this type of labour to increase more slowly than the use of other types of labour.

The above four equations give the solution to the cost minimising problem of the firm in the ORANI model and represents the linearised demand equations for intermediate inputs, capital, land, labour and labour of different skill types.

7.3 A REVIEW OF EQUATIONS USED FOR HOUSEHOLDS AND OTHER FINAL DEMAND EQUATIONS IN ORANI

i. Household demands for consumer goods

Household demands for different goods are represented by a nested structure. It is assumed that households derive utility from the consumption of goods and services and that each household maximises its utility subject to a budget constraint. At the top nest, each household determines the allocation of household expenditure between different commodity composites by maximising a Klein-Rubin utility function subject to a CES composite of each product and an aggregate consumer budget.

$$U = \frac{1}{Q} \prod (X^3_i - \delta_i)^{\theta_i}$$

$$\textit{subject to}:$$

$$\frac{X^3_i}{Q} = \underset{s=1,2}{CES} \left\{ \frac{X^3_{is}}{Q} \right\}$$

$$i = 1, \ldots g$$

$$\textit{and}$$

$$\sum_{s=1}^{2} \sum_{i=1}^{g} P^3_{is} \frac{X^3_i}{Q} = C$$

where Q is the number of households and X_{is}^{3} and P_{is}^{3} are the quantities consumed and prices paid by households for units of good *i*. δ_i and θ_i are behavioural parameters with $\delta > 0$ and $\sum_i \theta_i = 1$. C is the aggregate consumer budget constraint and remains exogenous. The solution to this utility maximising problem of the consumer results in the linear expenditure demand equations for each good:

$$X_i^3 = \delta_i + \theta_i \frac{\varsigma}{P_i^3}$$
$$where:$$
$$\varsigma = C - \sum_i \theta_i P_i$$

As is evident from the expression above, the expenditure on each good is a linear function of prices and expenditure. δ_i is the subsistence requirements of each good that a household needs and purchases regardless of the price of the commodity. The ς is the residual of the consumer's budget after subsistence expenditures are deducted and can be viewed as the luxury expenditure. The θ_i represents the shares that each of the luxury goods receives from the "luxury budget" (the marginal budget shares).

X_{is}^{3} and P_{is}^{3} are the quantities consumed and prices paid by households for units of good *i* from source s, with s=1 referring to domestic sources and s=2 referring to imports. The A^3's are positive coefficients, introduced to allow for changes in tastes. C remains exogenous and Q is the number of households in the economy.

The linearised solution to the above maximisation problem is given by the following demand equations which represent the households' decision between imported and domestically produced goods, as well as the households' demand for each of the *g* commodities in the economy.

$$x_i^3 - q = \varepsilon_i (c - q) + \sum_{K=1}^{g} \eta_{ik} p_k^3 + a_i^3 + \sum_{k=1}^{g} \eta_{ik} (a_k^3 + \sum_{s=1}^{2} S_{ks}^3 a_{ks}^3)$$
$$i = 1, \ldots, g$$
$$and$$
$$x_{is}^3 = x_i^3 - \sigma_i^3 (p_{is}^3 - \sum_{s=1}^{2} S_{is}^3 p_{is}^3) + a_{is}^3 - \sigma_i^3 (a_{is}^3 - \sum_{s=1}^{2} S_{is}^3 a_{is}^3)$$

where S_{is}^3 is again the share of good *i* from source s in the household's consumption budget. The parameters ε_i and η_{ik} are the expenditure and own- and cross-price elasticities that satisfy the usual restrictions of homogeneity, symmetry and Engel's aggregation. These parameters are the effects on (per) household consumption of effective units of good *i* arising from a one percent increase in the general price of good *k*.

ORANI assigns values for the elasticities by making use of the Klein-Rubin utility function:

$$U = (\overline{X}_1^3, \ldots\ldots \overline{X}_g^3) = \sum_i^1 \delta_i \ln(X_i^3 - \theta_i)$$

where δ_i and θ_i are parameters and the elasticities can then be derived:

$$\varepsilon_i = \frac{\delta_i}{S_i^3}$$

$$\eta_{ik} = \frac{-\delta_i S_k^{*3}}{S_i^3}$$

and

$$\eta_{ii} = -\varepsilon_i - \sum_{k \neq i} \eta_{ik}$$

where

$$S_i^3 = \frac{\overline{P}_i^3 \overline{X}_i^3}{\sum_k \overline{P}_k^3 \overline{X}_k^3}$$

$$S_i^{*3} = \frac{\overline{P}_i^3 \theta_i^3}{\sum_k \overline{P}_k^3 \overline{X}_k^3}$$

In summary, the ORANI household demand specification can be described as follows:

- Consumers maximise a single utility function subject to a budget constraint.
- The utility function that is used to derive the elasticities is the Klein Rubin utility function results in a linear expenditure demand system.
- The consumption of good *i*, in general is defined by a CES aggregate of the consumption of good *i* from domestic and foreign sources. Consumers are assumed to substitute

between the two sources of supply of good *i* in response to changes in the relative prices of good *i* from the two sources.

- Consumers are assumed to substitute between good i and good k in response to changes in the relative general prices of k and *i*.

Changes in household preferences can be simulated using quantity augmenting variables that closely parallel those of changes in technology.

ii. Demands for inputs for the production of fixed capital

The demand for inputs to construct a unit of fixed capital is determined by a nested structure. At the top level of this nest, the ORANI model assumes that a unit of fixed capital in industry j can be created according to a Leontief technology that combines the different inputs *i* that are available in the economy. It is assumed that primary factors of production are not used in the production of fixed capital. The production of investment goods can therefore be expressed as:

$$A_j^2 Y_j = Leontief\left\{\frac{X_{ij}^2}{A_{ij}^2}\right\}$$

where Y_j is the number of fixed capital units that is created for industry *j*, X_{ij}^2 is the direct effective input of good *i* that is used to create capital for industry j, and A_j^2 and A_{ij}^2 are positive coefficients that represent technological change in the production of fixed capital. The level of fixed investment that industry *j* will conduct is assumed to be exogenous when the demand for inputs are derived. The treatment of the firm's decision on the level of investment is discussed towards the end of this chapter.

At the second level of this nest, the inputs that are used in the first nest are created by a combination of both imported and domestically produced goods. As in the case of the production of intermediate goods, imported and domestically produced products are combined by a CES technology in the production of fixed capital. This technology can be expressed as:

$$X_{ij}^{2} = CES\left\{\frac{X_{(is)j}^{2}}{A_{(is)j}^{2}}\right\}$$

where $X_{(i1)j}^{2}$ and $X_{(i2)j}^{2}$ are inputs of good *i*, from domestic (s=1) and imported (s=2) sources and the $A_{(is)j}^{2}$ is another set of technological coefficients.

Because it is assumed that markets are perfectly competitive, producers of capital for the different industries do not have any price setting power, and have to take input prices as if they are determined by the market. Therefore, to determine the amount of inputs that the capital producer will demand from the domestic or foreign market, the producer will choose a combination that minimises his/her cost subject to the CES production technology. The producer therefore choose $X_{(is)j}^{2}$ to minimise:

$$\sum_{i=1}^{g}\sum_{s=1}^{2} P_{(is)j}^{2} X_{(is)j}^{2}$$

subject to

$$X_{ij}^{2} = CES\left\{\frac{X_{(is)j}^{2}}{A_{(is)j}^{2}}\right\}$$

where $P_{(is)j}^{2}$ is the price of good *i* from source *s* when it is used as an input for creating capital for industry *j*.

The linearised solution to the above minimisation problem is given by:

$$x_{is}^{2} = y_{j} - \sigma_{ij}^{2}(p_{(is)j}^{2} - \sum_{s=1}^{2} S_{(is)j}^{2} p_{(is)j}^{2}) + a_{j}^{2} + a_{ij}^{2} + a_{(is)j}^{2} - \sigma_{ij}^{2}(a_{(is)j}^{2} - \sum_{s=1}^{2} S_{(is)j}^{2} a_{(is)j}^{2})$$
$$i = 1,\ldots,g$$
$$j = 1,\ldots,h$$

where $S_{(is)j}^{2}$ is the share of good *i* from source *s* in the total cost of good *i*, used in the creation of capital in industry *j*, and is expressed as:

$$S^2_{(is)j} = \frac{P^2_{(is)j} X^2_{(is)j}}{\sum_s P^2_{(is)j} X^2_{(is)j}}$$

It is clear that a change in the price of one source of commodity *i*, relative to the other source, will allow for substitution possibilities between the different sources.

In summary, the assumptions concerning the construction of fixed capital are:

- Fixed capital for industry *j* is created by combining effective units of produced inputs according to a Leontief production function.
- The effective input of good *i* to construct a unit of capital for industry *j* is a CES combination of inputs from domestic and foreign sources.
- The composition of units of capital varies across industries.

iii. Demand for export products from the rest of the world

The ORANI-G model distinguishes between two different groups of exports. Namely the individual export commodities and the collective export commodities. The individual export commodities include all the main export commodities of the exporting country, and it is assumed that the demand equations for these commodities are downward sloping and a function of the foreign price elasticity of demand for these goods. These demand equations can be expressed as follows:

$$X_i^{4ind} = A_i^{4indQ} \left(\frac{P_i^{ind4}}{\phi * A_i^{4indP}} \right)^{\gamma_i}$$

where X_i^{4ind} is the individual export demand for good *i*, P_i^{4ind} is the domestic price for individual export good *i* (which includes transport costs), and ϕ is the exchange rate that converts the domestic price of the export good to a foreign price. The foreign price elasticity of export demand of good *i* is given by γ_i while A_i^{4indQ} and A_i^{4indP} are technological coefficients that allow for horizontal and vertical shifts in the individual export demand schedules of the export demand equations.

The linearised demand equation for individual export commodities is:

$$x_i^{4ind} - a_i^{4indq} = \gamma_i (p_i^{4ind} - \phi - a_i^{4indp})$$

This indicates that an increase in the foreign currency price of collective export commodity, *i*, will result in a decrease in the foreign demand for this commodity, as is implied by the price elasticity of this export product.

In contrast to the individual export demand equations, the foreign demand for collective export commodities is inversely related to the prices of all the collective export commodities and usually includes all the commodities for which individual export demand equations seem inappropriate. Typical inclusions are the service commodities where export volumes do not necessarily depend on the corresponding price of the commodity. A "collective exports" commodity is therefore created through a Leontief technology, expressed as:

$$Leontief\left\{\frac{X_i^{4col}}{A_i^{4col}}\right\} = X^{4col}$$

where X^{4col} is the Leontief aggregate of the individual collective export commodities (X_i^{4col}). The demand for the aggregate (X^{4col}) is a function of the collective foreign price of these commodities and can be expressed as:

$$X^{4col} = A^{4colQ}\left(\frac{P^{4col}}{\phi * A^{4colP}}\right)^{\gamma col}$$

where X^{4col} is the collective export demand, P^{4col} is the domestic price for the collective export price (which includes transport costs), and ϕ is the exchange rate that converts the domestic price of the collective exports to a foreign price. The foreign price elasticity of the collective export good is given by γ^{col} while A^{4colQ} and A^{4colP} are technological coefficients that allow for horizontal and vertical shifts in the collective export demand schedule. The linearised collective demand equation is expressed as:

$$x^{4col} - a^{4colq} = \gamma col\ (p^{4col} - \phi - a^{4colp})$$

As in the case with the individual export demand equations, the demand for the collective export product will decrease if the foreign price increases, as indicated by the collective export price elasticity.

iv. "Other" final demands and demands for margins

"Other" final demands consist mainly of government demands for both domestically and imported goods. The ORANI-G methodology includes no theoretical explanation for this category of final demands and expresses the linearised "other" demand equations simply as:

$$x_{is}^{5} = c_r h_{is}^{5} + f_{is}^{5}$$

where x_{is}^{5} is the percentage change in "other" demands for good *i* from source s. c_r is the percentage change in real aggregate household expenditure and can be expressed as:

$$c_r = c - \xi^{3}$$

where ξ^{3} is the consumer price index. f_{is}^{5} are shift variables and the h_{is}^{5} are parameters that allow other final demands to change relative to household demands. If h_{is}^{5} are set equal to 1, and the f_{is}^{5} are set equal to zero, "other demands" will move in line with real household expenditure. However, if h_{is}^{5} are set equal to zero, government consumption is exogenously determined by f_{is}^{5}.

In the ORANI framework it is assumed that the demand for margins associated with the delivery of inputs for current production and capital construction is proportional to the demand for the specific inputs that it is used for. It can be expressed as:

$$X_{r1}^{(is)jk} = A_{r1}^{(is)jk} X_{(is)j}^{k}$$
$$i, r = 1,..., g$$
$$j = 1,...., h$$
$$k, s = 1,2$$

where $X_{r1}^{(is)jk}$ is the quantity of good *r1* used as a margin to facilitate the flow of good *i* from source *s* to industry *j* for purpose k. $A_{r1}^{(is)jk}$ is a technical coefficient that indicates the proportionality of the margin demand to the total demand for the input. In the absence of any technical change, this demand specification allows the demand for margins to be proportional to commodity flows with which the margins are associated. The linearised demand for margins associated with the delivery of inputs for current production and capital construction is given by:

$$x_{r1}^{(is)jk} = x_{(is)j}^{k} + a_{r1}^{(is)jk}$$

Similarly, margin flows that are associated with the delivery of commodities to households and "other" users are handled by the following equations:

$$X_{r1}^{(is)k} = A_{r1}^{(is)k} X_{is}^{k}$$
$$k = 3,5$$
$$r, i = 1,\ldots,g$$
$$s = 1,2$$

These equations represent the demand for margins associated with the delivery of commodities to households and "other users", while

$$X_{r1}^{(is)4} = A_{r1}^{(is)4} X_{is}^{4}$$
$$i, r = 1,\ldots.,g$$

represent the margin demand associated with the delivery of commodities from export producers to the port of delivery.

In percentage change form, the margin demand for capital, household, and exports demand are given by:

$$x_{r1}^{(is)k} = x_{is}^{k} + a_{r1}^{(is)k}$$
and
$$x_{r1}^{(is)4} = x_{is}^{4} + a_{r1}^{(is)4}$$

7.4 A REVIEW OF PRICING EQUATIONS THAT RELATE COMMODITY PRICES TO COSTS IN THE ORANI MODEL

The ORANI-G methodology distinguishes between 5 sets of commodity prices. These are purchaser prices, basic values, prices of capital units, foreign currency export prices and foreign currency import prices. In determining the relationship between these prices it is assumed that there are no pure profits in any economic activity and that basic prices are uniform across all users and producing industries for both domestic and imported goods.

i. Basic values of products

Basic values for domestic goods are the prices received by producers. Basic values therefore exclude sales taxes and margin costs. With regards to the basic value of imports, they represent the prices received by importers. Given the assumptions of no pure profits and uniformity of basic prices across the economy, the basic value of each product *i* can be expressed as the sum of the value of intermediate inputs, the value of labour, the value of capital used, the value of land used, and the value of other cost tickets. This can be expressed as (with no change in the notation as already defined):

$$\sum_{i=1}^{g} P_{i1}^{0} X_{(i1)j}^{0} = \sum_{i=1}^{g}\sum_{s=1}^{2} X_{(is)j}^{1} P_{(is)j}^{1} + \sum_{m=1}^{M} P_{(g+1,1,m)j}^{1} X_{(g+1,1,m)j}^{1} + \sum_{s=2}^{3} P_{(g+1,s)j}^{1} X_{(g+1,s)j}^{1} + P_{(g+2)j}^{1} X_{g+2,j}^{1}$$

In percentage change form this relationship is:

$$\sum_{i=1}^{g} p_{i1}^{0} H_{(i1)j}^{0} = \sum_{i=1}^{g}\sum_{s=1}^{2} p_{is}^{1} H_{(is)j}^{1} + \sum_{m=1}^{M} p_{(g+1,1,m)}^{1} H_{(g+1,1,m)j}^{1} + \sum_{s=2}^{3} p_{(g+1,s)j}^{1} H_{(g+1,s)j}^{1} + p_{g+2,j}^{1} H_{g+2,j}^{1} + a(j)$$

where

$$a(j) = a_{j}^{0} + \sum_{r=1}^{N(j)} a_{(r^{*})j}^{0} H_{(r^{*})j}^{1} + \sum_{i=1} a_{(i1)j}^{0} H_{(i1)j}^{0} + a_{j}^{1} + \sum_{i=1}^{g+2} a_{ij}^{1} H_{ij}^{1} + \sum_{i=1}^{g}\sum_{s=1}^{2} a_{(is)j}^{1} H_{(is)j}^{1} + \sum_{s=1}^{3} a_{(g+1,s)j}^{1} H_{(g+1,s)j}^{1} + \sum_{m=1}^{M} a_{(g+1,1,m)j}^{1} H_{(g+1,1,m)j}^{1}$$

The H's in the linearised equation represent the revenue and cost shares of each input in the production process. $H_{(i1)j}^{0}$ and $H_{(r^{*})j}^{0}$ are the shares of industry *j*'s revenue accounted for by its sales of commodity *i1* and composite commodity *r*. $H^1_{(is)j}, H^1_{ij}$ and $H^1_{(g+1,1,m)j}$ are the shares of *j*'s costs accounted for by inputs of *is*, by inputs of *i* from all sources and by inputs of labour of skill *m*.

Intuitively the linearised equation is easily explained if no technical change were to take place. For each industry *j*, the expression implies that a weighted average of the percentage changes in the basic prices of outputs equals a weighted average of the percentage changes in the relevant purchasers prices of inputs. The technological change terms are included to insure that the zero pure profits condition applies in the case of a technical change event that reduces/increases the efficiency of production.

ii. The price of a unit of capital

As in the case of basic prices, the value of a unit of capital is equal to the cost of its production. Because no primary inputs are used in the production of capital, the value of a unit of capital can be expressed as the sum of the value of the intermediate inputs used:

$$\pi_j Y_j = \sum_{i=1}^{g}\sum_{s=1}^{2} P^2_{is} X^2_{(is)j}$$

In linearised form this relationship is expressed as:

$$\pi_j = \sum_{i=1}^{g}\sum_{s=1}^{2} p^2_{(is)j} H^2_{(is)j} + a^2_j + \sum_{i=1}^{g} a^2_{ij} H^2_{ij} + \sum_{i=1}^{g}\sum_{s=1}^{2} a^2_{(is)j} H^2_{(is)j}$$

where π_j is the percentage change in the price of a unit of capital for industry j and the $H^2_{(is)j}$ and H^2_{ij} are cost shares. They are, respectively, the share of good *i* from source s and the share of good *i* from all sources in the cost of constructing a unit of capital for industry *j*. Once again, if there is no technical change in the production of capital, a percentage change in the cost of a unit of capital for industry *j* is a weighted average of the percentage changes in the prices of inputs, the weights being the cost shares.

There is a difference between the cost of using (or renting) a unit of capital ($P^1_{(g+1,2)j}$) and the cost of buying or producing a unit of capital π_j. The ratio $\frac{P^1_{(g+1,2)j}}{\pi_j}$ represents the gross rate of return on units of capital for industry *j*. In the ORANI-G methodology, this ratio could enter the investment decision of industry *j*. This is discussed at the end of this chapter.

iii. Determining the basic price of imported good i

The basic price of imports is the sum of the foreign price of the imported goods (expressed in domestic currency units), and tariffs or quotas on the specific good. This relationship can be expressed as:

$$P_{i2}^{0} = P_{i2}^{m}\phi + G(i2,0)$$

where P_{i2}^{0} is the basic price of imported good *i*, P_{i2}^{m} is the foreign currency price of imported good *i*, ϕ is the exchange rate and G(i2,0) is the tariff in domestic currency raised on a unit import of *i*.

The linearised expression for the basic price of imports is then given by:

$$p_{i2}^{0} = (p_{i2}^{m} + \phi)\xi_1(i2,0) + g(i2,0)\xi_2(i2,0)$$

where $\xi_1(i2,0)$ and $\xi_2(i2,0)$ are, respectively, the shares in the basic price of imported good *i* accounted for by the foreign currency price in domestic currency, and the tariff, G(i2,0).

iv. Determining the equation that relates prices of domestic goods to export prices

The prices of the export goods are the basic price of the good and the taxes and margins that are involved in delivering the good at domestic ports. This price is then converted into domestic currency by making use of the exchange rate. It can be expressed as:

$$P_{i1}^{e}\phi = P_{i1}^{0} + G(i1,4) + \sum_{r=1}^{g} A_{r1}^{(i1)} P_{r1}^{0}$$

where P_{i1}^{e} is the export price of good *i*, G(i1,4) is the export tax per unit of export of *i1* and $A_{r1}^{(i1)} P_{r1}^{0}$ is the value of each margin that is used to deliver the export product to the domestic port of delivery. In the case of an export subsidy, G(i1,4) will be negative. The above relationship can be expressed in linear form as:

$$(p_{i1}^{e}+\phi)=p_{i1}^{0}\zeta_{1}(i1,4)+g(i1,4)\zeta_{2}(i1,4)+(\sum_{r=1}^{g}M_{r1}^{(i1)4}p_{(r1)}^{0})\zeta_{3}(i1,4))+\sum_{r=1}^{g}M_{r1}^{i1}a_{r1}^{(i1)4}\zeta 4(i1,4)$$

where $\zeta_1(i1,4), \zeta_2(i1,4), \zeta_3(i1,4)$ and $\zeta_4(i1,4)$ are, respectively, the shares accounted for by the basic value, the export tax and the margins in the domestic currency price paid by foreigners for units of good *i1* at domestic ports. $M_{r1}^{(i1)4}$ is the share in the total cost of margin services involved in transferring good *i1* from domestic producers to the ports of exit represented by the use of good *r1*.

v. Determining the equation that relates purchaser's prices paid by domestic users of good *i* from domestic and imported source to its basic values.

Purchaser's prices are the sums of basic values, sales taxes and margins. Sales taxes are treated as *ad valorem* on basic values. ORANI-G relates purchaser's prices to basic values by using the following equation:

$$P_{(is)j}^{k}=P_{is}^{0}+G(is,jk)+\sum_{r=1}^{g}A_{r1}^{(is)jk}P_{r1}^{0}$$

and

$$P_{is}^{3}=P_{is}^{0}+G(is,3)+\sum_{r=1}^{g}A_{r1}^{(is)3}P_{r1}^{0}$$

where the G's are tax terms (for example G(is,jk) is the tax associated with the sale of good *i* from source s to industry *j*). The first equation therefore equates the price paid in industry *j* for good *is* to the sum of the basic value of good *is* and the cost of the relevant taxes and margins. The second equation describes the purchaser's price of good, *is*, when households use it.

It is important to note that the G's are taxes on sales and not on production. In the ORANI-G methodology, producer taxes can be included via other cost tickets. Taxes are allowed to vary across users (which is not a feature of producer taxes).

The above two equations can be expressed in percentage change form as:

$$p^{k}_{(is)j} = p^{0}_{is}\zeta_1(is, jk) + g(is, jk)\zeta_1(is, jk) + (\sum_{r=1}^{g} M^{(is)jk}_{r1} p^{0}_{r1})\zeta_3(is, jk) + (\sum_{r=1}^{g} M^{(is)jk}_{r1} a^{0}_{r1})\zeta_3(is, jk)$$

and

$$p^{3}_{(is)j} = p^{0}_{is}\zeta_1(is,3) + g(is,3)\zeta_1(is,3) + (\sum_{r=1}^{g} M^{(is)3}_{r1} p^{0}_{r1})\zeta_3(is,3) + (\sum_{r=1}^{g} M^{(is)3}_{r1} a^{0}_{r1})\zeta_3(is,3)$$

where the coefficients ζ and M, are once again the share coefficients of basic values, taxes and margins. For example, $\zeta_1(is,3)$ is the share in the purchasers' price to households of good *is* accounted for by the basic price, while $M^{(i1)3}_{r1}$ is the share in the total cost of margin services involved in transferring good *i1* from producers to households, accounted for by the use of good *r1*.

The five equations described above determine the prices in the ORANI-G general equilibrium model. They can be summarised as follows:

- The first system of equations relates changes in the basic prices of outputs to changes in the purchaser prices of inputs and to changes in technology for current production.
- The second system of price equations relates changes in the cost of capital to changes in the purchaser prices of inputs to capital creation and to changes in the technologies for capital creation.
- The third system of price equations defines the changes in the basic prices of imports in terms of changes in their foreign currency prices, the exchange rate and the tariff rates.
- The fourth system of price equations relates basic prices of domestic commodities to export prices and tariffs.
- The fifth system of price equations relates changes in the prices paid by domestic users to changes in basic prices, the relevant taxes and changes in the cost of margin services.

7.5 A REVIEW OF THE MARKET CLEARING EQUATIONS IN ORANI

The ORANI model distinguishes between market clearing equations that ensure that demand equals supply for both domestically produced commodities and the primary factors of production.

i. An equation that equates the supply and demand of each of the domestically produced goods.

The first market clearing relationship ensures that the total supply of goods is equal to the total demand for goods. As seen above, total demand in the ORANI model consists of:

- Demand for intermediate inputs into current production.
- Demand for inputs to the production of capital equipment.
- Demand for consumption goods.
- Export demand.
- "Other demands".
- Demand for margins on the delivery of goods to households and to "other users".
- Demand for margins on the delivery of goods to industrial users for current production and capital creation.
- Demand for margins on the delivery of exports from domestic producers to ports of exit.

This market clearing relationship for goods and services can therefore be expressed as:

$$X^0_{r1} = \sum_{j=1}^{h} X^1_{(r1)j} + \sum_{j=1}^{h} X^2_{(r1)j} + X^3_{r1} + X^4_{r1} + X^5_{r1} + \sum_{i=1}^{g}\sum_{s=1}^{2}\sum_{j=1}^{h}\sum_{k=1}^{2} X^{(is)jk}_{r1} + \sum_{i=1}^{g}\sum_{s=1}^{2}\sum_{k=3,5} X^{(is)k}_{r1} + \sum_{i=1}^{g} X^{(i1)4}_{r1}$$

where

$X^0_{r1} = \sum_{i=1}^{h} X^0_{(r1)j}$ is the total supply of commodities in the economy.

In percentage change form, this market clearing relationship can be written as:

$$x^0_{r1} = \sum_{j=1}^{h} x^1_{(r1)} B^1_{(r1)j} + \sum_{j=1}^{h} x^2_{(r1)j} B^2_{(r1)j} + x^3_{r1} B^3_{r1} + x^4_{r1} B^4_{r1} + x^5_{r1} B^5_{r1} + \sum_{i=1}^{g}\sum_{s=1}^{2}\sum_{j=1}^{h}\sum_{k=1}^{2} x^{(is)jk}_{r1} B^{(is)jk}_{r1}$$
$$+ \sum_{i=1}^{g}\sum_{s=1}^{2}\sum_{k=3,5} x^{(is)k}_{r1} B^{(is)k}_{r1} + \sum_{i=1}^{g} x^{(i1)4}_{r1} B^{(i1)4}_{r1}$$

The B's represent the shares of the sales of domestically produced goods that are absorbed by the various types of demands.

ii. An equation that equates the supply of labour of skill m (L_m) to demand.

The second market clearing equation ensures that the supply and demand for labour is equal within each skill group. This relationship can be expressed as:

$$L_m = \sum_{j=1}^{h} X^{1}_{(g+1,1,m)j}$$

This equation implies that labour is homogenous within each skill group and is shiftable between industries. It does not imply that ORANI is a full employment model. Setting the L_m variables exogenously at their full employment levels will impose full employment in the model. However, as an alternative, wages might be set exogenously and the L_m variables would become endogenous. The model will then generate the employment levels, L_m corresponding to the given wage rates.

The equation, in percentage change form, is:

$$l_m = \sum x^{1}_{(g+1,1,m)j} B^{1}_{(g+1,1,m)j}$$

The B's in this equation are employed shares. That is, $B^{1}_{(g+1,1,m)}$ is the share of total employment of labour of type *m* that is accounted for by industry *j*.

iii. An equation that equates the supply and demand for capital in each industry

The third market clearing equation ensures that the supply and demand for capital is equal within each industry and can be expressed as:

$$K_j(0) = X^{1}_{(g+1,2)j}$$

This expression indicates that it is assumed that capital is industry specific, and therefore cannot be shifted between industries. This market clearing equation can be expressed in percentage change terms as:

$$k_j(0) = x^{1}_{(g+1,2)j}$$

iv. An equation that equates the demand and supply for land in each industry

The final market clearing equation within the ORANI model equates the demand and supply of land in each industry and is expressed as:

$$N_j = X^1_{(g+1,3)j}$$

As in the case of capital, it is assumed that land is industry specific and cannot be shifted between industries. The percentage change form of this market clearing equation is given by:

$$n_j = x^1_{(g+1,3)j}$$

These four market-clearing equations complete the description of the structural equations of the ORANI model that will be employed within this study. There are, however, additional equations within this model which either complete the description of the economy or allow for easier interpretation of the results.

7.6 ADDITIONAL EQUATIONS FOR EXPLAINING GROSS DOMESTIC PRODUCT AND ALLOCATION OF INVESTMENT ACROSS INDUSTRIES

Apart from the above equations, the ORANI model also includes equations that explain gross domestic product and allocation decisions across industries. The first set of these equations allows for the calculation of gross domestic product from both the income and the expenditure side of the economy. GDP from the income side is calculated by simply adding the total payments to labour, capital, land and other cost tickets, as well as production and indirect tax revenue, while GDP from the expenditure side is calculated by subtracting total imports from the sum of total investment use, government demands, inventories, household demands and exports.

The ORANI model contains three alternative investment rules, which determine the amount of investment that each industry undertakes. The model does not, however, attempt to explain aggregate investment in fixed capital. It only attempts to explain how aggregate investment is allocated across the relevant industries. The first rule relates the creation of new capital stock in each industry to the profitability of each industry. If one assumes that the rate of return on fixed capital is given by $R_j(0) = \frac{P^1_{(g+1,2)j}}{\pi_j}$, and that investors expect that industry j's rate-of-return schedule in one period's time will have the form

$$R_j(1) = R_j(0)(\frac{K^1_j(1)}{K,(0)_j})^{-\beta_j}$$

where β_j is a positive parameter, $K_j(0)$ is the current level of capital stock in industry j and $K_j(1)$ is the level at the end of one period then investment will increase if the price of capital increases. It is further assumed that aggregate total investment is allocated across industries in a manner which equates the expected rates of return which means that there exists some rate of return ω, such that

$$(\frac{K_j(1)}{K_j(0)})^{-\beta_j} R_j(0) = \varpi$$

which allows new capital for industry j to be acquired according to:

$$K_j(1) = K_j(0) + Y_j$$

The second rule allows investment to be determined exogenously according to the aggregate investment of the economy and is an appropriate assumption for those industries which have a close relationship with government spending. The third rule allows investment to move along fixed capital growth rates where investment follows the industry capital stock.

Because the labour market will be analysed within this study, it is important to note that the ORANI model does not allow any theory for the labour supply of an economy. The model allows an option of setting employment exogenously, with market clearing wage rates determined endogenously, or setting the wage rates exogenously and allowing employment to be demand determined, as it is assumed that supply of each skill type is elastic.

The labour market decisions are usually made at an economy-wide level, but could be applied individually and differentially to different industries or types of labour.

7.7 CONCLUSION

This chapter briefly summarised the theoretical equations that underlie the ORANI-G modelling methodology. It has shown that the model consists of equations that represent both the production and demand side of an economy, as well as pricing and market clearing equations. This methodology will be applied to a South African database to test the effect of a revenue neutral tax on coal.

CHAPTER 8

A CGE MODEL FOR SOUTH AFRICA: THE DATA BASE AND ELASTICITIES

8.1 INTRODUCTION

The examination of the ORANI-G theoretical structure indicated that it is necessary to obtain the relevant elasticities with respect to the South African economy, which will then be used within the ORANI-G framework to represent a relevant CGE model for South Africa. The model can then be applied to evaluate the economy-wide effects of different environmental policy suggestions. The purpose of this chapter is to briefly describe the database that is used for the South African CGE model and the methodology that is used to arrive at the relevant elasticities that are used within this model.

CGE models are frequently criticised for resting on weak empirical foundations. The use of (apparently) arbitrary values and a lack of model validation are two aspects that receive severe criticism (Liu *et al*, 2001, p3). According to Liu *et al* (2001), several approaches have been used for parameter estimation in CGE models. These approaches include micro-econometric studies, the calibration method, the econometric method and the semi-econometric method. The micro-econometric studies on parameter estimations are usually commodity and partial equilibrium based and have been criticised by many macro- and CGE-modellers for this reason. The calibration method focuses on the selection of a particular functional form and its associated parameterisation. The parameters that must be estimated are then determined by forcing the model to replicate the data of the chosen benchmark year. This method requires limited data but has been criticised for its lack of statistical validity. Apart from this, the calibration method sometimes requires further "subjective inputs" when certain functional structures are used (such as the CES form). The econometric approach to CGE parameter estimation requires substantial time series data and is usually criticised for the onerous data requirements that it needs to allow for econometric estimation. It is also criticised for the fact that econometric estimation is usually conducted on separate subsystems of the general equilibrium system (Liu *et al*, 2001, p5).

Although there are caveats to each of these methods, the approach that is followed to determine the elasticities for the South African model is a combination of the micro-econometric and econometric methods in which the elasticities of several subsystems are estimated. Where data requirements are to onerous or where data is simply not available, elasticities are obtained from the current economic literature of the South African economy. This is further complimented with elasticities that are suggested by the literature on the ORANI model of the South African economy.

8.2 DESCRIPTION OF THE SOUTH AFRICAN DATABASE THAT WILL BE USED FOR A CGE MODEL

The main source of data that will form the basis of the CGE model is a 2001 Social Accounting Matrix (SAM) produced by Quantec by request of the World Bank. This SAM distinguishes between 45 different products and 45 different industries. Each of these industries is allowed to produce only one output. Distinction is made between 4 different labour groups and 14 different households. The original SAM also distinguishes between 7 different types of government expenditures, 13 different export destinations and 12 different types of fixed investment in the South African economy. For purposes of this study the different export destinations, government expenditures and types of fixed investment are aggregated to allow for aggregated government expenditure, aggregated exports and aggregated investment for the South African economy.

The 45 different industries and products that are distinguished within the 2001 SAM are (abbreviation of the industry in brackets: Appendix One gives a thorough description of each of these industries):

1. Agriculture, forestry and fishing (Agric)
2. Coal mining (Coal)
3. Gold and uranium ore mining (Gold)
4. Other mining (Othmin)
5. Food (Food)
6. Beverages (Bev)
7. Tobacco (Tob)
8. Textiles (Text)
9. Wearing apparel (Wear)
10. Leather and leather products (Leath)
11. Footwear (Foot)
12. Wood and wood products (Wood)
13. Paper and paper products (Paper)
14. Printing, publishing and recording media (Print)

15. Coke and refined petroleum products (Coke)
16. Basic chemicals (BasChem)
17. Other chemicals and man-made fibres (OthChem)
18. Rubber products (RubProd)
19. Plastic products (PlastProd)
20. Glass and glass products (Glass)
21. Non-metallic minerals (NonMetMin)
22. Basic iron and steel (BasIrSt)
23. Basic non-ferrous metals (BasNFer)
24. Metal products excluding machinery (MetProd)
25. Machinery and equipment (MachEq)
26. Electrical machinery (ElecMach)
27. Television, radio and communication equipment (Telv)
28. Professional and scientific equipment (ProfEq)
29. Motor vehicles, parts and accessories (MotVeh)
30. Other transport equipment (OthTrnsp)
31. Furniture (Furn)
32. Other industries (OthInd)
33. Electricity, gas and steam (Elect)
34. Water supply (WatSup)
35. Building construction (BuildCnst)
36. Civil engineering and other construction (Civil)
37. Wholesale and retail trade (WhSale)
38. Catering and accommodation services (CatAcc)
39. Transport and storage (TrnspStor)
40. Communication (Com)
41. Finance and insurance (FinIns)
42. Business services (BusServ)
43. Medical, dental and other health and veterinary services (MedDent)
44. Other community, social and personal services (OthComServ)
45. Other producers (OthProd)

Given the 45 industries that are distinguished, the four different types of labour that are employed within these industries are:

1. Highly skilled (H)
2. Skilled (S)
3. Semi- and unskilled (SS)
4. Informal labour (I)

(Appendix One describes the labour types in more detail)

Households are distinguished according to income groups and the 14 different groups of households that are distinguished are (Classified according to real household incomes):

1. d0: (0 - 10): R4.9 billion
2. d1 (10 – 20) R7.0 billion
3. d2 (20 – 30) R9.8 billion
4. d3 (30 – 40) R13.2 billion
5. d4 (40 – 50) R17.8 billion
6. d5 (50 – 60) R23.3 billion
7. d6 (60 – 70) R33.6 billion
8. d7 (70 – 80) R49.3 billion
9. d8 (80 – 90) R78.4 billion
10. d91 (90 – 95) R63.5 billion
11. d921 (95 – 96.25) R21.5 billion
12. d922 (96.25 – 97.5) R25.2 billion
13. d923 (97.5 – 98.75) R29.1 billion
14. d924 (98.75 – 100) R58.0 billion

As stated above, distinction is also made between different export destinations, fixed investment categories and different types of government expenditures. Because these categories are aggregated for purposes of this study, these macroeconomic aggregates are described in Appendix One.

8.3 ELASTICITIES THAT NEED TO BE OBTAINED FOR A CGE MODEL OF THE SOUTH AFRICAN ECONOMY

Given the theoretical structure and the databases that are used for the South African version of the ORANI-G model, there are a number of elasticities that need to be obtained. These elasticities could have a significant effect on the outcome of policy simulations within the model. They are:

i. The CES substitution elasticity between different skill types.
ii. The CES substitution elasticity between primary factors.
iii. The Armington elasticities between the domestic and imported use of commodities for intermediate inputs.
iv. The CET transformation elasticities if the data base that is used allows for each industry to produce more than one output. The SAM that is applicable in this study only allows each industry to produce one product and the CET elasticity is therefore not applicable.
v. The elasticity of transformation between exports and locally used products. This elasticity allows for the possibility that goods that are destined for exports are not the same as those that are destined for local use. Once again, the database does not allow for export commodities to differ from domestic commodities and it can be assumed that this elasticity is zero.
vi. The Armington elasticities between the domestic and imported use of commodities for inputs into the production of investment.
vii. The Armington elasticities between the domestic and imported use of commodities by households.
viii. The household expenditure elasticities for each of the products in the economy.
ix. The Frisch linear expenditure household consumption parameter.
x. The export demand elasticities for the individual export demand functions.
xi. The export demand elasticity for the collective export demand function.

The elasticities are obtained by a combination of econometric estimations and a review of the relevant literature. Despite this, a lack of historical data and relevant research material on the markets of the South African economy renders the attainment of the true elasticities a difficult task. There is significant room for research in this particular field of CGE modelling in South Africa. The methodology that is followed and the consequent results are described below.

i. The CES substitution elasticity between different skill types

There is very little (if any) data available for the estimation of the CES substitution elasticities between highly skilled, semi-skilled, unskilled and informal sector workers. Despite the difficulty of obtaining reliable historical time series for the number of workers employed within each of these groups, reliable wage data on the industry level for each of these groups is virtually non-existent. Given this, econometric estimation of the elasticity of substitution between the different types of labour would not yield statistically significant results. It is therefore not surprising that the current literature does not provide any insight into the exact values of these elasticities.

The uncertainty that surrounds the substitution elasticity between different skill types in South Africa is, however, not unique when international literature is examined. Dixon *et al* (1980, p190) state that there is considerable uncertainty that exists within the literature about the extent to which changes in occupational wage relativities influence occupational labour demands in Australia. Dixon *et al* (1980) refer to a study done by Ryland and Parham (1978) in which an attempt was made to obtain substitution elasticities between five types of labour, and although the results were not entirely satisfactory, a fairly well-determined value of 0.2 was obtained for the labour-labour substitutional elasticity, where occupational labour inputs were assumed to be combined by a CES function to generate the overall labour input.

Despite the uncertainty and difficulty that surrounds these elasticities, the discussion of the South African labour market earlier in this study has indicated that one should not expect a high degree of substitutability between the different types of labour in South Africa, as there are structural and institutional factors that allow for very little substitution within the labour market. One could therefore also assume a low elasticity of substitution for the South African labour market. Given the Ryland and Parham (1978) result for the Australian economy, an elasticity of 0.2 is assumed for the South African model.

ii. Estimation of the CES parameter that reflects the degree of substitutability between the different primary factors in the production process of each industry.

A review of current literature of the elasticity of substitution between primary factors in the South African economy has not shed any light on the expected elasticities for the industries included within this study. An attempt is therefore made on estimating these substitution elasticities by following a widely used approach pioneered by Ferguson (1965).

The CES production function has been well received and extensively analysed since its introduction by Arrow, Chenery, Minhas and Solow in 1961. In their groundbreaking paper, Arrow et al (1961) derive the CES production function and apply the form to time series of all non-farm production in the United States. The results indicated an overall elasticity of substitution between capital and labour that is significantly less than unity (Arrow et al, 1961). The elasticity of substitution of the

CES production function can be estimated by using conditions of profit maximisation. This results in the following equation that can be estimated with linear regression techniques:

$$\log(\frac{V}{L}) = \alpha + \sigma \log(\frac{w}{p})$$

where

V = *Value Added* by capital and labour

L = *Labour*

σ = *Elasticity of substitution*

$\frac{w}{p}$ = Real wage per worker

However, Ferguson (1965) states that the above equation is only suitable for determining the elasticity of substitution from cross section data and not for use with time series data, due to there being no term to allow for technical progress or any other effects that the passage of time might have on the elasticity of substitution. He therefore expands the above specification to include a term for the rate of constant (neutral) technological progress that takes place over time. The time series counterpart for the above equation is therefore:

$$\log(\frac{V}{L}) = \alpha + \sigma \log(\frac{w}{p}) + \beta t$$

where

t = constant technological change

Although the CGE model in this study distinguishes between capital, labour and land as factors of production, the strong assumption is made that the elasticity of substitution between capital and labour holds for the substitution between capital and land, and land and labour as well. In order to obtain estimates for the elasticity of substitution between capital and labour for the 45 industries included in this study, the "Ferguson specification" is applied. Given South Africa's recent history, the above specification is expanded to include two dummy variables. The first dummy variable captures the effect that sanctions had on the South African labour market from 1985 to 1994, while the second dummy variable captures the effect of South Africa's re-instatement into the world economy following the 1994 democratic elections. The complete specification is therefore:

$$\log(\frac{V_j}{L_j}) = \alpha + \sigma_j \log(\frac{w_j}{p_j}) + \beta_j t + \delta D_{sanction} + \gamma D_{international}$$

where

V_j = *Value added by industry j*

L_j = *Labour employed by industry j*

σ_j = *Elasticity of substitution between labour and capital in industry j*

$\frac{w_j}{p_j}$ = *Real wage per worker in industry j*

t = *neutral technological change*

$D_{sanction}$ = *Dummy variable that represent the period of sanctions in South Africa*

$D_{internatonal}$ = *Dummy variable that represent the post 1994 period*

Time series data for value added, labour employed and real wage per worker was obtained for each of the 45 industries from the BFA McGreggor input-output database.

An ordinary least squares regression of the functional form described above was estimated for each of the 45 industries that are distinguished within the model. In order to allow for a level of credibility for the estimated elasticities, the estimated equations had to conform to the following criteria:

- The coefficients of each variable in each equation had to make economic sense.
- The coefficients of each of the explanatory variables had to be statistically significant.
- The dependant variable and the explanatory variables had to form a cointegrating relationship.

Although the coefficients of the dummy and technological variable were not significant in all of the estimations, the real wage rate per worker was significant in most of the equations. The equations, in which some of the explanatory variables were insignificant, were re-estimated without including the insignificant variables. This resulted in estimations that complied with the above criteria for 40 of the industries. The only industries for which a cointegrating relationship could not be established were textiles, other production and other transport industries, while the coefficients for the tobacco industry and motor vehicle industries were insignificant. Although it was not part of the criteria, most of the estimations resulted in Adjusted R^2 values higher than 0.80. Appendix Two contains the results of the statistical tests performed on the estimations.

Table 8.1 summarises the estimated substitution elasticities for each of the industries. The average elasticity of substitution between labour and capital in the 40 industries is 0.66, with the water supply industry having the lowest elasticity of 0.17 and the communications industry the highest elasticity of 1.45. The average elasticity of 0.66 is assigned to the industries for which significant elasticity results could not be estimated.

Table 8.1: Elasticity of substitution between capital and labour in the South African economy.

Industry	*Elasticity of substitution*	*Industry*	*Elasticity of substitution*
Agric	0.74	MetProd	0.91
Coal	0.38	Macheq	0.77
Gold	0.42	ElecMach	0.66
Othmin	0.29	Telv	0.83
Food	0.34	ProfEq	0.77
Bev	0.28	MotVeh	0.66
Tob	0.66	OthTrnsp	0.91
Text	0.66	Furn	0.58
Wear	0.78	OthInd	0.66
Leath	1.02	Elect	0.26
Foot	0.81	WatSup	0.173
Wood	0.38	BuildCnst	1.05
Paper	0.36	Civil	0.91
Print	0.61	WhSale	0.74
Coke	0.28	CatAcc	0.5
BasChem	0.83	TranspStor	0.66
OthChem	0.27	Com	1.45
RubProd	0.85	FinIns	0.34
PlastProd	0.73	BusServ	0.29
Glass	0.72	MedDent	0.35
NonMetMin	0.69	OthComServ	0.66
BasIrSt	1.01	OthProd	0.66
BasNFer	0.81		

Source: Own calculations

The above results indicate that most of South Africa's industries operate at an elasticity of substitution below one. A one percent increase in the use of capital will therefore result in a less than one percent decrease in the use of labour (and vice versa) for most of the industries.

iii. Estimation of the elasticity of substitution between domestic and foreign sources for use as a current input in the production, investment and household consumption.

Traditional trade theory analysis of import demand is founded on the assumption of perfect substitution between domestic and imported goods. However, this assumption fails to explain the continued demand for both sources of the same good despite changes in their relative prices over time. This observation has given rise to the notion of Armington elasticities. Armington elasticities capture the degree of substitutability between domestic and foreign sources of supply. The higher the value of this parameter, the closer the degree of substitution between the two sources, while a low value would mean that these sources are weak substitutes.

Although Armington elasticities can be estimated separately for each level of demand (as seen in the specification of the CGE model), available data can seldom support such an attempt. Because of data inadequacies, this study follows Dixon et al (1980, p181) and imposes the restriction:

$$\sigma_{ij}^{1} = \sigma_{ij}^{2} = \sigma_{i}^{3} = \sigma_{i}$$

That is, the elasticity of substitution between domestic and imported good *i* is the same for use as an input in the production process, investment or household consumption. Dixon *et al* (1980, p182) defend this assumption by pointing out that most of Australia's major imports are used predominantly in the one end-use category only, and this assumption will suffice for South Africa as well.

In order to estimate the Armington elasticities for the 45 industries of the South African economy, the methodology set out by Reinert and Roland-Holst (1992) is followed. According to these authors, if a representative consumer has a well-behaved utility function, then the consumption decision is amenable to neoclassical utility maximisation or expenditure minimisation. In terms of the choice between imported and domestically produced goods, the hypothetical consumer obtains utility from a composite (Q) of imported (M) and domestic (D) goods, and it is assumed that there are continuous substitution possibilities. The consumer's decision problem is then to choose a mix of M and D that minimises expenditure, given respective prices p_M and p_D and the desired level of Q. In the Armington specification, a CES functional form is chosen for Q:

$$Q = \alpha\left[\beta M^{\delta} + (1-\beta)D^{\delta}\right]^{\frac{1}{\delta}}$$

where α and β are calibrated parameters and $\sigma = \frac{1}{1+\delta}$ is the constant elasticity of substitution between imports and domestic goods. The solution to the consumer's optimisation problem is then to choose imports and domestic goods whose ratios satisfy the first order condition:

$$\frac{M}{D} = \left[\frac{\beta}{1-\beta}\frac{P_D}{P_M}\right]^{\sigma}$$

Under the assumption that the utilities in composite consumption are weakly separable, Armington elasticities can be estimated for disaggregated commodity categories, by taking the logarithmic form of the above first order condition. That is:

$$\log(\frac{M}{D}) = \sigma\log\left[\frac{\beta}{1-\beta}\right] + \sigma\log\left[\frac{P_D}{P_M}\right]$$

which can be estimated accordingly:

$$y = b_0 + b_1 x$$

where

$$x = \log(\frac{P_D}{P_M})$$

$$b_1 = \sigma$$

Kapuscinsky and Warr (1996) highlight some problems with this specification:

- The above specification is a static specification. It is therefore not likely to adequately capture dynamic relationships between imports, domestic production and prices.
- The quantity of imports entering a country is frequently subject to various regulations, such as tariffs, and it is important to include variables that capture these factors.

According to Kapuscinsky *et al* (1996) these problems can be addressed by making use of a partial adjustment model or an error correction model (dynamic specification), as proposed by Engle and

Granger (1987). They include dummy variables to represent qualitative events in each sector for which Armington elasticities are estimated.

In their study, the problems highlighted by Kapuscinsky *et al* (1996) are addressed by including dummy variables in the Reinert *et al* (1992) specification that will represent qualitative factors in each industry. These will include factors such as the sanctions that have been imposed on the South African economy between 1985 and 1994 and restricted trade between South Africa and the rest of the world. The model used to estimate the Armington elasticities for the 45 products distinguished within the South African CGE model is given by:

$$y = b_0 + b_1 x + b_2 Z$$

where

$$x = \log(\frac{P_D}{P_M})$$

$$b_1 = \sigma$$

$$Z = \text{Dummy variables}$$

As was the case in the estimation of the elasticities of substitution between capital and labour, an ordinary least squares regression was estimated for each of the 45 industries that are distinguished within the model. The same evaluation criteria were used in this instance (as was the case for the elasticities of substitution).

The result for the Armington elasticities for each industry is summarised in Table 8.2, while the statistical results are presented in Appendix Two.

Table 8.2: Estimated Armington elasticities for 45 South African industries

Product	Armington elasticity	Product	Armington elasticity
Agric	0.318	MetProd	0.85
Coal	1.423	Macheq	1.07
Gold	No imports	ElecMach	0.94
Othmin	0.94	Telv	0.91
Food	1.14	ProfEq	0.99
Bev	0.68	MotVeh	0.71
Tob	0.73	OthTrnsp	1.37
Text	1.24	Furn	0.75
Wear	0.68	OthInd	0.43
Leath	1.83	Elect	0.94
Foot	0.94	WatSup	No imports
Wood	0.37	BuildCnst	1.57
Paper	1.37	Civil	2.84
Print	0.42	WhSale	0.94
Coke	0.47	CatAcc	0.94
BasChem	0.56	TranspStor	1.17
OthChem	0.71	Com	0.94
RubProd	1.00	FinIns	0.94
PlastProd	0.94	BusServ	0.98
Glass	0.35	MedDent	1.05
NonMetMin	0.94	OthComServ	0.58
BasIrSt	0.94	OthProd	0.65
BasNFer	0.94		

Source: Own calculations

The elasticities for the footwear, plastic products, non-metal and minerals, basic iron and steel, basic non-ferrous metals, electricity, wholesale and finance & insurance industries were either insignificant or did not form a cointegrating relationship. The average elasticity is therefore assigned to these industries. With the exception of a few industries, the estimated Armington elasticities are below 1 and the average elasticity is 0.94 which indicates that there is not a very high degree of substitution between imported and domestic commodities at this level of disaggregation of the South African economy. This result can be expected, as each of the 45 industries that are distinguished within this study, could be disaggregated further, which could increase the substitution between imported and domestic commodities. It can be deducted therefore that at this level of aggregation there is a low degree of substitutability between imported and domestic goods within the 45 industries distinguished within this study.

iv. The household expenditure elasticities for each product in the economy.

In order to obtain the relevant parameters for the commodity demand equations for each of the 14 households that are distinguished within the South African database, it is necessary to obtain an estimate of the expenditure elasticity of each household for every product that these households consume in the South African economy. Analysis of the SAM indicates that households do not consume any products that are produced by the gold, other mining, the basic iron and steel, the non-ferrous metals, the construction and the civil engineering industries. Expenditure elasticities must be obtained for the remaining 39 products.

Once again, the literature of the South African household expenditure does not provide expenditure elasticities at a level that will provide insight into the expenditure pattern of each one of the 14 households. This is not surprising, as very little historical data is available for the expenditure of each household on each of the 39 commodities in the South African economy. The lack of data also hampers econometric estimation of the expenditure elasticities for each of the 14 households.

Because of the lack of detailed historical data, expenditure elasticities are estimated for an "aggregated household" that encompasses the expenditure of the 14 households that are distinguished within this study. It is then assumed that these expenditure elasticities are representative for each of the individual households. Despite the lack of data for disaggregated households, there is sufficient data available to estimate the aggregated household's expenditure elasticity for each of the 39 products in the model.

The demand function that is estimated for each of the 39 products is the commonly used log-linear demand equation of the form (Intrilligator, 1978, p218):

$$\ln(C_i) = \alpha_i + \beta_i \ln(Yd) + \delta_i \ln(\frac{P_i}{P}) + \varepsilon_i$$

where

C_i = Expenditure on good i

Yd = Personal disposable income

$\frac{P_i}{P}$ = Relative price of good i to all goods

β_i = Expenditure elasticity of good i

δ_i = Price elasticity of good i

The same criteria that were established for the estimation of the Armington and CES substitution elasticities were used for each of the 39 household demand equations that were estimated. The complete set of statistical tests is presented in Appendix Two. Table 8.3 includes the estimated expenditure elasticities for the 39 products. The results indicate that the elasticities for the leather, footwear, non-metal and mineral and machinery equipment industries are not significant, or that the estimated equation does not form a cointegrating relationship. For these industries the average elasticity of 0.89 is adopted. Except for the household expenditure elasticity of tobacco, all the other elasticities are economically viable. The estimated expenditure elasticity for tobacco is, however, negative and a very low elasticity of 0.05 is assigned.

Table 8.3: Household expenditure elasticities for 39 commodities distinguished within a CGE model for South Africa

Product	Expenditure Elasticity	Product	Expenditure elasticity
Agric	0.99	MetProd	0.86
Coal	1.72	Macheq	0.72
Gold	0	ElecMach	0.03
Othmin	0	Telv	2.24
Food	0.96	ProfEq	1.2
Bev	1	MotVeh	1.2
Tob	0.05	OthTrnsp	1.41
Text	0.43	Furn	1.85
Wear	0.25	OthInd	0.19
Leath	0.89	Elect	0.89
Foot	0.89	WatSup	0.62
Wood	0.65	BuildCnst	0
Paper	1.11	Civil	0
Print	0.75	WhSale	0.81
Coke	1.62	CatAcc	0.9
BasChem	1.69	TranspStor	1.68
OthChem	1.17	Com	2.31
RubProd	0.35	FinIns	1.84
PlastProd	0.71	BusServ	1.28
Glass	0.83	MedDent	1.83
NonMetMin	0.89	OthComServ	0.72
BasIrSt	0	OthProd	0.72
BasNFer	0		

Source: Own calculations

v. The Frisch linear expenditure household consumption parameter.

As indicated in the previous chapter, the linear expenditure system that represents household demand distinguishes between luxury expenditure and subsistence demand. Because of this distinction, it is necessary to obtain the ratio of household luxury expenditure to total expenditure. It has also been indicated that the ORANI methodology makes use of the household expenditure elasticities, as well as the Frisch parameter to calculate this ratio. The Frisch parameter is usually fixed at a value of -1.82 in the ORANI models. This value represents a weighted average of values for different types of Australian households. This value is, however, also based on pooled international evidence and the same assumption is made for the South African version of the ORANI-G model.

Given the household expenditure elasticities that have been estimated above, and the Frisch parameter, the ratio of luxury to total expenditure can be calculated for the base year of the model. This ratio should change for each household and every product as relative prices adjust in the economy.

vi. Estimation of the foreign elasticity of demand for the 45 different commodities

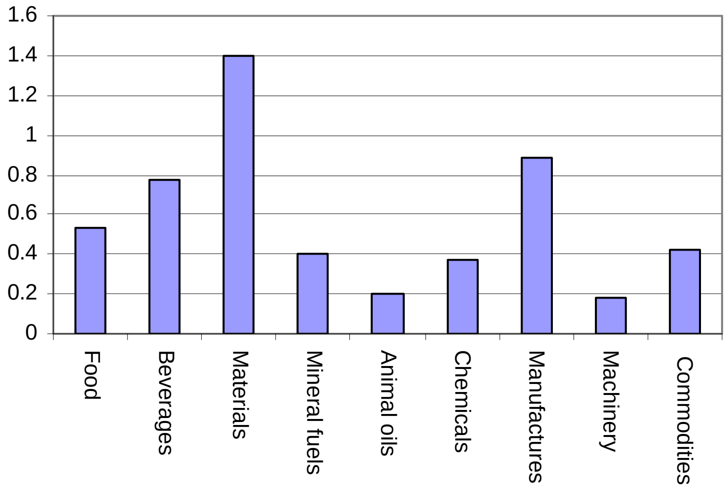
The theoretical summary of the ORANI-G export equations indicates that a distinction is made between individual export demand functions and a collective export demand function. As indicated, the collective export demand function usually includes service commodities. For this reason three commodities are included in the collective export demand function. These are;

- medical, dental and other health services,
- other producers; and
- other community and social services.

In order to derive and motivate the use of the price elasticities of exports for the remaining 42 individual commodities within the model, the methodology behind the ORANI model of the Australian economy has been used. Demand elasticities in the ORANI model are assumed to be –4 for those goods for which Australia does not have sufficient market share to influence the market price.

In this regard, South Africa is generally accepted to be a small open economy with little pricing power in international markets. Figure 8.1 below indicates the small market share that South Africa enjoys within total world exports for 9 broad groups of commodities. These groups include each of the 45 industries that are distinguished within this model.

Figure 8.1: South Africa's share of total world exports in 9 broad commodity categories



Source: BFA, McGreggor, 2001

Given the 41 commodities for which individual price elasticities of demand need to be determined within the South African version of ORANI-G model, South Africa can only expect to exert sufficient market power in the gold market, as the country remains the world's biggest exporter of gold. In spite of this, the international gold price is set exogenously and South African gold mines are price takers at a given international gold price. Therefore, the price elasticity of –4, has been adopted for all of the 41 individual industries included in the South African version of the ORANI model. As is the case in the ORANI model, the price demand elasticity for common export products are assumed to be –4.

vii. The economy-wide rate of return on investment

The theoretical exposition in the previous chapter has indicated that investment for each industry can be determined according to three alternative investment rules. One of the investment rules allows investment to be endogenised. In this case investment is determined by the profitability of each industry. This rule represents the investment decision for most of the industries in the South African version of the ORANI-G model. The other investment rule which is assigned to the remaining industries allows investment to grow at a rate that is equal to the economic growth rate in the model. The industries for which investment is determined in this manner are the industries that have a high degree of government intervention. These are the electricity & gas & steam, water supply; other community & social services and other producers. For the remaining industries the parameter β_j (the elasticities of the expected rate of return schedule) must be estimated.

In order to find a value for β_j, Dixon et al (1980, p197) solve industry j's next period rate of return schedule (see previous chapter) for β_j, that is:

$$\beta_j = \frac{\ln R_j(0) - \ln \Omega}{\ln(\frac{K_j(1)}{K_j(0)})}$$

where Ω represents the economy-wide safe rate of return on investment.

8.4 CONCLUSION

This chapter described the database, and the elasticities used within the South African version of the ORANI-G model. It also described the assumptions and methodology that were used to obtain them. It is evident that there is room for improving the current elasticity file (as data availability and economic literature develops). Given the scope of this study, however, these elasticities currently represent the best available data and should be utilised and adapted as new information becomes available.

CHAPTER 9

MODEL CLOSURE AND POLICY SHOCKS

9.1 INTRODUCTION

It is evident from the theoretical description of the CGE model that the model has more variables than equations. It is therefore necessary to choose which of the variables will be determined endogenously within the model, and which variables will be determined exogenously. The number of exogenous variables must be chosen such that the economic environment in which the policy shock is tested, best reflects the true economic environment in which the policy shock is applied. This must, however, take place with the constraint that the number of endogenous variables and the number of equations in the model are equal. Within modelling methodology, the assumptions about exogenous and endogenous variables are known as "model closure". Apart from reflecting the economic environment, the choice of model closure usually reflects two types of considerations.

The first consideration is the time frame under which economic variables are allowed to adjust to a new equilibrium after the shock. This assumption affects the manner in which factor markets are modelled. If one wants to analyse the effect of the policy shock on an economy in the short run, capital stocks are usually held fixed, as fixed capital takes time to adjust to economic shocks. Employment, however, is allowed to change in the short run as firms can employ more labour, or workers could supply more labour. In such a scenario, the price of capital is allowed to vary in order to keep the stock of capital constant, while the price of labour is fixed. If the time frame under consideration is deemed to be of long-term nature, capital stock is allowed to vary, while labour supply is assumed to be fixed. This reflects the economic reality that capital can adjust over time, but that employment is bound by demographic constraints over longer periods of time (the natural rate of unemployment). In a long-term scenario, the price of labour is allowed to vary, while the price of capital remains fixed.

The second consideration that must be taken into account in closing the model is the particular hypothesis that needs to be tested within a simulation, and the viewpoint of the modeller on those variables that the model does not explain. Because the ORANI-G methodology provides little theory to explain the size and composition of absorption, the major expenditure side aggregates for GDP are usually held fixed. Therefore, if a policy shock reduces GDP, the balance of trade could move into a deficit to reflect dissaving on a national level, or the balance of trade could be fixed to allow consumption expenditure to change. The change in expenditure could then serve as an indication of the change in the welfare of society (Horridge, 2002, p54).

The distinction between short- and long run closures assists in the decision of an acceptable model closure. However, Horridge (2002) stresses that many different closures may be used for different purposes and that there is not a unique, or correct closure. Despite this, the choice of closure is bound by certain restrictions of which an important one is that the price variables in the model's equations always appear as price ratios, and that there has to be at least one exogenous variable measured in local currency in order to determine the overall price level (Horridge, 2002, p55).

Given this background, a suitable short-run and long-run closure needs to be established to test the effects of a revenue neutral tax on the intermediate use of coal in the South African economy. In establishing these closures, the features of the South African factor markets must be considered, as well as the economic variables that need to be evaluated in the experiment, such as coal consumption, labour absorption and the welfare of South African society.

9.2 A SUGGESTED SHORT-RUN CLOSURE FOR PERFORMING REVENUE NEUTRAL COAL TAX SHOCKS ON THE SOUTH AFRICAN ECONOMY

The hypothesis of the attainment of a double dividend in the South African economy is tested within a short-run setting. The reasons are:

i. The double dividend literature indicates that the hypothesis holds positive benefits for an economy regardless of the level of technological change. Because the possibility of technological change cannot be ignored over a long-run perspective, a short-run analysis is deemed appropriate.

ii. The possibility of obtaining a double dividend is appealing from both an environmental and a political perspective. The political time-horison is usually short-term.

The short-run assumptions of the closure are made keeping the realities of the South African labour market in mind (see Chapter 3). Chapter 3 indicated that the supply of unskilled and informal sector labour is highly elastic and that a significant amount of unemployment exists within the unskilled and informal labour markets. A realistic closure for these two components of the South African labour market would therefore be to fix the wages for these two groups (highly price elastic). This will allow unskilled and informal sector employment to change in the face of a policy shock, while wages of these components of the labour market remain constant.

The supply of highly skilled and semi-skilled labour is different from unskilled and informal sector labour. There seem to be very little (if any) unemployment in these two groups of South Africa's labour force and wages tend to adjust as the demand for this type of labour increases or decreases. It is therefore plausible to assume that the labour supply of highly skilled and semi-skilled labour is fixed (highly wage inelastic) and that wages will adjust in the face of policy shocks without much scope for a change in the level of employment in these two groups.

Because of the short-run nature of the policy analysis, it is assumed that capital and land remains fixed within the model and that the price of capital and land will adjust in the face of any policy shocks. This assumption allows firms to change the amount of unskilled and informal sector workers that they employ in order to adjust output, while the quantity of capital, land and highly skilled and skilled labour remains fixed.

Because of the short-run nature of the policy analysis, and because the model does not contain much information on the theory behind the macroeconomic aggregates, it is assumed that government spending and aggregate investment spending are exogenous. This allows consumer expenditure and the trade balance to be endogenised, which will allow for the analysis of both the welfare and balance of trade effects of the policy shock.

Apart from the above, all technical change and shift variables are exogenised as it is widely accepted that technological change is a long-term phenomenon and should therefore be evaluated under constraints that reflect a long-term economic scenario.

Finally, all tax rate variables are exogenised and the tax rate on the intermediate use of coal can be shocked to determine the effect of such a shock on the South African economy.

9.3 *T*HE PROPOSED SHORT-RUN POLICY SHOCKS

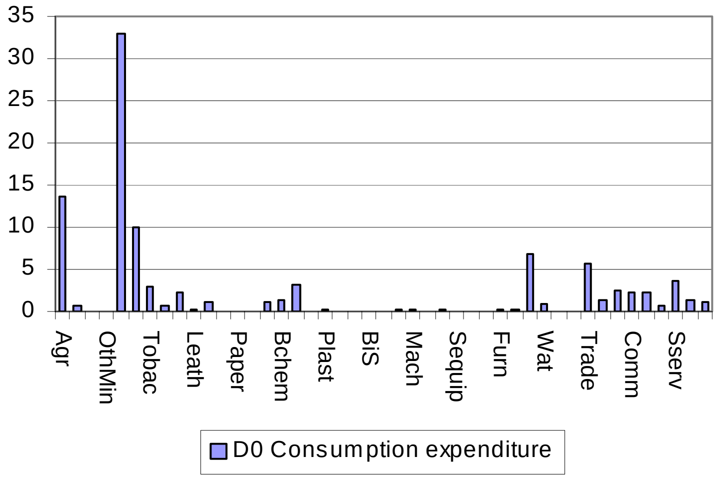
Given the closure backdrop, a number of policy simulations are tested in order to determine the effect of a revenue neutral tax on coal.

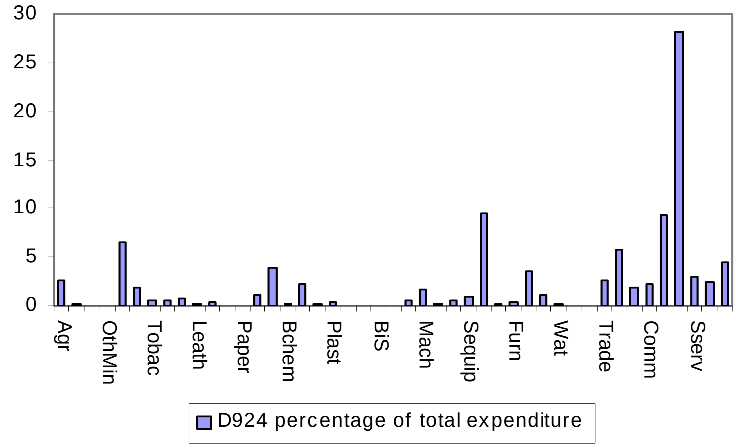
i. The first policy shock that is simulated with the South African CGE model is an increase in the tax rate on the intermediate use of coal across all industries in the South African economy. The tax increase should increase the price of coal by 50 percent. The increase of 50 percent is chosen in order to get a clear indication of the economy-wide effects of such a tax. Of particular interest will be the effect of the tax on the demand for coal, consumer welfare, employment and GDP growth. It must also be determined whether the tax will result in a positive tax receipt for the government, and, if it does, the magnitude of this tax receipt.

ii. The second policy proposal is a revenue neutral shock in which a 50 percent tax on coal is introduced. The revenue that is raised through the tax is then redistributed as a lump-sum transfer to the households that are included in the three lowest income groupings within the model (D0, D1, D2).

iii. The third policy proposal is a revenue neutral shock in which a 50 percent tax on coal is introduced along with a revenue neutral cut in intermediate taxation of food and agricultural products. The assumption that is made in this scenario is that the revenue raised by the tax on coal is redistributed in the economy by reducing the cost of those products that constitute the bulk of the consumption expenditure of the poorest households of the South African economy. Figure 9.1 reflects a comparison of the expenditure patterns of the poorest household groups (D0), with that of the richest (D924) in South Africa.

Figure 9.1: A comparison between the consumption expenditure patterns of the poorest and the richest households in South Africa



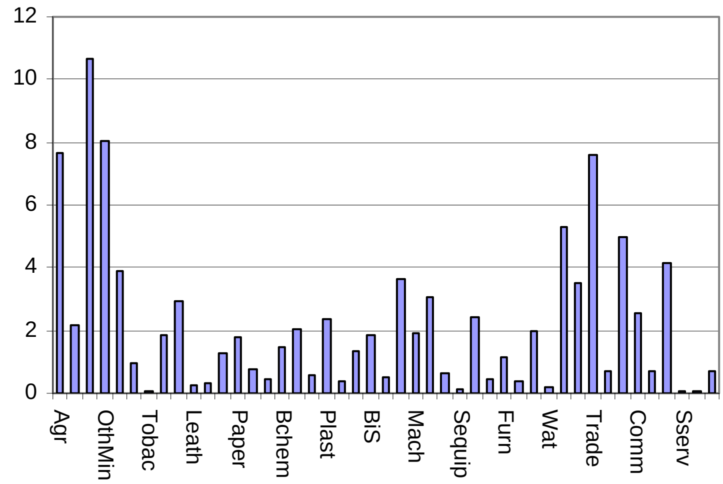


Source: SAM, 2001

Consumption expenditure on food and agricultural products constitute nearly 50 percent of the total consumption expenditure of the poorest households, while it only constitutes about 10 percent of the total expenditure of the richest households.

Apart from the potential impact that cheaper food and agricultural products will have on the poorest households, these industries are relatively labour intensive and contribute towards 12.5 percent of the unskilled employment in South Africa, and 6.5 percent of total employment in the country. Figure 9.2 shows that only the gold mining sector employs more unskilled labour than the agricultural sector.

Figure 9.2: Employment of unskilled labour in South African industries



Source: SAM, 2001

Given that the agricultural and food industries are relatively intensive in the use of unskilled labour, a tax that reduces the cost of these products should indirectly result in a decrease in the tax burden that this factor carries in the economy.

The results of the policy shocks will indicate whether these policy proposals could result in a double dividend for the South African economy in the short term. This will be the case if the net result of the policy shock is a decrease in pollution that results from the use of coal, while unemployment decreases and welfare increases as a result of the lump sum transfer to households or the lower cost of food and agricultural products. Other economic variables that are of interest include the change in the level of unskilled and informal sector employment and the effect that these proposals have on South Africa's external competitiveness.

9.4 A SUGGESTED LONG-RUN CLOSURE FOR PERFORMING REVENUE NEUTRAL COAL TAX SHOCKS ON THE SOUTH AFRICAN ECONOMY.

The literature review on technological change and environmental policy has indicated that technological change could be induced by environmental policy. Technological change is more of a long-run phenomena than a short-run phenomenon, and therefore the effect of technological change is tested over the long-term.

To allow the analysis of the long-term effects of a tax on coal, capital is allowed to change, while the rate of return on investment is fixed. Convention would dictate that, in the long run, employment would be fixed, while real wages would adjust to accommodate policy changes. However, because of the high unemployment rate that persist in the unskilled and informal labour sectors of the South Africa economy, it is assumed that the real wages of these two groups remain fixed while employment can adjust in reaction to the policy shock.

As is the case in the short-run closure, all tax and technological change variables are fixed by assumption.

9.5 THE PROPOSED LONG-RUN POLICY SHOCKS

Despite the double dividend literature, the review of the literature on technological innovation and the environment have indicated that technological innovation could also result in a "free-lunch".

This would be the case if environmental regulation results in technological innovation that reduces environmental damage and increases economic growth. Apart from this, taxing coal without any technological innovation would only delay the environmental impacts of the use of coal. Because technological innovation develops over a time frame that should extend beyond a short-run perspective, the effect of technological innovation on the environment and South African economic performance is tested within a long-run time frame.

Therefore, a policy proposal is tested in which the use of coal in production processes is taxed by 50 percent. However, instead of returning the tax revenue to the economy solely by means of a reduction in other intermediate taxes or a lump-sum transfer, the revenue is used to fund research and development in technology that will reduce the use of coal across the production processes of all industries. In this case, a number of policy proposals are tested, of which two proposals will be discussed in detail. These are:

i. the long-run effects of a 50 percent tax on coal if the tax revenue were not returned to the economy.
ii. the long-run effects of a 50 percent tax on coal if the revenue were used to fund research and development that would reduce the use of coal in the production process by 50 percent.

Because of the uncertainty that surrounds the outcome of investments in research and development expenditure, the results of policy simulations with differing levels of taxation and technological change are also reported.

9.6 CONCLUSION

The short-run and long-run closures that are adopted to test the policy proposals reflect the realities of the South African economy. They allow a relevant analysis of the economy-wide effect of coal-tax proposals on the South African economy in both the short run, as well as the long run. Important assumptions within this context are that unskilled and informal sector labour is supplied elastically within all industries, and highly skilled and skilled labour is supplied inelastically.

These policy proposals can now be tested within the CGE model described in Chapters 7 and 8. The software that is used for solving the model is the Gempack software that has been developed at the Centre for Policy Studies at the University of Monash, Clayton Campus, Melbourne.

CHAPTER 10

SHORT-RUN POLICY SIMULATION RESULTS

10.1 INTRODUCTION

This chapter reports and explains the results of the short-run policy simulations. Each policy simulation affects numerous macro- and micro economic variables. The idea of this report is not to indicate how each one of these variables has changed, but to report and explain changes in certain macroeconomic and industry specific variables that would be of interest to both policy makers and economic agents who have interest in policies. These variables include macroeconomic aggregates such as gross domestic product, consumption, exports, employment and prices of certain inputs. Apart from this, the effect of each policy simulation on selected industries is also reported.

The results of the short-run simulations 1, 2 and 3 are reported in sections 10.2, 10.3 and 10.4 respectively. Section 10.5 contains a brief comparison of the macroeconomic results from each policy simulation.

10.2 A FIFTY PERCENT TAX ON COAL (SIMULATION 1)

10.2.1 Macroeconomic results

Before examining the simulation results from the first policy proposal, it would be informative to obtain a prior expectation of the macroeconomic effects of the coal tax proposal. A stylised model proposed by Adams (2003) is used for this purpose. The stylised model represents a single-country and allows for exogenous changes in the positions of foreign demand schedules for exports and foreign supply schedules for imports and also allows changes in the global rate of return on capital. This model is representative of a model such as ORANI (Adams, 2003). The complete model is summarised in Appendix Three and reference is made to the relevant equations from the stylised model to form an expectation prior to the simulation results.

Equation (16) of the stylised model indicates that the increase in the indirect tax on coal should increase the cost of skilled and informal sector labour (variable factors of production) if the terms of trade remains unchanged or decreases. This result also follows from the assumption that real wages are fixed in the short run. Simulation results indicate that the terms of trade effect is indeed negative (the terms of trade decreases). It is therefore clear from equation (16) that the price of the variable factor of production will increase as a result of the tax proposal.

$$RP_V \uparrow = F_{RPV}(\overline{RW}, (\frac{1}{TOT \downarrow}), (1 + T \uparrow)) \tag{16}$$

Equation (15), which relates the price of the variable factors of production to that of the fixed factors (capital, land, highly skilled and skilled labour), indicates that the increase in the price of the variable factors should result in a decrease in the price of the fixed factors.

$$RP_V^{S_V} \uparrow = RP_F^{-S_F} \downarrow \tag{15}$$

The increase in the price ratio between the price of the variable factor of production and that of the fixed factor of production implies that the quantity of the variable factor that is employed will decrease. This is indicated by equation (14) which relates the relative factor inputs to relative factor prices.

$$\frac{\overline{F}}{V \downarrow} = \frac{RP_V \uparrow}{RP_F \downarrow} \tag{14}$$

As indicated by equation (2), the decrease in the use of variable factors of production will result in a decrease in gross domestic product (GDP) at factor costs.

$$Y^{FC} \downarrow = F_Y(V \downarrow, \overline{F}) \tag{2}$$

Our simulation results indicate that the increase in the quantity of GDP on which indirect taxes are applied is less than the fall in the gross domestic product at market prices, and a fall in GDP at market prices is observed.

$$Y^{MP} \downarrow = Y^{FC} \downarrow + Y^{TAX} \tag{3}$$

The effect of the fall in GDP at market prices on the demand side aggregates is, once again, a function of the closure assumptions and the terms of trade. As mentioned above, the policy simulation results in a fall in the terms of trade. Because the nominal exchange rate is fixed (by assumption), the fall in the terms of trade will result in an increase in the trade balance. The fall in gross domestic product at market prices and the increase in the trade balance implies then that consumption should decrease.

$$Y^{MP} \downarrow = C \downarrow + \overline{I} + \overline{G} + (X - M) \uparrow \qquad (1)$$

The prior expectations are confirmed by the simulation results. Table 10.1 reflects the actual results from the CGE simulation. As expected, gross domestic product, consumption and employment decrease. Because highly skilled and skilled labour are fixed by assumption, the decrease in employment represents a decrease in the use of unskilled and informal sector labour in the production process. The prices of capital, land, highly skilled and skilled labour fall. As mentioned above, the terms of trade decreases, which is the result of a fall in the price of exports. The fall in the terms of trade results in an increase in exports. The increase in exports allows the trade balance to increase.

Table 10.1: The estimated macroeconomic effects of imposing a 50 percent tax on the intermediate use of coal (percentage changes)

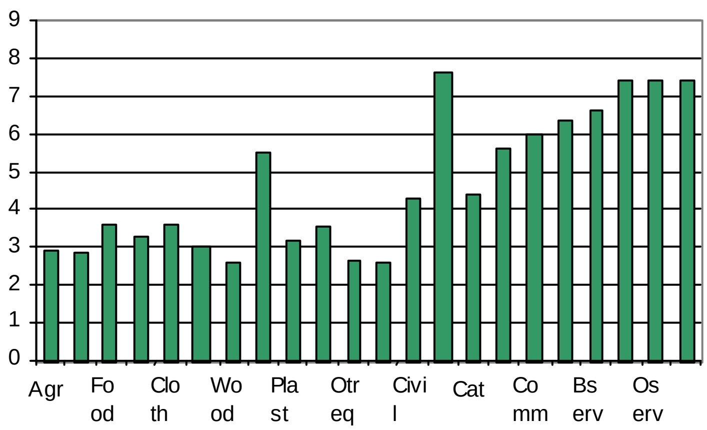
Real GDP	-0.099
Employment	-0.028
Consumption	-0.632
Exports	0.388
Imports	0.144
Terms of trade	-0.265
Price of exports	-0.265
Price of capital	-2.029
Price of highly skilled labour	-2.299
Price of skilled labour	-2.162

10.2.2 The terms of trade

It is evident from the macroeconomic results that the fall in the terms of trade holds significant (positive) consequences for South Africa's exports and therefore also for the country's competitiveness. If anything, the result seems somewhat counter-intuitive for a tax policy simulation, as one would expect the intermediate tax hike to increase export prices, which should have a negative effect on South Africa's competitiveness.

Analysis of the change in the terms of trade indicates that the fall in export prices can be contributed to two important factors. The first is the fact that the tax on coal is not directly raised on the export product, but on the intermediate use of coal. Although the intermediate tax could raise the export price, its inflationary effect on export prices is less severe than it would be if the tax were directly levied on exports. The second is that the significant fall in the price of the fixed factors of production offsets the inflationary effect of the tax increase. It seems as if South Africa's biggest export products are intensive in the use of unskilled labour and in the use of land. These industries represent mostly the primary sector of South Africa's production and include the gold mining, other mining and agricultural sectors. The significant decrease in the price of land therefore reduces the export prices of these products. Although the bulk of South Africa's exports are from the primary sector (about 30 percent), the database indicates that another sector that contributes significantly towards the exports is the services sector. The services sector makes relatively intensive use of capital and skilled-labour in the production process and the fall in the prices of these fixed factors of production results in a decrease in the export prices of these goods and services. Figure 10.1 illustrates the relative changes in the exports of a select number of industries that experience a significant increase in their exports.

Figure 10.1: The increase in the exports of a select number of industries



10.2.3 Consumption

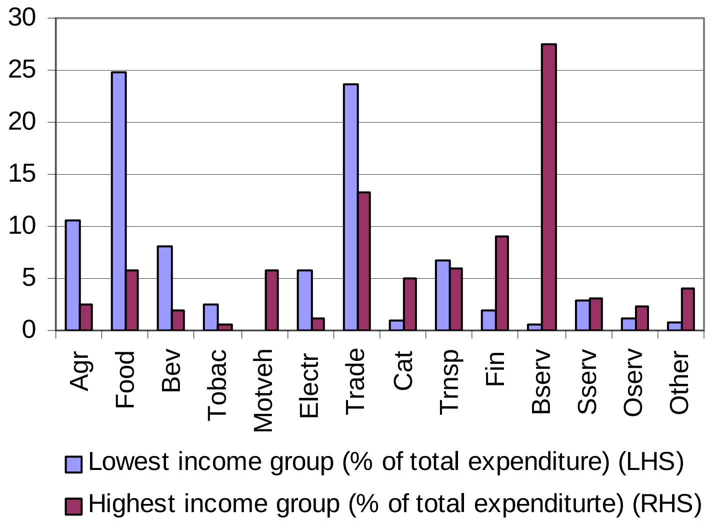
Despite the positive effect that the tax has on the competitiveness of the South African economy, it has a negative effect on aggregate consumption in South Africa. If consumption is taken as a proxy for welfare, the decrease in consumption implies that welfare in South Africa decreases as a result of the tax.

Apart from the fall in aggregate consumption, further analysis of individual household consumption indicates that the tax on coal has a negative effect on the redistribution of welfare in the South African economy. The simulation results indicate that the consumption of households in the lowest income groups would decrease more than that of the households in the higher income groups. The fall in household consumption is a result of the fall in household income, which is a result of the fall in labour income. Labour income decreases because of a decrease in the wages of highly skilled and skilled labour and a decrease in the level of employment of unskilled and informal sector labourers. However, because high-income households consume more capital-intensive products, these households experience a significant decrease in their consumer price baskets (once-again because of the fall in the prices of the fixed factors of production). In fact, the fall in consumer prices of households in the highest income group is enough to offset the decrease in nominal income. Households in the highest income group therefore experience an increase in real consumption. On the other hand, the consumer basket of the lower income households consists mostly of labour (unskilled) intensive products. As a result these households do not experience the same fall in their consumer price baskets, and their real consumption declines. Table 10.2 summarises the change in the real consumption of individual households and their consumer price baskets, while Figure 10.2 compares the consumer baskets of the households in the lowest income group with the households in the highest income group. It is evident from Figure 10.2 that a far greater portion of the expenditure of high-income households is on capital-intensive products, such as financial services.

Table 10.2: Changes in real consumption and consumer price baskets of household groups

Income group	Decrease in consumption	Decrease in consumer price basket
D0	1.22	0.57
D1	1.14	0.65
D2	1.05	0.73
D3	0.99	0.79
D4	0.94	0.84
D5	0.92	0.87
D6	0.88	0.91
D7	0.88	0.91
D8	0.87	0.91
D91	0.85	0.94
D921	0.83	0.96
D922	0.80	0.98
D923	0.81	0.98
D924	0.74	1.05

Figure 10.2: A comparison of the lowest and highest income group expenditures



10.2.4 The effect on the demand for coal

The effect that the tax has on the demand for coal appears to be relatively small. The domestic demand for coal falls by only 1.39 percent. The decrease is mainly the result of a fall in domestic demand for coke and refined petroleum products, basic iron and steel products, and electricity. Due to the fact that the structure of the South African economy does not provide any other source of energy for these industries, the tax increase is passed on to the final user. The higher prices for end users result in a decrease in the demand for these products and subsequently in a decrease in the domestic demand for coal. However, because the elasticity of demand for these products is relatively low, the fall in the demand for coal intensive products is limited and the positive dividend that arises from the tax is small.

The simulation results, therefore, indicate that the tax policy does not improve the pollution problem significantly. The cost of the environmental benefit could, therefore, be high (in terms of the loss in employment and welfare).

10.2.5 Industry-specific results

Apart from the effect that the tax has on macroeconomic aggregates, it is evident from the simulation results that the coke and refined petroleum industry, the basic iron and steel industry and the electricity industry will suffer the most under the proposed tax, as these are the industries that rely most on coal as an input in the production process. The output of the coke and refined petroleum industry, the basic iron and steel industry and the electricity industry will decrease by 1.42 percent, 3.37 percent and 1.24 percent respectively. This decrease is a result of a fall in the intermediate-, household- and export demands for these products. Table 10.3 summarises the changes in respective demand categories in these industries.

Table 10.3 Change in intermediate-, household and export demand in selected industries

	Intermediate demand	Household demand	Export demand
Coke and refined petroleum	-0.07	-0.61	-0.73
Basic iron and steel	-0.12	0	-3.25
Electricity	-0.32	-0.85	-0.06

The macroeconomic results indicate that there is an increase in aggregate exports. The decrease in the prices of fixed factors of production is not enough, however, to offset the inflationary effect of the tax increase on the industries that make intensive use of coal in the production process. The export price of these industries therefore increases and, as a result, exports decline. The decline in the output of the said industries implies a fall in employment of unskilled and informal sector labour in these industries. The simulation results indicate that employment in the coke and refined petroleum industry declines by 5 percent, while employment in the basic iron and steel and electricity industries decline by 8.10 and 3.27 percent respectively.

The increase in exports implies that there should be industries that benefit from the proposed tax. These are the industries that make relatively little use of coal in the production process. The simulation results indicate that the machinery and equipment, and motor vehicle equipment industries would reap the most benefit from the tax proposal. The machinery industry increases its exports by 1.42 percent, while the exports of motor vehicle equipment increase by 2 percent.

10.3 A FIFTY PERCENT TAX ON COAL, AND A LUMP SUM TRANSFER TO LOW INCOME HOUSEHOLDS (SIMULATION 2)

10.3.1 Macroeconomic results

The result of Simulation 1 indicates that the tax on coal raises revenue of R 5.044 billion for the government in the form of indirect taxes. The second policy simulation evaluates the effect of a lump-sum transfer to households that are within the lowest three income groupings of the South African economy. The revenue for the transfer is obtained from the indirect tax revenue raised by the taxation of coal.

In this policy simulation the stylised model for the CGE (Appendix 3) indicates that the intermediate tax will increase the cost of the variable factor of production. However, analysis of the effect of the policy proposal on the terms of trade indicates that it increases. This increase in the terms of trade slightly offsets the effect of the tax increase in the stylised model. As a result the fall in employment and the decrease in GDP is slightly less than is the case of the previous policy simulation. With reference to the stylised model in Appendix 3, the result of the policy shock is once again that:

i. The tax increases the cost of the variable factor of production.
ii. The increase in the cost of the variable factor of production results in a decrease in the cost of the fixed factor of production.
iii. The relative factor price movements result in a fall in the quantity of the variable factor that is employed.
iv. The decrease in the employment of the variable factor of production results in a fall in GDP.
v. The fall in GDP is reflected by a fall in exports (as a result of the positive terms of trade effect). The policy results indicate, however, that consumption increase as a result of the lump sum transfer to the households at the lower end of the income distribution.

Table 10.4 reports the effects of this policy simulation on selected macroeconomic variables.

Table 10.4: The estimated macroeconomic effect of a 50 percent tax on coal and a lump-sum transfer to low-income households (percentage change)

Real GDP	-0.019
Employment	-0.020
Consumption	0.893
Exports	-1.868
Imports	-0.028
Terms of trade	0.472
Price of exports	0.472
Price of capital	-0.265
Price of land	-0.745
Price of highly skilled labour	-0.549

Price of skilled labour	-0.209

10.3.2 The terms of trade

The tax results in an increase in the price of intermediate goods, and, although there are economy-wide decreases in the prices of the fixed factors of production, these decreases are not enough to offset the intermediate price increases. As a result the aggregate price of exports increases. Because the nominal exchange rate is fixed by assumption, the price of exports increases which results in a decrease in aggregate exports.

The fall in the prices of the fixed factors of production is less than the fall experienced in the benchmark simulation (Simulation 1) because the lump-sum transfer to lower income households results in an increase in the demand for products which are relatively capital, land and skilled labour intensive. The increase in the demand for these factors supports the prices of the factors of production that are used in the industries that produce these products.

10.3.3 Consumption

The simulation results indicate that the policy proposal will result in an increase in aggregate consumption. This increase in consumption is the result of the lump-sum transfer to the lowest income households, which offsets the negative effects of a decrease in household income and an increase in consumer prices. Household income decreases as a result of a decrease in the real wages of highly skilled and skilled labour, and the decrease in employment of unskilled and informal sector labour. On the other hand, consumer prices increase because of the inflationary effect of the intermediate tax. It is therefore not surprising that households that do not receive the lump-sum transfer are negatively affected. Table 10.5 summarises the effects of the policy proposal on household consumption and consumer prices.

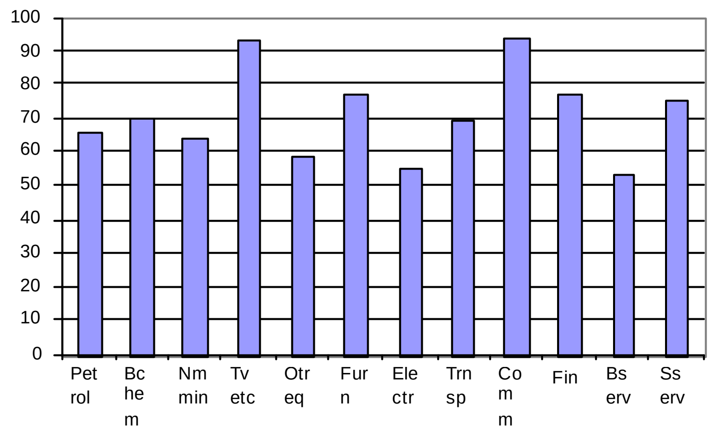
Table 10.5: Change in household consumption and consumer prices

Income group	Change in consumption	Change in the consumer price basket
D0	42.65	1.41
D1	30.05	1.29

D2	21.47	1.16
D3	-1.22	1.06
D4	-1.14	0.97
D5	-1.07	0.91
D6	-0.99	0.83
D7	-0.94	0.78
D8	-0.86	0.70
D91	-0.77	0.60
D921	-0.69	0.52
D922	-0.68	0.51
D923	-0.66	0.49
D924	-0.57	0.40

As mentioned above, the prices of goods and services that make intensive use of the fixed factors of production decrease relative to the prices of other goods and services. Because of this relative price change, the households that receive the lump-sum transfer direct their expenditure towards the relatively "cheaper" capital and land intensive goods. The simulation results indicate that the lowest income group will increase their consumption of televisions, motor vehicles, furniture and financial services significantly. Figure 10.3 reflects the change in consumption of goods and services for lowest income households.

Figure 10.3: Change in consumption of selected goods and services for lowest income households



10.3.4 The effect on the demand for coal

For the same reasons as mentioned in the results for the benchmark simulation (Simulation 1), the demand for coal falls, but only by 1.31 percent. The decrease is a result of a fall in output of the industries that make relatively intensive use of coal in the production process, and not because of a more efficient production process. Once again the conclusion can be reached that the tax on coal will be more efficient if there is an improvement in technology or an alternative to the use of coal in the production process.

10.3.5 Industry-specific results

The taxation of coal has an inflationary effect on the final demand prices of those products that are relatively intensive in the use of coal. The output of the coke and refined petroleum industry, the basic iron and steel industry and the electricity industry are negatively affected. The outputs of these industries fall by 1.53, 5.05 and 0.17 percent respectively. The fall in the output of the electricity industry is cushioned by an increase in the demand for electricity by households that receive the lump-sum transfer. In spite of this, all three of these industries are negatively affected by a fall in their exports. Table 10.6 reflects the changes in the respective demand categories for these industries. The exports of the iron and steel industry are, once again, significantly affected.

Table 10.6 Change in intermediate-, household and export demand for selected industries (coal-intensive)

	Intermediate demand	Household demand	Export demand
Coke and refined petroleum	-0.10	-0.19	-1.24
Basic iron and steel	-0.76	0	-4.29
Electricity	-0.53	0.50	-0.14

As mentioned above, the lump-sum transfer to households results in an increase in household demand for certain products and, although the lowest income households increase their expenditure on products that are relatively intensive in the use of capital, land and skilled labour in the production process, overall household demand for agricultural, food and beverage products increases significantly. Table 10.7 reflects the changes in the demand for these products.

Table 10.7 Change in intermediate-, household and export demand for selected industries

	Intermediate demand	Household demand	Export demand
Agriculture	0.32	1.11	-0.83
Food	0.09	1.74	-0.67
Beverages	0.02	1.58	-1.24

10.4 A FIFTY PERCENT INCREASE IN THE TAX ON COAL, AND A DECREASE IN THE INTERMEDIATE TAXATION OF FOOD AND AGRICULTURAL PRODUCTS (SIMULATION 3)

10.4.1 Macroeconomic results

In the third policy simulation the revenue that is raised through the tax on coal is returned to the economy by reducing the intermediate tax rate on food and agricultural products. The revenue that is raised by the tax on coal allows for a 4 percent reduction in the intermediate tax rate of food and agricultural products. With reference to equation 16 of the stylised model (Appendix 3), the reduction in the intermediate tax on food and agricultural products implies that the change in intermediate tax collection should be close to zero and the change in the terms of trade seems to drive the macroeconomic results of this policy simulation. The simulation results indicate that the policy proposal has a positive terms of trade effect (the price of exports increase relative to the price of imports). With this in mind, the stylised model (Appendix 3) gives insight into the following macroeconomic changes:

i. The change in real wages paid to the variable factor of production is zero by assumption while the net effect of this policy proposal is that the change in intermediate taxes should be zero. Equation (16) indicates that an increase in the terms of trade will result in a decrease in the price of the variable factor of production.

ii. As indicated by equation (15), the decrease in the price of the variable factor of production results in an increase in the price of fixed factors of production.

iii. Equation (14) indicates that the relative price changes of the factors of production will result in an increase in the use of the variable factor of production.

iv. The increase in the use of the variable factor of production translates into an increase in gross domestic product as indicated by the production function (equation 2).

v. The positive terms of trade effect results in a fall in the trade balance (decrease in exports). The increase in GDP implies that consumption will increase if the trade balance is decreasing.

The results that are reported in Table 10.8 confirm the prior expectations generated by the stylised model.

Table 10.8: The estimated macroeconomic effects of imposing a revenue-neutral tax on the South African economy (percentage change)

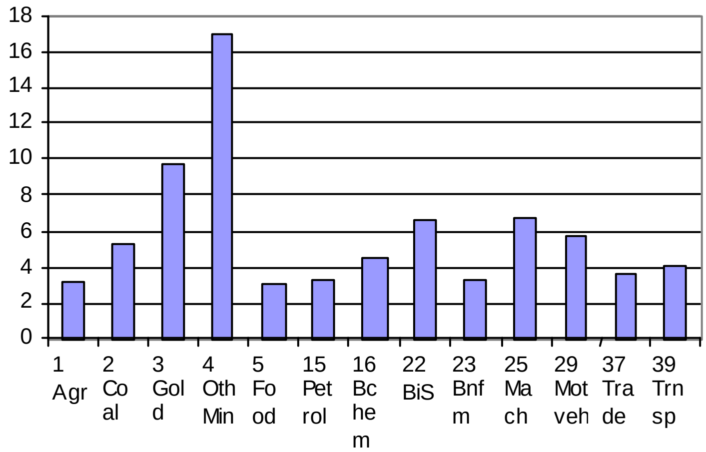
Real GDP	0.02
Employment	0.06
Consumption	0.15
Exports	-0.39
Imports	-0.15
Terms of trade	0.10
Price of exports	0.10
Price of capital	-0.64
Price of land	0.24
Price of highly skilled labour	-0.94
Price of skilled labour	-0.53

It is interesting that the prices of all the fixed factors of production decrease, with the exception of the price of land. The increase in the price of land should be enough to offset the decreases in the prices of other fixed factors of production. This results in a slight increase in the price of fixed factors of production.

10.4.2 The terms of trade

The terms of trade increases by 0.1 percent. This slight increase is the result of South Africa's export composition. The inflationary effect of the tax on coal is not completely offset by the decrease in the prices of food and agricultural products. The inflationary effect is also higher because the basic iron and steel industry contributes significantly towards South Africa's exports. The slight increase in the prices of fixed factors of production should also add to the price of exports, despite of the decrease in the price of variable factors of production. The increase in the price of land contributes significantly to the increase in the price of exports. The reason for this is that exports of primary factor products contribute significantly towards South Africa's aggregate exports. Figure 10.4 reflects South Africa's export composition.

Figure 10.4: Contribution towards South African exports (% of total exports)



10.4.3 Consumption

The macroeconomic results indicate that aggregate consumption increases. An analysis of this increase shows that low-income households increase their consumption expenditure, while the consumption expenditure of high-income households actually falls. Household income decreases because of the fall in the wages of skilled and highly skilled labour, despite the small increase in the employment of unskilled labour. The differences in the changes of household consumption are attributed to differences in composition of household consumer baskets. As indicated in the previous chapter, households in the lower income brackets spend a far greater proportion of their income on food and agricultural products than higher income households. It was also shown that the high-income households spend a greater proportion of their budgets on products that are relatively capital, land and skilled-labour intensive. Given the decrease in the price of food and agricultural products, the households in the lower income groups experience a greater decrease in their consumer baskets than high-income households. In the case of low-income households, the decrease in consumer prices is enough to offset the fall in nominal income, which results in an increase in real consumption. Table 10.9 summarises the changes in household consumption and consumer prices as a result of the proposed policy.

Table 10.9 Change in household consumption and consumer prices

Income group	Change in consumption	Change in the consumer price basket
D0	1.04	-1.70
D1	1.02	-1.68
D2	0.97	-1.62
D3	0.89	-1.55
D4	0.74	-1.40
D5	0.60	-1.26
D6	0.43	-1.10
D7	0.26	-0.93
D8	0.03	-0.71
D91	-0.11	-0.55
D921	-0.22	-0.44
D922	-0.20	-0.46
D923	-0.19	-0.48
D924	-0.15	-0.51

It is interesting to note that low-income households will increase their expenditure on agricultural and food products by 2.3 percent and 2.6 percent respectively, while there is also an increase in expenditure on televisions and furniture. There is, however, a significant decrease in expenditure on coal (25 percent) and electricity (1.53 percent), which could have consequences for welfare that are not reflected by increased consumption expenditure.

10.4.4 The effect on the demand for coal

The effect on the demand for coal is, once again, small. The domestic demand for coal decreases by 1.43 percent. The reason for the small decrease is (as in the previous simulations) the lack of an alternative input in the production process. The decrease in the use of coal is therefore a result of a decrease in the output of the industries that make intensive use of coal in their production processes. Once again, it is the outputs of the coke and refined petroleum industries, the basic iron and steel industry and the electricity industry that decrease significantly.

10.4.5 Industry-specific results

There are clear "winners and losers" in this policy simulation, and it is not surprising that the industries that are closely linked to the agriculture and food industries are the "winners", while those industries that are linked to the coal industry are the "losers". The higher price of coal results in higher consumer and export prices of coal intensive industries, while lower food and agriculture prices result in lower consumer and export prices of the industries that are closely linked to the food and agricultural industry. As is the case in the other short-run simulations, the coke and refined petroleum, basic iron and steel and electricity industries are negatively affected by the policy proposal. The output of these industries decreases by 1.43 percent, 4.29 percent and 1.10 percent respectively. The industries that are positively affected by the policy simulation are the agricultural, food and leather industries. The output of these industries increases by 1.00 percent, 1.96 percent and 2.55 percent respectively. Table 10.10 reflects the changes in the selected demand components of these industries.

Table 10.10 Change in intermediate-, household and export demand in selected industries

	Intermediate demand	Household demand	Export demand
	The "losers"		
Coke and refined petroleum	-0.02	-0.30	-1.10
Basic iron and steel	-0.46	0	-3.83
Electricity	-0.41	-0.59	-0.09
	The "winners"		
Agriculture	0.62	0.69	-0.30
Food	0.27	1.44	0.24
Leather	0.59	0.13	1.81

Apart from changes in the demand components of these industries, it is also interesting to note the changes in employment in each of these industries. Table 10.11 summarises the change in employment of the different industries.

Table 10.11 Change in employment: policy "winners" and "losers"

	Percentage change	Employment opportunities
Coke and refined petroleum	-5.06	-723
Basic iron and steel	-10.23	-420
Electricity	-2.90	-2 256
Agriculture	2.96	23 525
Food	3.87	6 203
Leather	4.42	362
Total		**26 691**

Although there are positive changes in the levels of employment in some other industries, it is evident that the change in the levels of employment in the agricultural industry is significant and is the biggest contributor to the increase in the overall level of employment.

10.4.6 A comparison of the short-run simulation results

The discussion above indicates that the three different policy simulations have different consequences for the South African economy in the short run. The only similarity between the three simulations is the effect that each one has on the domestic demand for coal. The decrease in the domestic demand for coal is around 1.40 percent in each one of the simulations. A comparison of the respective macroeconomic results gives further insight into the policy proposal which should find favour with policy makers over the short run. Table 10.12 highlights the differences for the macroeconomic aggregates by comparing the results of the respective policy simulations.

Table 10.12: A comparison of the short-run macroeconomic results

	Simulation 1	Simulation 2	Simulation 3
Real GDP	-0.099	-0.019	0.02
Employment	-0.028	-0.020	0.06
Consumption	-0.632	0.893	0.15
Exports	0.388	-1.868	-0.39
Imports	0.144	-0.028	-0.15
Terms of trade	-0.265	0.472	0.10

Price of exports	-0.265	0.472	0.10
Price of capital	-2.029	-0.265	-0.64
Price of land	-0.052	-0.745	0.24
Price of highly skilled labour	-2.299	-0.549	-0.94
Price of skilled labour	-2.162	-0.209	-0.53

From the above comparison it would appear that Simulation 3 holds the most favourable outcome for the South African economy over the short run. Simulation 3 is the only policy proposal that has a positive effect on both employment and economic growth. Apart from this, Simulation 3 has a positive effect on aggregate consumption, which should translate into a positive effect on aggregate welfare. Although the policy proposal that is tested in Simulation 2 has a positive effect on aggregate consumption, the increase in consumption is accompanied by a decrease in employment and economic growth. Both the second and third policy proposals result in losses in external competitiveness, which are the consequence of increased export prices.

It is also evident from Table 10.12 that a policy proposal in which the government increases its savings will have significant negative consequences for the economy. Economic growth will decrease, employment will fall and consumption will falter. The only positive effect of this policy is an increase in exports. This would, however, be the consequence of a significant fall in the price of the fixed factors of production, which would only sustain higher exports in the short run.

10.5 CONCLUSION

There are a few interesting results that are worth mentioning at the conclusion of this chapter. The first is that the results from all three policy simulations indicate that, over the short run, a tax on coal will decrease domestic demand for coal. This decrease should have a positive effect on the environment (a positive first dividend). Although the decrease in demand for coal is encouraging, it seems small in comparison to the magnitude of the measure taken to reduce the use of coal. Policy makers will have to ask themselves whether such drastic measures are worth the small gain for the environment. It is clear that the lack of an alternative energy input is the main reason for the small decline in the domestic use of coal. A tax on coal would therefore be relatively “sterile” if there is no technological development that could reduce the use of coal.

Apart from the small (but positive) effect that the tax on coal has on the South African economy, the simulation results have also indicated that the use of the revenue that is obtained from the tax holds important consequences for the economy. A policy that reduces the cost of agricultural products and food will have a small positive benefit on the economy in terms of an increase in aggregate consumption, economic growth and employment. Such a policy will also have positive benefits on the welfare distribution of the country because it decreases the prices of those products that low-income households purchase most.

CHAPTER 11

LONG-RUN POLICY SIMULATION RESULTS

11.1 INTRODUCTION

This chapter reports the results of the long-run policy suggestions for the South African economy. As in chapter 11, the effects of the suggested policy proposals on the macroeconomic aggregates and selected industries are analysed and reported. Of particular interest is the effect that the policy will have on consumption, welfare and the competitiveness of the South African economy. Because a certain level of technological innovation is assumed in the second policy simulation, the results will provide important insight into the level of technological innovation that needs to be achieved in order to obtain a positive benefit for both the economy and the environment.

The results of long-run simulation 1 (LRsim1) are reported in section 11.3 and the results of the second policy suggestion (LRsim2) are reported in section 11.4. Because of the importance of the findings in simulation 2, section 11.5 is used to report results of simulations that establish the relationship between technological innovation and the tax that is needed to fund the innovation.

11.2 A FIFTY PERCENT TAX ON COAL: THE LONG-RUN CONSEQUENCES

11.2.1 The macroeconomic results

As is the case in the short-run simulation, the stylised model proposed by Adams (2003) is used to obtain an expectation of the macroeconomic consequences that the tax has on the South African economy in the long run. It is important to note that the capital stock is allowed to change in the long run. Apart from the capital stock, the unskilled and informal sector labour force is also allowed to change. The supply of land, skilled and highly skilled labour is fixed. The assumption with regard to the South African labour market is made to reflect the high level of unemployment of unskilled labour in the country, which seems to be a problem with long-term dimensions.

With reference to equation (17) of the stylised model, the tax on the intermediate use of coal should increase the price of the variable factors of production. This would be the case if the terms of trade decreased or remained constant. The real rate of return is fixed by assumption. The simulation results, however, indicates that the terms of trade will actually increase which results in a decrease in the price of the variable factors of production.

$$RP_V \downarrow = F_F(ROR, \frac{1}{TOT \uparrow}, (1+T \uparrow)) \tag{17}$$

Because the combination of the terms of trade effect and the fall in the price of the variable factor of production has significant consequences for the South African economy, the effects of these changes are analysed first.

Equation 7 of the stylised model indicates that an increase in the terms of trade results in a decrease in the demand for South African exports.

$$X \downarrow = F_X(-RER \uparrow) \times Y_W \tag{7}$$

The decrease in the demand for exports should result in a decrease in output (if one assumes that all other demand components remain constant). This is illustrated by equation 1.

$$Y^{MP} \downarrow = C + I + G + (X \downarrow - M) \tag{1}$$

As indicated in equation 2, the fall in the output will result in a decrease in the demand for the variable factors of production (capital, unskilled labour and informal labour).

$$Y^{FC} \downarrow = F_Y(\overline{F}, V \downarrow) \tag{2}$$

Because the rate of return is fixed (by assumption), the decrease in the use of capital (the variable factor of production) should result in a decrease in investment. This is indicated by equation (8).

$$\frac{I \downarrow}{K \downarrow} = \overline{\Phi} \tag{8}$$

With consumption being a function of GDP at market prices, consumption decreases, as indicated by equation (4).

$$P^C C = \Omega P_{GDP}^{MP} Y^{MP} \tag{4}$$

Finally, because of the significant increase in the terms of trade, the price of the fixed factors of production (highly skilled labour, skilled labour and land) also decreases. Although the terms of trade effects were higher in the short-run simulations, the fixed factors of production are a much smaller portion of total production in the long-run simulations and the prices of these factors are therefore much more sensitive to terms of trade changes.

$$RP_F \downarrow = F_{RPF}(RW, \frac{1}{TOT \uparrow}, (1+T \uparrow))$$

The simulation results confirm prior expectations. Table 11.1 reports the results for selected macro-economic aggregates.

Table 11.1: The estimated macroeconomic effects of imposing a 50 percent tax on the intermediate use of coal (percentage changes): Long run

Real GDP	-0.76
Employment	-0.25
Consumption	-2.05
Investment	-1.34
Exports	-0.76
Imports	-0.51
Terms of trade	0.190
Price of exports	0.190
Price of capital	-0.238
Price of highly skilled labour	-2.987
Price of skilled labour	-3.191
Price of land	-1.963

11.2.2 The terms of trade

The terms of trade increase because of the increase in the price of exports. Although the tax policy results in a decrease in the prices of the fixed factors of production, it is not enough to offset the increase that is caused by the tax on coal. It is therefore not surprising that the products that make intensive use of coal in the production process experience the biggest decline in exports. These industries are the usual suspects - the coke and refined petroleum, basic iron and steel and electricity industries. The fall in the prices of fixed factors of production, however, hold positive effects for the exports of those products that do not make intensive use of coal. The services industries especially benefit from increased exports because of the fall in the prices of highly skilled and skilled labour.

11.2.3 Consumption

The fall in aggregate real consumption is large. Analysis of this decrease indicates that it is the result of a fall in nominal income, which is not offset by the fall in consumer prices.

Consumer prices fall because of the fall in the prices of the fixed factors of production. It is clear from the simulation results that the increase in the prices of the variable factors of production (capital and unskilled labour), plus the addition of the tax, is not enough to offset the decrease in the price of the fixed factors of production (land and skilled labour). As a result, the aggregate consumer price decreases (0.32 percent). Despite this, nominal income of households decreases. The wages of the highly skilled and skilled labour fall, while the number of unskilled and informal sector labourers that are employed decrease.

The fall in aggregate consumption is reflected by a fall in consumption across all households. There are, however, distributional effects, as the high-income households experience a bigger decrease in the prices of their consumer basket than that of the low-income household. Table 11.2 reflects the change in consumption and consumer prices for the different households.

Table 11.2: Changes in real consumption and consumer price baskets of household groups

Income group	Decrease in consumption	Decrease in consumer price basket
D0	-2.40467	0.025136
D1	-2.31492	-0.06677
D2	-2.21489	-0.169
D3	-2.1458	-0.23948
D4	-2.09769	-0.28851
D5	-2.08094	-0.30556
D6	-2.05287	-0.33413
D7	-2.06117	-0.32569
D8	-2.07802	-0.30853
D91	-2.05345	-0.33354
D921	-2.04272	-0.34446
D922	-2.02634	-0.36112
D923	-2.0045	-0.38332
D924	-1.94226	-0.44655

11.2.4 The effect on the demand for coal

The domestic demand for coal decreases with 1.13 percent. As is the case for the short-run simulation results, the fall in the demand for coal is mostly the result of a decrease in output of the industries that make significant use of coal in the production process (the coke and refined petroleum industries, the basic iron and steel industries and the electricity industries). Because of the lack of alternative sources of energy, there is no substitution effect and the considerable high level of taxation results in a relatively small decrease in the use of coal. It is debatable whether this small decrease could result in a positive environmental benefit. It does, however, serve as further motivation for the allocation of sufficient investment in research, development and technological innovation in order for the South African economy to be less dependant on coal as a primary source of energy.

11.2.5 Industry specific results

It is evident from the macroeconomic aggregates that the tax policy has negative effects on the South African economy over the long term. The industries that are most affected by the tax on coal are those industries that are highly dependant on coal in the production process. These industries experience a decline in both the domestic and the foreign demand for their product. Table 11.3 reports the decrease in the demand components of the coke and refined petroleum industry, the basic iron and steel industry, and the electricity industry.

Table 11.3: The change in the demand components of selected industries

	Intermediate demand	Household demand	Export demand
Coke and refined petroleum	-0.58	-1.26	-2.42
Basic iron and steel	-0.83	0	-6.56
Electricity	-1.24	-1.6	0.13

The level of investment in these industries also fall significantly with the investment expenditure of the coke and refined petroleum industry falling by 4.13 percent. Investment in the basic iron and steel industry falls by 8.02 percent and the electricity industry experiences a fall in investment of 1.34 percent.

11.3 A FIFTY PERCENT TAX ON COAL THAT IS USED TO FUND TECHNOLOGICAL CHANGE

The results of the simulations that assume a short-run closure indicate that there is a need for technological innovation in order to reduce the dependence of the South African economy on coal. The simulation results above confirm that this would also be the case over the long run. The results of the long-run simulation indicate that the proposed tax policy will raise intermediate tax revenue of R 5.94 billion per year. In the simulation results that are reported below, it is assumed that this revenue is used to subsidise investment in technological innovation to reduce the use of coal by 50 percent. This level of technological innovation is found to be the lowest level of technological improvement that would negate the negative effects of the 50 percent tax in terms of economic growth welfare and employment. Although technological innovation that reduces the use of coal by 30 percent would already have positive effects on economic growth, it would not negate the negative effect that the tax on coal has on employment and welfare of the society. A technological innovation that reduces the use of coal by 40 percent would have positive effects on economic growth and welfare but it would not negate the negative effects of the tax policy on employment. The result of a technological innovation that reduces the use of coal by 50 percent is reported below.

11.3.1 Macroeconomic results

The simulation results indicate that technological innovation has a positive effect on the South African economy. The effects of the tax changes should be the same as in the first long-run simulation, but, the technological change introduces significant positive effects to the economy, which offsets the negative effects of the tax policy.

Because of technological change, it is difficult to obtain a prior expectation of the movements in the macroeconomic aggregates, and the results are therefore reported in Table 11.4. These results are then used, along with the stylised model, to obtain economic insight into the effect that the policy shock has on the macroeconomic aggregates.

Table 11.4: The policy simulation effect on the macroeconomic aggregates in the SA economy

Real GDP	1.248
Employment	0.020
Consumption	0.918
Investment	-0.408
Exports	0.824
Imports	-0.496
Terms of trade	-0.205
Price of exports	-0.205
Price of capital	0.168
Price of highly skilled labour	1.816
Price of skilled labour	1.705
Price of land	-2.243

As was the case in the first long-run simulation, highly skilled labour, skilled labour and land are assumed to be the fixed factors of production, while capital, unskilled labour and informal sector labour are assumed to be the variable factors of production.

Because it is assumed that the rate of return and the real wages of unskilled and informal sector labour are constant, equation (17) indicates that the tax increase and negative terms of trade effect will result in an increase in the real price of the variable factor of production. The simulation results indicate that the terms of trade effect is indeed negative.

$$RP_V \uparrow = F(\overline{ROR}; \frac{1}{TOT \downarrow}; (1+T\uparrow)) \qquad (17)$$

Equation (15), which relates the prices of the fixed and variable factors of production is also affected by the technological change. It is evident that the effect of technological change on the price of the fixed factors of production is ambiguous, and it depends on whether the change in the price of the variable factors of production is bigger than the technological change. The results summarised in Table 11.4 suggest that the technological change is bigger than the change in the price of the variable factor of production, which implies that the price of the fixed factor of production increases (highly skilled labour, skilled labour and land).

$$RP_v^{S_V} \uparrow = \frac{A\uparrow}{RP_F^{S_F}\uparrow} \qquad (15)$$

Equation (14) indicates that the simultaneous increase in the fixed and the variable factors of production will have a positive effect on the employment of the variable factors of production if the price increase in the fixed factors of production is higher than the price increase in the variable factors of production. The results in Table 11.4 suggest that this is indeed the case, as the use of capital and unskilled labour increases.

$$\frac{V\uparrow}{\overline{F}} = \frac{RP_F\uparrow}{RP_V\uparrow} \qquad (14)$$

The increase in the employment of the variable factor of production and the technological innovation increases GDP at factor prices (equation 2).

$$Y^{FC}\uparrow \times A\uparrow = F(\overline{F}, V\uparrow) \tag{2}$$

As indicated by equation (3), the increase in GDP at factor costs implies an increase in gross domestic product at market prices.

$$Y^{MP}\uparrow = Y^{FC}\uparrow + \overline{Y}\uparrow^{TAX} \tag{3}$$

The trade balance is fixed by assumption, although there are changes in both the import and export component of the trade balance. Because economic activity increases, final consumption expenditure will also increase (equation 4).

$$P^{C}C = \Omega \times P_{GDP}^{MP} \times Y^{MP} \tag{4}$$

Government consumption expenditure is fixed by assumption, while investment expenditure decreases. The decrease in investment expenditure is the result of the increase in the use of capital, while the rate of return for investment is fixed (equation 8).

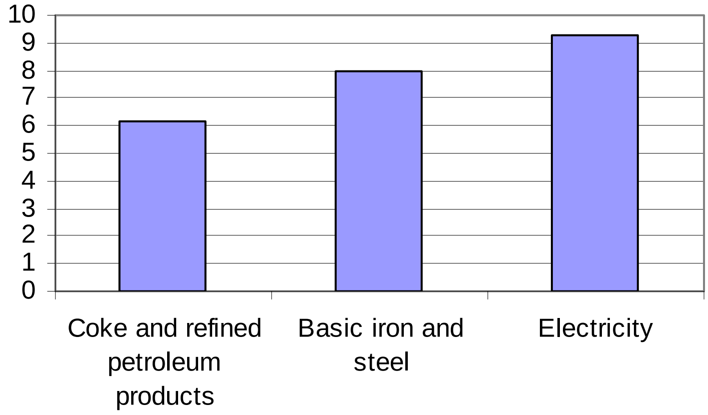
$$\frac{I}{K} = \Phi \tag{8}$$

It is evident that the technological innovation leads to an increase in economic growth, which results in an increase in consumption. Investment decreases slightly, however, because of the fall in the use of capital. The decrease in the use of capital is countered by an increase in the use of labour. This should be seen as a positive result for the South African economy because of the high levels of unemployment that persist in the country.

11.3.2 Terms of trade

There is a decrease in the terms of trade, which is the result of a fall in the price of exports. The significant tax on coal is offset by a number of factors that allow the price of exports to decrease. These factors include the technological innovation that reduces the cost of producing basic iron and steel, coke and refined petroleum products and electricity. Apart from the technological change, the fall in the price of land also contributes to the decrease in the price of exports. Figure 11.1 shows the increase in the exports of selected industries as a result of the change in the price of exports.

Figure 11.1: Increase in exports of selected industries

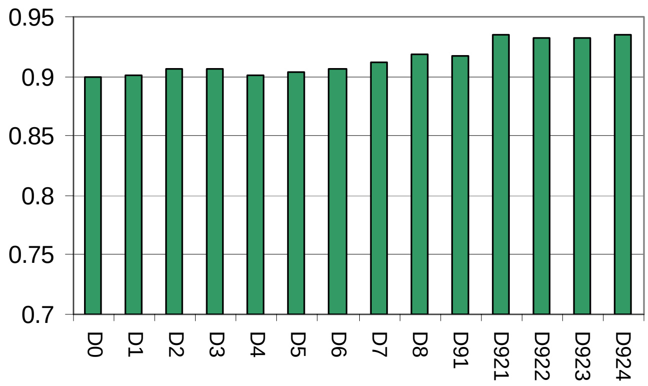


Apart from the increase in exports, there is an increase in imports. The increase in imports is the result of the increased economic activity, and it is especially the imports of transport equipment that experience a significant increase in imports (5.18 percent).

11.3.3 Consumption

The increase in real consumption is the result of an increase in the nominal income of households, which is partly offset by an increase in the prices of consumer goods. The nominal income of households increases as a result of the increase in the real wages of the highly skilled and skilled labour force. Apart from the increase in real wages, the increase in the employment of unskilled and informal sector labour also contributes towards the increase in nominal income. The policy proposal does not have a positive effect on the distribution of welfare although, consumption across all households increases by roughly the same magnitude. Figure 11.2 reflects the increase in household consumption across all households.

Figure 11.2: Change in household consumption after the policy shock



A breakdown of household consumption indicates that the use of electricity will increase significantly across all household income groups. Apart from this, households will also increase their expenditure on television sets and furniture. Table 11.5 summarises the change in individual household consumption and consumer prices.

Table 11.5: Changes in real consumption and consumer price baskets of household groups

Income group	Increase in consumption	Increase in consumer price basket
D0	0.899	0.378
D1	0.900	0.377
D2	0.905	0.372
D3	0.905	0.372
D4	0.901	0.376
D5	0.903	0.373
D6	0.906	0.371
D7	0.911	0.365
D8	0.919	0.358
D91	0.917	0.360
D921	0.935	0.342
D922	0.931	0.345
D923	0.932	0.345
D924	0.935	0.342

11.3.4 The effect on the demand for coal

The demand for coal decreases with 13 percent, which is the result of a decrease in intermediate demand (16.64 percent) and household demand (0.71 percent). Foreign demand for coal increases by 4.34 percent. The decrease in the intermediate and household demand for coal constitutes a decrease in the domestic demand for coal of 18 percent. This is a significant decrease in comparison with the decrease that was experienced in each of the policy simulations where technological change was held constant. In contrast to the previous policy proposals, the decrease in the demand for coal is not the result of a decrease in the output of the coal intensive industries – it is the result of the improved technology. The industry that bears the brunt of this policy proposal is the coal industry. The demand for the coke and refined petroleum industry's product increases by 2.26 percent, the demand for electricity increases by 1.47 percent and the demand for basic iron and steel increases by 4.48 percent.

The 18 percent decline in the domestic use of coal represents an improvement in the environment.

11.3.5 Industry specific results

The industry that experiences the biggest decline in final demand is the coal industry, which constitutes a decline in domestic use of coal and an increase in exports. The 13 percent decline in the demand for coal is accompanied by a 17 percent decline in employment within the coal industry. The decline of the coal industry is offset by increases in the output of the coke and refined petroleum industries (2.26 percent), the basic iron and steel industries (4.48 percent) and electricity industries (1.47 percent). The increase in these industries is accompanied by an increase of employment in these industries.

11.4 THE RELATIONSHIP BETWEEN THE TAX ON COAL AND TECHNOLOGICAL INNOVATION

The result of the second long-run simulation (LRSim2) is exciting, as well as daunting. It implies that the tax revenue that is raised from a 50 percent tax on coal needs technological innovation that reduces the use of coal by 50 percent in order for the policy proposal to have positive effects on economic growth, welfare and employment. In order to determine whether the "one-on-one" relationship between the tax increase and technological innovation holds across tax proposals of between 10 and 50 percent, simulations were performed that tested the effect of a 10, 20, 30, 40 and 45 percent increase in the tax rate on coal and an improvement in technological innovations of the same magnitude. Table 11.6 summarises the effects of the policy proposals on economic growth, consumption and employment.

Table 11.6: Tax and technological innovation: The effect on selected macroeconomic aggregates (percentage changes)

Simulation	Tax proposal	Innovation	Effect on economic growth	Effect on consumption	Effect on employment	Tax revenue (R billions)
LRSim3	10	10	0.18	0.016	-0.014	R 1.511
LRSim4	20	20	0.39	0.11	-0.019	R 2.803
LRSim5	30	30	0.64	0.29	-0.015	R 3.881
LRSim6	40	40	0.92	0.561	-0.0018	R 4.746
LRSim7	45	45	1.083	0.728	0.008	R 5.097

The results summarised in table 11.6 indicate that a tax proposal, which funds a technological innovation that reduces the use of coal with the same amount as the tax increase, should have unambiguous positive effects for economic growth and consumption. This result is not applicable for the effect on employment - it is only when a tax increase of 45 percent funds a technological improvement that reduces the use of coal by 45 percent that the economy obtains a positive dividend for employment as well. Although it is highly unlikely that such a one-on-one relationship will be pursued, it is clear that the percentage change in the technological innovation that is funded by the tax increase will have to be higher than the proposed increase in the tax rate. Table 11.7 reports the effects of combinations of tax and technological increases which is higher than the suggested tax increase.

Table 11.7: Tax and technological innovation: The effect on the economy

Simulation	Tax increase	Technological innovation	Economic growth	Consumption	Employment	Demand for coal	Revenue
LRSim8	10	10	0.18	0.016	-0.014	-2.54	R 1.511
LRSim9	10	15	0.35	0.238	0.003	-3.70	R 1.641
LRSim10	20	20	0.39	0.11	-0.019	-5.09	R 2.803
LRSim11	20	25	0.57	0.35	0.0007	-6.29	R 2.887
LRSim12	30	30	0.64	0.29	-0.015	-7.67	R 3.881
LRSim13	30	35	0.83	0.56	0.0070	-8.91	R3.911
LRSim14	40	40	0.92	0.56	-0.0018	-10.30	R 4.746
LRSim15	40	45	1.08	0.72	0.008	-11.64	R 5.097
LRSim16	50	50	1.24	0.91	0.029	-13.00	R 5.394
LRSim17	55	50	1.20	0.80	0.0076	-13.05	R 5.726

These results confirm that the technological change that the tax revenue will fund should be higher than the tax increase in order to obtain positive benefits for employment up to a level of a tax increase of 50 percent. At this level a one-on-one relationship between the tax increase and the technological innovation results in a positive employment benefit. From this level the technological innovation can be less than the tax increase for the policy to result in a positive benefit for employment and the environment. Not surprisingly it is also clear that high levels of technological and tax change, holds the highest benefit for the environment.

11.5 CONCLUSION

The results from the long-run policy simulations indicate that technological innovation is a necessary development for South African policy makers to obtain a sustainable environmental policy. The result of the first simulation, in which the tax policy is unable to significantly reduce the demand for coal, prompts the introduction of technological change as part of the policy recommendation.

The assumption that the introduction of an environmental tax could induce positive technological change is consistent with the Porter Hypothesis of technological change. The introduction of the tax provides both an incentive to the polluting industries to reduce their use of coal as well as revenue that could be used to fund research and development projects to achieve the relevant levels of technological efficiency.

The results from the policy simulations that assume certain levels of technological change indicate that a combination of environmental tax and technological changes will hold positive benefits for the South African environment, economic growth, consumption and unemployment.

CHAPTER 12

LONG AND SHORT TERM RESULTS: A CRITICAL POLICY EVALUATION

12.1 INTRODUCTION

It is evident from both the short-run and long-run policy simulations that South African policy makers should carefully consider their policy objectives before implementing environmental management measures such as environmental taxation. Apart from the consequences that environmental taxation has for the environment, it also holds important consequences for employment, welfare distribution and economic growth. This Chapter serves to highlight the economic consequences that an environmental taxation policy in South Africa could have.

12.2 ENVIRONMENTAL TAXATION AND THE ENVIRONMENT

The results from both the short-run and long-run policy simulations indicate that a tax on coal would do very little to decrease the domestic demand for coal in South Africa. Table 12.1 compares the change in the demand for coal in the short-run and long-run policy simulation in which all other exogenous variables were left unchanged (i.e. no tax revenue returns or technological changes).

Table 12.1: The change in the domestic demand for coal in the short-run and the long run

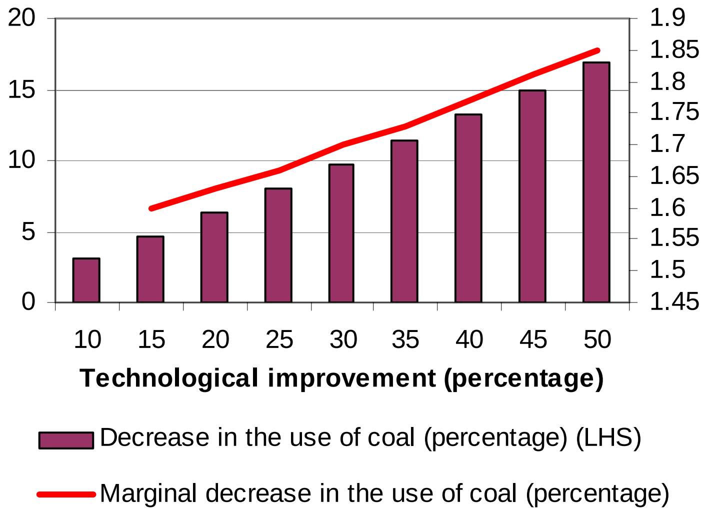
	Change in domestic demand (%)	Rand value of the change in demand R millions (2001 = R11 782)	Approximate change in quantity (millions of tonnes) (R62/tonne)
Short-run	1.39	R163	2.63
Long-run	1.13	R133	2.15

Although an environmental tax would result in a decrease in the domestic use of coal, it is unlikely that a reduction of 1.39 percent (in the short-run) or 1.13 percent (in the long-run) would have significant environmental benefits. Policy makers should bear in mind that these reductions would be achieved by levying an environmental tax of 50 percent on the use of coal, which is, by most measures, a relatively high level of taxation.

The reason for the lack of any significant environmental success with a tax on coal is the current lack of a feasible substitute for coal. This lack of a substitute is especially evident in the electricity, synthetic fuel and basic iron and steel industries. The lack of a coal substitute makes the demand for coal very inelastic and any decrease in the demand for coal is the sole result of a decrease in aggregate domestic demand.

Given the lack of any feasible alternative to the use of coal, it is important that South African policy makers recognise the important role of technological innovation in the management of South Africa's environmental resources (with specific reference to the use of coal and the pollution problems that emanate from the use of this natural resource). Technological innovation is more likely to occur over the long-term and for this reason long-term policy simulations are performed that incorporates technological change that increases the efficiency of the use of coal in the production processes in South Africa. Figure 12.1 reflects the percentage change in the domestic use of coal that is associated with different levels of technological innovation. It is evident that the marginal decrease in the use of coal increases up to (and including) a level of 50 percent of technological innovation.

Figure 12.1: The percentage change decrease, and marginal percentage decrease in the domestic use of coal due to technological improvement



This result indicates that the authorities that are involved in environmental management will have to consider a strategy to induce technological innovation that decreases the dependence of the economy on coal. The suggested environmental taxation will have little effect on the environment if technological innovation is neglected.

12.3 ENVIRONMENTAL TAXATION AND GOVERNMENT REVENUE

Because the price elasticity of demand for coal in South Africa is currently very inelastic, the short-run and long-run simulation results indicate that a tax on coal will generate significant indirect tax revenue for the government. In the short-run, the 50 percent tax on coal (with all other exogenous variables unchanged) will increase the government revenue by approximately R5.044 billion. This represents an increase of 2.2 percent in total government revenue (2001/2002 fiscal year).

Although the increase in indirect taxes is relatively high, the CGE model that was used in this study does not include the effects of the tax on other sources of government revenue. These include corporate taxes and personal income taxes, which are ultimately the main drivers of government revenue. If one makes the assumption that companies pay corporate taxes based on their levels of gross operating surplus, and that households pay income taxes based on some level of nominal consumption expenditure, tax revenue collections from both these sources will decrease as a result of the environmental taxation. Nominal consumption expenditure will decrease by 1.79 percent across all households in the short run and by 2.38 percent across households in the long run. Gross operating surplus decreases by 1.93 percent in the short-run and by 1.61 percent in the long-run.

The short-run simulations in which the government returns the indirect tax revenue to the economy by means of a lump sum transfer to poorer households, or by means of a subsidy on the cost of food and agricultural products, indicate that the government will be able to significantly reduce the negative effects of the tax on coal on personal- and corporate income taxes. By redistributing the tax revenue by means of a subsidy on food and agricultural products, the gross operating surplus would only decline by 0.28 percent, while nominal consumption expenditure only declines by 0.17 percent across households that do not receive the transfer. Nominal consumption expenditure increases by between 20 and 40 percent for households that receive the subsidy.

The results from the long-run policy simulations, in which technological changes are introduced (for example in the case of Simulation 2 in Chapter 11), indicate that an improvement in technological change holds the biggest benefit for South African government revenue. Although the reduction in the use of coal implies a decrease in government revenue collected from this source, the increase in economic activity would actually result in an increase in indirect tax revenue collection from other sources of expenditure. It should also result in an increase in tax revenue collection from corporate taxation (as gross operating surplus would increase by 0.69 percent) and personal taxation (as nominal consumption would increase by 1.28 percent across households).

12.4 ENVIRONMENTAL TAXATION AND THE UNEMPLOYMENT PROBLEM

Given the assumption (in both the short-run and long-term simulations), that the unskilled and informal sector labour supply is perfectly elastic, while the highly skilled and skilled labour supply is perfectly inelastic, the results of the CGE simulations provide valuable insights into the effect that environmental taxation would have on the South African labour market.

As expected, both the short-term and long-term policy simulations indicate that an environmental tax policy in which tax revenue is used to increase government savings (zero revenue recycling scenario) would result in a decrease in the employment of unskilled and informal sector labour. The simulation results indicate that, in the case of a 50 percent tax on coal, the short run effect (of such a zero revenue recycling policy on employment) would be a slight increase of 0.008 percent in the number of unskilled workers and a decrease of 0.51 percent in the number of informal sector workers employed. This represents a head count of 3 954 and 5 202 lost job opportunities in the unskilled and informal sector labour markets, respectively. The negative effect of the tax on coal is even more pronounced in the long-run, where the demand for unskilled and informal sector labour decreases by 0.65 and 0.95 percent respectively. This represents lost job opportunities of 15 375 and 9 689 in the unskilled and informal sector labour markets respectively.

As discussed in Chapters 4 and 5, the double dividend literature indicates that there is a possibility that the labour market could reap positive benefits if the Government recycles the environmental tax revenue. This possibility would appeal to policy makers with political ambition, and for this reason it was tested within a short-term framework by:

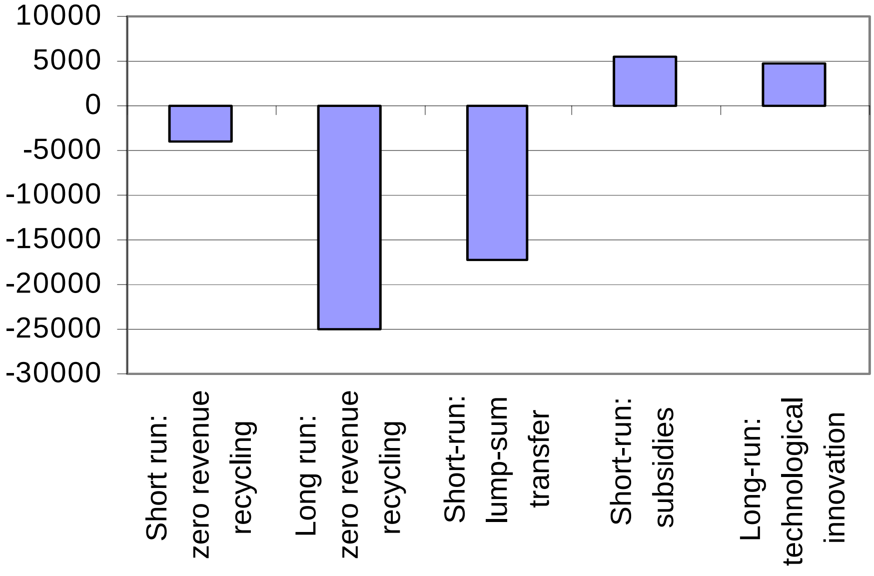
i. Recycling the tax revenue as a lump-sum transfer towards the poorest households; and
ii. Recycling the tax revenue as a subsidy on agricultural - and food products.

The simulation results indicated that a lump-sum transfer would actually increase the negative effects of the environmental tax on the economy over the short-term, the reason being that the positive effect that the tax policy has on exports is reduced in such a setting (see Chapter 11). Employment of unskilled labour will decrease by 15 375, while employment of informal sector labour will decrease by 1 783.

A positive effect could, however, be achieved by subsidising labour intensive products such as food and agricultural products. The policy results indicate that employment of the unskilled and informal sector labour force would increase by 5203 and 387 employment opportunities, respectively. Policy makers should keep in mind that tax revenue from personal income and corporate taxes would (in all probability) be negatively affected in this policy setting. This could decrease the ability to subsidise labour intensive products.

A long-run simulation, which incorporates a 50 percent tax on coal and technological innovation that reduces the use of coal by 50 percent in the production process, shows that employment would increase by 3 400 job opportunities. This increase represents a decrease of 700 opportunities in the unskilled labour market and an increase of 4 100 opportunities in the informal labour market. Figure 12.2 compares the effect of the different policy proposals on the South African labour market.

Figure 12.2: Environmental taxation and the demand for unskilled and informal sector labour: a comparison of policy results

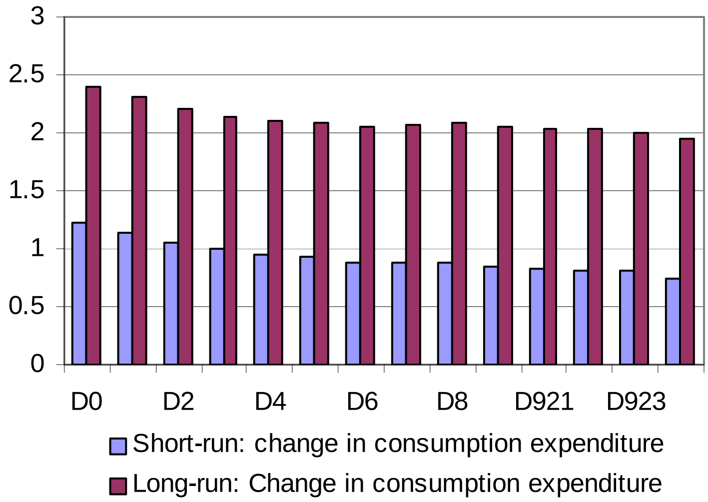


The conclusion that can be reached from the different policy simulation results is that the negative effects of environmental taxation on South Africa's labour market could be negated, and even reversed, if policy makers apply the revenue in a fashion which would stimulate the demand for labour, i.e. increase the demand for labour intensive products. There is, however, a degree of uncertainty as to the revenue that would be available to the Government in order to affect stimulatory policies in the labour market. It is evident that environmental technological innovation holds benefits for the South African labour market, but without uncertainty about government revenue collections.

12.5 ENVIRONMENTAL TAXATION AND THE REDISTRIBUTION OF WELFARE

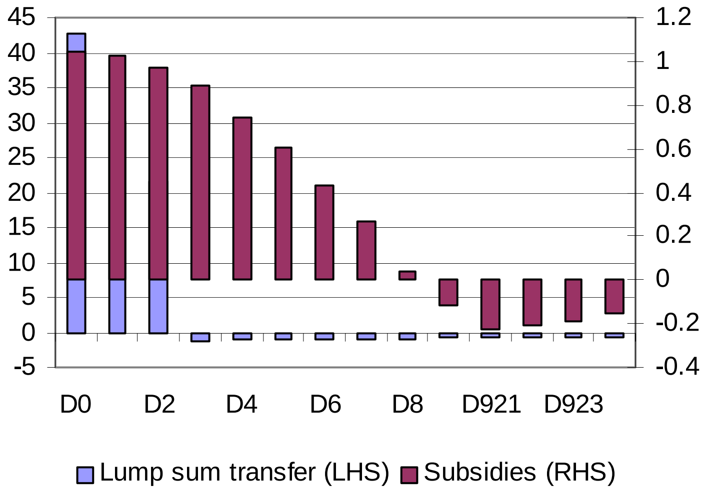
If it is assumed that consumption expenditure serves as a proxy for welfare, it is evident that an environmental tax policy with zero revenue-recycling would have negative effects on welfare and welfare distribution across all households in South Africa in both the short- and long-run. This is reflected in Figure 12.3.

Figure 12.3: Decrease in real consumption expenditure in the short and long-run: zero revenue recycling.



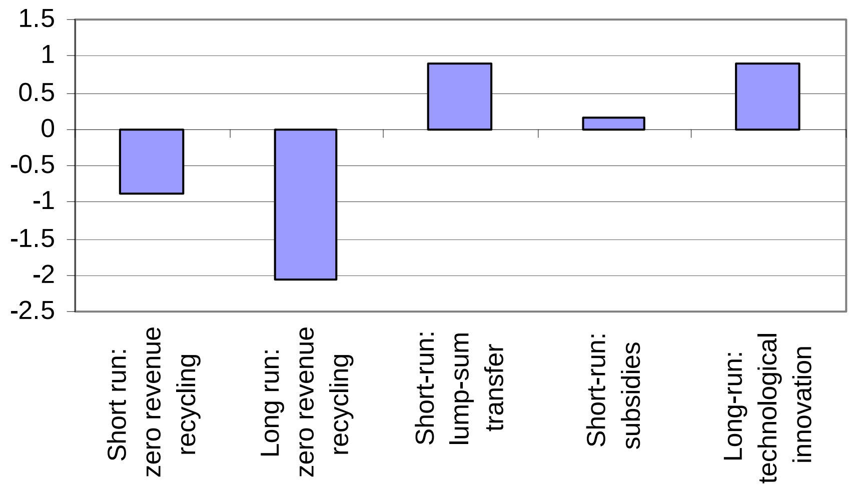
Given South Africa's welfare problems and skew income distribution, such a policy would be difficult to sell to policy makers. The policy results indicate that the Government would be able to address these problems in the short-run by using tax revenue either as a lump sum transfer to households at the lower end of the income distribution, or as a subsidy on products that constitute a significant portion of the budgets of poorer households. Figure 12.4 compares the results of these two policy simulations with one another. Not surprisingly, a lump-sum transfer would benefit all households that receive it, while the benefit of a subsidy would be the highest for low-income households and gradually decrease towards higher income households. The aggregate welfare increase is positive in both cases.

Figure 12.4: A comparison of changes in real consumption expenditure: lump-sum transfers and product subsidies



The long-run policy simulation results indicate that an environmental tax that is accompanied by technological innovation will also hold positive benefits for aggregate welfare the economy. A 50 percent tax on coal, which induces technological innovation, in turn reducing the use of coal by 50 percent, would result in an aggregate increase in real consumption expenditure of close to one percent. Although such a policy would result in a redistribution of welfare, it would increase aggregate real consumption across all households by approximately the same amount (0.9 percent). Figure 12.5 compares the change in aggregate consumption expenditure for the different policy simulations.

Figure 12.5: Change in aggregate consumption expenditure



As is the case with unemployment, the policy simulation results indicate that the South African government should be able to address the negative welfare effects of environmental taxation by recycling the revenue in an appropriate fashion. Technological innovation would, however, be critical in the long-term.

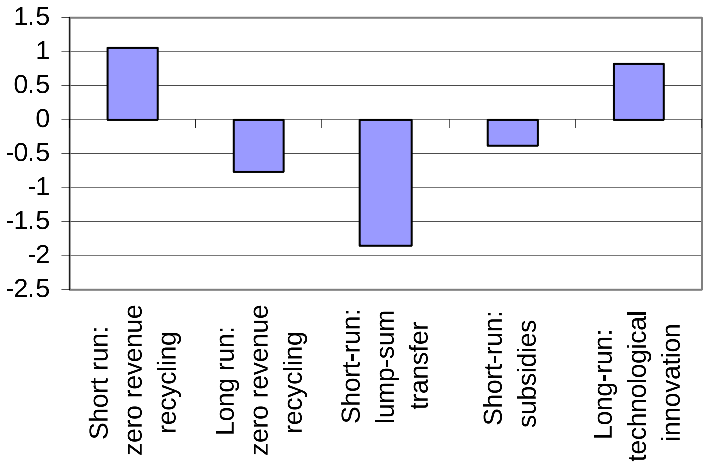
12.6 ENVIRONMENTAL TAXATION AND EXTERNAL COMPETITIVENESS

The policy simulation results indicate that a zero-revenue recycling policy would have a positive effect on South Africa's competitiveness in the short-run (exports would increase by 1.06 percent). This is because the fall in the price of fixed factors of production would result in a decrease in the price of South Africa's aggregate exports. A zero-revenue recycling policy would, however, result in a decrease in South Africa's exports in the long-run (0.76 percent).

It is interesting to note that revenue recycling would negate the positive effect on the country's competitiveness in the short-run. A policy that returns tax revenue in a lump-sum fashion would decrease South African exports by 1.86 percent, while a policy that subsidises food and agricultural products would reduce exports by 0.39 percent.

Technological innovation would induce positive benefits for South Africa's competitiveness. A technological improvement that reduces the use of coal by 50 percent would increase South Africa's exports by 0.82 percent. Figure 12.6 compares the effect of the various different policy results with one another.

Figure 12.6: Environmental tax policies and South African exports



12.7 CONCLUSION

There are two important policy conclusions that follow from the various simulations performed in this study.

Firstly, in the short-run, it can be concluded that the economic costs from environmental tax reform would be high, and that South Africa's economic structure would make the attainment of a double dividend difficult. The main reason for this is that there is currently no feasible alternative for the use of coal in South Africa. A tax on coal would thus not have significant environmental benefits. Although the tax on coal provides higher intermediate tax revenue collections, it is very likely that it would reduce personal income taxes and corporate taxes significantly. Although a lump-sum transfer of tax revenue to poor households could hold welfare benefits for the poor, it would not negate the negative effects on aggregate welfare, economic growth and employment. A policy that uses coal tax revenue to reduce the price of food and agricultural products could hold positive benefits. Before such a policy is implemented, further analyses will have to be done in order to assess the effect of the tax on total government revenue.

Secondly, in the long-run, the policy simulations indicate that the development of technology that will reduce the use of coal in the production process (i.e. increase the "productivity" of coal) will have significant benefits for the economy and the environment. South Africa's policy makers will therefore have to consider an environmental policy that will enhance technological innovation in the relevant industries. Coal tax revenue could be used to fund the development of such technologies. If successful, such policy would increase employment, economic growth and welfare, while reducing pollution in South Africa.

CHAPTER 13

SUMMARY AND CONCLUSIONS

13.1 INTRODUCTION

Probably the biggest concern for South African policy makers is the high level of unemployment that persists in the economy. There is thus an urgent need for policies that could increase employment growth. There is a widely held view that a decrease in unemployment should also address the skew income distribution that characterises the South African economy. Any policy that would address these issues, would undoubtedly find favour with policy makers.

Despite of high levels of unemployment and social imbalances, there are also concerns about South Africa's environmental management. It seems as if the debate of sustainable development, that has held the attention of policy makers in developed regions of the world for the past decade, has finally caught up with South Africa. One of the concerns that needs to be addressed is the relatively high level of CO_2 emissions created by economic activity in South Africa.

Given the issues discussed above, the purpose of this study was to determine whether policy makers in South Africa could introduce environmental taxation in the form of an intermediate tax on coal, without aggravating the problems of unemployment and the skew welfare distribution. The literature pertaining to the "double dividend" and the "Porter Hypothesis" motivated the possibility of achieving this result.

The study was conducted in four stages:

i. The first stage comprised a description of the use of coal and unemployment problems in South Africa. This description highlighted the need for an environmental policy that addresses high levels of carbon pollution. It indicated that such a policy should not aggravate the problem of unemployment. Apart from serving as a description of the labour market, the Chapter on the South African labour market provided valuable insights with regard to handling labour as an input within the modelling framework.

ii. The second stage of the study served as a literature review. An overview of the "double dividend" literature and the "Porter Hypothesis" indicated that, under certain conditions, both environmental and welfare benefits could be achieved by introducing environmental policies. The "double dividend" literature emphasised the importance of efficient redistribution of revenue raised through the policy, while the "Porter Hypothesis" emphasised the importance of technological innovation in the process of environmental management.

iii. The third stage of the study involved the description of the CGE model that was used to analyse the effect of environmental policies on the South African economy. A model, based on the ORANI model for Australia was described. This model was applied to a South African database and elasticities for the model were either estimated or values were motivated from current economic literature.

iv. The fourth stage of the study consisted of a description of the different policy proposals that were tested in the study. A distinction was made between short-run and long-run policy proposals. The short-run policy proposals tested whether it would be possible to achieve a “double dividend” for the South African economy, while the long-run policy proposals were concerned with the “Porter Hypothesis” and the benefits of technological improvements in the use of coal.

13.2 THE DUAL CHALLENGE OF REDUCING CO_2 EMISSIONS AND SOLVING THE UNEMPLOYMENT PROBLEM

It was shown in Chapter 2 that the relatively high levels of CO_2 emissions in South Africa can be attributed to the intensive use of coal in providing for the country’s energy needs. The intensive use of coal can be attributed to the fact that South Africa enjoys an abundance of the resource, which has resulted in prices that are well below the marginal social cost of the resource. Previous governments that subsidised industries that make intensive use of coal further exaggerated dependence on the resource. These industries include the electricity and synthetic fuel industries, while the basic iron and steel industries are also dependant on coal for providing their energy needs.

It became evident in Chapter 2 that an environmental policy will have to include measures that motivate economic agents to reduce their use of coal. Although there are a number of measures available to policy makers, it was shown (Blackman *et al*, 1999) that indirect instruments, such as environmental taxes stand a better chance of being effective in developing nations (than command and control measures), because they are less demanding on regulators than direct measures of pollution control. An illustrative tax that would increase the price of coal in the production process by 50 percent was therefore implemented throughout the study in order to address the high demand for coal.

Due to the fact that the problems of unemployment and social inequity are foremost on the agenda of policy makers, a description of the South African labour market was necessary. An important conclusion from this description was that the unemployment problem in South Africa is not a labour supply-side problem, but rather a labour demand problem. While there seems to be a shortage of highly skilled and skilled labour, there seems to be an excess supply of unskilled and informal sector workers for which there is very little demand. It is therefore not surprising that the high level of unemployment emanates from the unskilled and informal sectors of the labour market. Based on this observation, the assumption was made that the supply of unskilled and informal sector labour is perfectly elastic, while that of highly skilled and skilled labour is perfectly inelastic.

13.3 THE THEORIES BEHIND ENVIRONMENTAL TAXATION AND UNEMPLOYMENT

The above challenge of taxing coal while avoiding any damage to South African employment fits neatly within the "double dividend" literature. The "double dividend hypothesis" postulates that recycling tax-revenues that were obtained through environmental taxation can reap both environmental and socio-economic benefits. However, the review of the host of literature on this topic indicated that the achievement of a double dividend is ambiguous. It does seem, however, that there are certain economic conditions in which a double dividend could be achieved. One of the relevant conditions for the South African case is that the problem of unemployment should emanate from the demand side of the labour market and not its supply side. Concern is also raised in the literature that the tax base of an environmental tax could be to small to raise significant revenue to achieve significant "revenue–recycling" effects in an economy.

Although the "double dividend" literature seemed appealing, environmental problems are essentially long-term in nature and one should not ignore the possibilities that technological innovation offers. In this regard, the economic literature about the "Porter Hypothesis" was deemed to be relevant. The "Porter Hypothesis" postulates that the introduction of environmental incentives, such as environmental taxation, could induce and increase technological innovation, resulting in environmental and socio-economic benefits. Although the literature that examines the "Porter Hypothesis" indicates that the achievement of environmental and other economic benefits is unambiguous, in reality achievement of these benefits is uncertain.

Due to this uncertainty, a review of the levels of research and development in South Africa was done. This indicated that the South African government recognises the need for higher levels of research and development that could increase the levels of technology in the country. It is also evident that those industries that contribute significantly towards CO_2 pollution have recognised the need for increasing investments aimed at increasing technological innovation. Despite the fact that both government and industry recognise the need for increased levels research and development, there seems to be a lack of funding for this type of investment.

Finally, it was evident from the literature review, that the achievement of a "double dividend" and the implications of the "Porter Hypothesis", need to be tested within a general equilibrium framework.

13.4 A GENERAL EQUILIBRIUM MODEL OF THE SOUTH AFRICAN ECONOMY

In order to test:

i. whether the South African economy could achieve a "double dividend"; and
ii. the implications of the Porter Hypothesis for the South African economy;

a CGE model for the South African economy was developed. This model is based on the ORANI-G methodology, as explained in detail in Dixon *et al* (1980) and Horridge (2002). A 2001 SAM served as the primary database for the model. The model distinguishes between 45 different industries, while the final demand components consists of 14 households, a government sector, external sector, investments and change in inventories. A distinction is also made between highly skilled, skilled, unskilled and informal sector labour. Behavioural elasticities were either estimated in cases where data were available, or taken from existing literature.

13.5 POLICY PROPOSALS AND RESULTS

As mentioned above, the review of the labour market indicated that one could assume that the supply of unskilled and informal sector labour is perfectly elastic, while that of highly skilled and skilled labour is perfectly inelastic. This assumption was fixed across all policy proposals and time horizons.

Because the achievement of a double dividend could hold significant political consequences for policy makers with in the short-term, the attainment of the "double dividend" was tested within a short-run framework. A tax on coal was implemented and the revenue raised through this tax was subsequently returned to the economy by:

i. lump-sum transfer to low-income households; and
ii. a subsidy on food and agricultural products.

Although the results indicated that subsidising food and agricultural products could achieve some welfare benefits, it became evident that the environmental benefit was negligible. The lack of any real environmental benefit is the result of the fact that there are very little (if any) substitution possibilities for South African industries that do not want to make use of coal.

The short-run result served as further motivation to examine the possibilities that the "Porter Hypothesis" holds for the South African economy in the long-term. Because of the lack of alternative sources of energy, technology that increases the efficiency of the use of coal in the production process across all South African industries was introduced.

Due to the uncertainty that accompanies technological investment, a number of policy simulations were performed to determine the level of technological improvement that would hold simultaneous environmental and socio-economic benefits (along with a 50 percent tax rate on the use of coal). The results indicate that a (percentage) tax increase should be accompanied by a similar (or higher percentage) technological improvement in the efficient use of coal in order for the economy to reap simultaneous environmental and socio-economic benefits. Although technological investments are uncertain at the best of times, the revenue that would be raised through the environmental tax could be used to fund these investments. The increase in economic activity that would result from such a tax would also imply that policy makers would be able to increase their indirect tax receipts, despite the decrease in the demand for coal that would result from the efficiency improvement.

13.6 CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

The results from this study indicate that South African policy makers should approach the problem of controlling the demand for coal with caution. It was shown that any policy that attempts to increase the price of coal would achieve very little environmental benefit. The main reason for this is the lack of any feasible alternative energy source in the South African economy. Although such a tax could serve as an attractive source of revenue for the government, the socio-economic benefits achieved through recycling of the tax would also be small and it is debatable whether they would warrant the administration and political debate that would accompany them.

It is therefore evident that policy makers will have to invest in research and development programs that will result in a reduction in the use of coal within the production process. Results from policy simulations have indicated that successful implementation of such an investment would not only reduce CO_2 emissions significantly, but could also increase economic growth, welfare and employment. These investments could be funded through raising a tax on the use of coal. This tax would also serve as additional incentive for industry to increase their levels of technological innovation in the use of coal.

Although these results hold important consequences for policy makers, the analysis could be extended. Such extensions would include an analysis of the "double dividend" hypothesis within a framework in which environmental tax revenue is used to reduce income or corporate taxes. It should also be interesting to determine whether the environmental tax revenue could be used to fund a labour subsidy for unskilled labour.

Another extension of this research would entail the calculation of the cost of technological innovation that would increase the efficient use of coal. If the cost could be linked to a certain level of efficiency, policy makers would be able to calculate the tax revenue that will be needed to fund investment in technological innovation. A further extension that would be closely linked to the aforementioned suggestion would be to incorporate coal within an energy nest in the CGE model. This would allow substitution possibilities between coal and other sources of energy. In the latter case, however, researchers would have to determine which sources of energy would serve as a feasible alternative to the use of coal in South Africa.

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APPENDIX 1

DESCRIPTION OF THE DATA BASE USED IN THE STUDY

1.1 DIFFERENT INDUSTRIES AND PRODUCTS IN THE MODEL

- **Agriculture, forestry and fishing**

This industry represent establishments which are primarily engaged in farming activities, such as the growing of field crops, the raising of livestock and the production of milk, wool and eggs. Establishments rendering agricultural services such as harvesting, baling, threshing and spraying are also classified under this division. Also included are establishments engaged in commercial hunting and game propagation and forestry, logging and fishing.

- **Coal mining**

This industry includes mines that are primarily engaged in producing anthracite, bituminous coal, brown coal and lignite; and coal crushing, pulverising, cleaning, screening and sizing plants, whether or not operated in conjunction with the mines served. Also included are the manufacture of coke and the agglomeration of coal and lignite into briquettes, and other compressed fuels at mining sites.

- **Gold and uranium ore mining**

This sector represents the mining of gold and uranium ore, the dressing, beneficiating and otherwise preparing of such ores. Gold tailings, clean-up works, alluvial gold mining and the reclamation of gold from mine dumps are included. Gold mines also produce sulphuric acid and mine iron pyrites for this purpose as a by-product of gold mining.

- **Other mining**

This industry represent mining activities that relate to the extraction of natural gas, iron ore, non ferrous metals, stone quarrying, diamonds, chemicals, salt, precious and semi-precious stones as well as asbestos.

- **Food**

The food industry includes the production of meat and meat products, fish, fruit and vegetables, oils and fats, dairy products, grain mills, starch and starch products, prepared animal feeds, bakery products, sugar, chocolate, pasta and other food products.

- **Beverages**

The beverage industry includes the beer and malt industries, soft drink and mineral water, as well as the blending of spirits.

- **Tobacco**

This group includes the manufacture of tobacco products such as cigarettes or cigars, pipe tobacco, chewing tobacco or snuff, as well as the manufacture of homogenized or reconstituted tobacco.

- **Textiles**

Represent the spinning, weaving and finishing of textiles industries. It also represents the manufacturing of carpets, rope and other textiles.

- **Wearing apparel**

Includes the manufacturing of knitted and crocheted fabrics, the manufacturing of wearing apparel and the dying of fur.

- **Leather and leather products**

This sector includes the tanning and dressing of leather, as well as the manufacturing of leather luggage and handbags.

- **Footwear**

This group includes the manufacture of footwear for all purposes (other than orthopaedic footwear), of any material (other than of asbestos or of textile material lacking applied soles), by any process, including moulding. The materials used may be leather, rubber, plastics, textile materials, wood or other materials and the processes applied may be cutting and sewing, gumming, moulding or any other process. Also included is the manufacture of gaiters, leggings and similar articles and of parts of footwear, such as uppers and parts of uppers, inner and outer soles etc., of any material.

- **Wood and wood products**

Includes industries of saw milling and planning of wood, veneer sheets, plywood, laminated board, particle board, wooden containers, builders carpentry, other products of wood, articles of cork, straw and plaiting materials.

- **Paper and paper products**

This sector represents industries of pulp, paper and paperboard, as well as other articles of paper.

- **Printing, publishing and recording media**

This group includes publishing of books, brochures, musical books, newspapers, journals and periodicals, recorded media, printing and services relating to printing.

- **Coke and refined petroleum products**

Industries that produce coke oven products, petroleum refineries and nuclear fuel industries are included in this sector.

- **Basic chemicals**

This industry represents firms that produce basic chemicals, fertilisers and plastic in primary forms.

- **Other chemicals and man-made fibres**

This group includes the manufacture of insecticides, rodenticides, fungicides, herbicides, anti-sprouting products, plant growth regulators, disinfectants and other agro-chemical products not elsewhere classified. It also includes paints, pharmaceuticals, soap and other chemicals.

- **Rubber products**

Represents those industries that produce rubber tyres, tubes, retreading and other rubber products.

- **Plastic products**

This group includes the manufacture of plastic products such as plates, sheets, film, foil and strip; tubes, pipes and hoses; hose and pipe fittings; self-adhesive plates, sheets, film, foil, tape, strip and other flat shapes; plastic floor, wall or ceiling coverings in rolls or in the form of tiles; or other primary plastic products.

- **Glass and glass products**

This group includes the manufacture of glass in all its forms and articles of glass, including glass used in construction, glassware and glass fibre.

- **Non-metallic minerals**

This industry includes firms that manufacture non-structural, non-refractory ceramic ware, refractory ceramic products, clay and ceramic products. It further includes manufacturers of cement, lime and plaster, articles of concrete and cement as well as other non-metallic mineral products.

- **Basic iron and steel**

Includes the operation of blast furnaces, steel converters, rolling and finishing mills as well as the manufacturers of primary iron and steel products.

- **Basic non-ferrous metals**

This major group includes the manufacture of the precious metals, gold and silver, and metals of the platinum group.

- **Metal products excluding machinery**

This group includes the casting of iron and steel, non-ferrous metals as well as the manufacturing of structural metal products, tanks, reservoirs and similar containers of metal, cutlery and fabricated metals. It also includes the forging, pressing, stamping and roll forming of metal as well as the treatment and coating of metals.

- **Machinery and equipment**

This industry represent the manufacturing of engines, turbines (except aircraft, vehicle and motor cycle engines), pumps, compressors, taps, valves, bearings, gears, driving elements, ovens, furnaces, lifting equipment, agricultural and forestry machinery, machine tools, weapons and ammunition, special purpose machinery, household appliances and accounting and computing machinery.

- **Electrical machinery**

Includes manufacturing of electric motors, generators, transformers, electricity distribution, control apparatus, insulated wire and cable, accumulators, primary cells, primary batteries, electric lamps, lighting equipment and other electrical equipment.

- **Television, radio and communication equipment**

The manufacturing of electronic valves, tubes and other electric components, as well as, television and radio transmitters, television and radio receivers.

- **Professional and scientific equipment**

The manufacturing of medical and surgical equipment, appliances for measuring and checking purposes, industrial process control equipment, photographic equipment, watches and clocks.

- **Motor vehicles, parts and accessories**

Includes the manufacturing of motor vehicles and the bodies for motor vehicles. It further includes the manufacturing of trailers, semi-trailers and other parts and accessories for motor vehicles and their engines.

- **Other transport equipment**

This industry includes the building and repairing of ships, pleasure and sporting boats, railway and tramway locomotives, aircraft, spacecraft, motorcycles, bicycles and other transport equipment.

- **Furniture**

This group includes the manufacture of furniture of all kinds (household, office, hotel, restaurant and institutional furniture; fixtures; bed springs and mattresses), of any material (wood, osier, bamboo, base metal, glass, leather, plastics, etc., other than of stone, concrete or ceramics), for any place (dwellings, hotels, theatres, offices, churches, schools, restaurants, hospitals, ships, aircraft, motor vehicles, etc., other than furniture to which scientific, medical or laboratory equipment is attached) or for such purposes as cooking or dining, sitting or sleeping, storing (including filing cabinets) or displaying, working or resting.

- **Other industries**

This group includes manufacturers of jewellery, musical instruments, sports goods, games and toys as well as the recycling of metal waste and scrap and non-metal waste and scrap.

- **Electricity, gas and steam**

Includes the production, collection and distribution of electricity, the generation thereof as well as the manufacturing of steam and hot water supply.

- **Water supply**

This group includes the collection, purification and distribution of water to household, industrial, commercial and other users.

- **Building construction**

Includes the construction of buildings, homes and other structures.

- **Civil engineering and other construction**

This group includes site preparation, building installation, plumbing, electrical construction, shoplifting, building completion, painting and decoration and other building construction.

- **Wholesale and retail trade**

This industry consists of retail and wholesale trade across all sectors of the South African economy without any exception.

- **Catering and accommodation services**

This group encompass all hotels, camping sites and other provisions for short-stay accommodation. It also include restaurant, bar and canteen services.

- **Transport and storage**

This industry includes railway transport, land transport, passenger and land transport, freight transport by road, transport via pipelines, water transport, sea and coastal transport, inland water transport, air transport, cargo handling, storage and warehousing, other supporting transport activities, travel agency and related activities.

- **Communication**

The group includes national postal activities, courier activities, other national postal activities and telecommunications.

- **Finance and insurance**

Includes activities by the central bank, other monetary intermediation, financial intermediation, lease financing and other credit granting. It further includes insurance and pension funding, life insurance, pension funding, medical aid funding.

- **Business services**

This group includes all activities that are auxiliary to financial intermediation, except insurance and pension funding.

- **Medical, dental and other health and veterinary services**

Encompass all hospital, medical and other human health activities. It also includes supplementary health services or paramedical staff, clinics, nursing services, chiropractors, veterinary services and social work activities.

- **Other community, social and personal services**

Includes all other medical and human health services that are not included with the medical, dental and other health industry.

- **Other producers**

This group includes washing and dry-cleaning of textiles and fur products. It further includes hairdressing and other beauty treatments as well as funeral and related activities.

1.2 THE DIFFERENT TYPES OF LABOUR THAT ARE DISTINGUISHED WITHIN THE MODEL

Given the description of the 45 different industries that are distinguished in the model, the four different types of labour that are employed in these industries are:

- **Highly skilled**

Occupations that are included in the highly skilled category include professional, semi-professional and technical occupations, as well as managerial, executive, administrative, and certain transport occupations.

- **Skilled**

Skilled occupations include clerical, sales, transport and service occupations. It also encompasses farmers and farm managers, artisans, apprentices and production foremen and supervisors.

- **Semi- and unskilled**

This group includes all occupations that are neither highly skilled nor skilled.

- **Labour employed in the informal sector**

The table below summarises the number of workers of each skill type that are employed within each industry:

Table A1: Number of workers employed within each industry

Industry	*H*	*S*	*SS*	*I*	*Industry*	*H*	*S*	*SS*	*I*
Agric	16,919	35,840	713,496	28,509	MetProd	8,149	28,825	65,816	3,824
Coal	2,908	12,712	30,711	1,724	Macheq	9,522	25,648	32,878	2,532
Gold	5,381	19,218	178,996	7,575	ElecMach	14,179	17,983	47,617	2,968
Othmin	7,078	29,426	121,457	5,877	Telv	2,466	3,128	8,282	516
Food	10,390	59,819	84,323	5,750	ProfEq	1,006	1,276	3,380	211
Bev	3,460	8,836	14,106	982	MotVeh	13,315	24,411	39,812	2,885
Tob	279	713	1,138	79	OthTrnsp	1,872	3,432	5,597	406
Text	2,726	8,248	42,428	1,987	Furn	2,315	11,332	31,255	1,671
Wear	5,621	17,611	109,633	4,943	OthInd	1,553	8,133	9,278	706
Leath	270	1,348	6,278	294	Elect	16,525	23,316	24,436	13,526
Foot	370	815	11,573	475	WatSup	1,933	2,727	2,858	280
Wood	2,407	26,756	44,915	2,756	BuildCnst	6,605	23,238	89,163	64,090
Paper	3,349	12,488	25,998	1,557	Civil	5,539	19,487	74,769	17,873
Print	11,092	34,706	15,012	2,262	WhSale	103,163	569,032	169,889	167,501
Coke	2,984	5,190	5,581	512	CatAcc	14,432	107,755	41,683	6,097
BasChem	3,852	8,785	15,100	1,032	TranspStor	14,996	113,474	51,779	95,785
OthChem	11,499	26,919	28,823	2,502	Com	9,806	46,215	24,646	3,001
RubProd	1,177	2,852	8,692	473	FinIns	52,991	133,239	7,289	30,805
PlastProd	5,280	12,795	38,995	2,123	BusServ	60,731	195,184	55,765	114,986
Glass	500	1,336	5,027	255	MedDent	34,099	36,183	1,569	11,884
NonMetMin	2,503	6,688	25,169	1,278	OthComServ	50,162	66,388	3,065	49,879
BasIrSt	4,839	13,203	21,549	1,473	OthProd	38,534	266,500	19,147	109,130
BasNFer	1,443	3,938	6,427	439					

Total number of workers employed:	
Highly skilled	1107836
Skilled	2729498
Semi-skilled and unskilled	3444628
Informal	1019922

Source; SAM 2001

1.3 THE DIFFERENT EXPORT DESTINATIONS, TYPES OF INVESTMENTS AND GOVERNMENT EXPENDITURES THAT ARE DISTINGUISHED WITHIN THE 2001 SAM.

1.3.1 Export destinations: Distinction is made between exports to East Asia and the Pacific, East and Southern Africa excluding the SADC, the SADC, Rest of Europe excluding EU, EU, NAFTA, Eastern Europe and Central Asia, West Africa, Middle East, Americas excluding NAFTA, North Africa, South Asia and unspecified export destinations.

1.3.2 Government expenditure: Distinction is made between general administration-, defence-, law and order-, education-, health-, social-, economic- and other expenditures.

1.3.3 Fixed investment: Distinction is made between investment expenditure of firms on non-residential property, construction, transport equipment, machinery, as well as the transfer costs that are associated with this type of expenditure. Household fixed expenditure is categorised into residential and transfer cost expenditure, while government fixed expenditure is categorised as residential, construction and investment expenditure on machinery.

As stated in Chapter 8, these individual export destinations, types of investment and government expenditures are aggregated into aggregated exports, government expenditure and fixed investment.

APPENDIX TWO:

ECONOMETRIC RESULTS FOR ELASTICITY ESTIMATION

2.1 RESULTS FROM THE ESTIMATION OF THE CES PRIMARY FACTOR SUBSTITUTION PARAMETER.

Table A2.1: Statistical results from CES parameter estimation

Industry	*Coefficient*	*t-statistic*	*ADF*	*Cusum²*	*R^2*
Agric	0.74	11.63	-4.30	Pass	85.06
Coal	0.38	9.36	-3.10	Pass	74.4
Gold	0.42	10.85	-3.18	Pass	90.8
Othmin	0.29	2.47	-3.77	Pass	85.0
Food	0.34	4.04	-5.05	Pass	95.5
Bev	0.28	2.34	-4.09	Pass	93.9
Tob	0.66	0.13	-3.24	Pass	48.5
Text	0.66	17.58	-2.58	Fail	91.15
Wear	0.78	22.85	-2.66	Pass	95.4
Leath	1.02	8.48	-3.64	Fail	79.6
Foot	0.81	12.83	-2.70	Fail	85.44
Wood	0.38	8.08	-2.79	Fail	68.5
Paper	0.36	8.05	-4.39	Pass	92.6
Print	0.61	21.15	-3.02	Pass	93.7
Coke	0.28	4.65	-2.41*	Pass	79.0
BasChem	0.83	9.50	-3.14	Pass	91.8
OthChem	0.27	2.30	-3.35	Fail	97.6
RubProd	0.85	10.06	-2.66	Pass	91.49
PlastProd	0.73	10.93	-3.91	Fail	95.65
Glass	0.72	10.68	-3.20	Fail	97.38
NonMetMin	0.69	4.03	-2.59*	Fail	87.26
BasIrSt	1.01	8.18	-3.18	Fail	96.98
BasNFer	0.81	4.57	-2.55*	Fail	97.39
MetProd	0.91	17.35	-3.36	Pass	92.24
Macheq	0.77	13.02	-2.99	Fail	88.32
ElecMach	0.66				
Telv	0.83	10.04	-3.35	Pass	
ProfEq	0.77	8.10	-3.81	Pass	77.7
MotVeh	0.66	1.43	-3.24	Fail	91.17
OthTrnsp	0.91	13.65	-1.87	Pass	49.97
Furn	0.58	5.12	-2.63	Fail	86.13
OthInd	0.66			Fail	59.14
Elect	0.26	12.91	-3.34	Fail	84.76
WatSup	0.173	3.76	-3.21	Pass	84.18
BuildCnst	1.05	23.85	-4.07	Pass	97.87
Civil	0.91	14.49	-2.91	Pass	94.4
WhSale	0.74	7.68	-2.93	Pass	66.29
CatAcc	0.5	3.08	-3.42	Pass	77.06
TranspStor	0.66	6.63	-3.44	Pass	98.6
Com	1.45	12.26	-3.70	Pass	97.86
FinIns	0.34	3.40	-3.32	Pass	27.86
BusServ	0.29	2.21	-3.49	Fail	87.28
MedDent	0.35	8.11	-3.53	Fail	98.12
OthComServ	0.66				
OthProd	0.66	205.03	-1.84	Pass	99.99

Source: Own calculations

2.2 STATISTICAL RESULTS FOR THE ESTIMATED ARMINGTON ELASTICITIES OF THE 45 SOUTH AFRICAN INDUSTRIES

Table A2.2: Statistical results from Armington parameter estimation

Industry	*Coefficient*	*t-statistic*	*ADF*	*Cusum^2*	*R^2*
Agric	0.318	1.99	-3.24	Pass	23.8
Coal	1.423	3.41	-2.01	Pass	58.6
Gold	No imports				
Othmin	NS	8.18	-1.45	Pass	10.43
Food	1.14	7.54	-3.57	Pass	77.7
Bev	0.68	5.06	-4.98	Pass	53.51
Tob	0.73	9.29	-4.91	Pass	75.32
Text	1.24	14.00	-3.14	Pass	87.77
Wear	0.68	7.33	-2.51	Pass	67.46
Leath	1.83	10.90	-2.94	Pass	92.31
Foot	NS	1.37	-1.03	Pass	27.72
Wood	0.37	3.11	-3.15	Pass	75.35
Paper					
Print	0.42	4.32	-3.38	Pass	32.45
Coke	0.47	1.97	-2.68	Pass	30.82
BasChem	0.56	6.07	-2.36*	Pass	90.44
OthChem	0.71	7.73	-2.76	Pass	96.07
RubProd	1.00	6.69	-3.58	Fail	94.70
PlastProd	NC	1.50	-1.22	Fail	6.99
Glass	0.35	8.88	-3.43	Pass	17.30
NonMetMin	NC	3.01	-1.63	Fail	29.20
BasIrSt	NS	1.90		Fail	31.25
BasNFer	NC	2.64	-1.28	Pass	35.40
MetProd	0.85	11.59	-5.18	Fail	83.91
Macheq	1.07	9.29	-4.02	Pass	84.18
ElecMach	NS	5.94	-2.93	Pass	53.35
Telv	0.91	5.24	-4.78	Pass	87.80
ProfEq	0.99	5.59	-3.24	Pass	53.65
MotVeh	0.71	4.73	-2.72	Fail	62.63
OthTrnsp	1.37	8.96	-3.27	Fail	76.94
Furn	0.75	2.80	-3.20	Pass	87.91
OthInd	0.43	3.02	-3.69	Pass	70.86
Elect	NS	-1.22	-2.25	Fail	6.41
WatSup	No imports				
BuildCnst	1.57	4.12	-3.02	Pass	36.15
Civil	2.84	7.58	-3.40	Pass	65.71
WhSale	NS	2.11	-1.93	Fail	12.95
CatAcc	NS	-2.78	-2.49	Pass	39.17
TranspStor	1.17	7.08	-2.20*	Pass	75.3
Com	NS	-2.95	-2.94	Pass	29.16
FinIns	NS	-0.70	-3.40	Pass	82.93
BusServ	0.98	6.13	-2.90	Pass	91.02
MedDent	1.05	3.57	-3.81	Pass	88.45
OthComServ	NS				
OthProd	0.65	6.22	-3.49	Pass	56.37

2.3 STATISTICAL RESULTS FOR THE ESTIMATED HOUSEHOLD EXPENDITURE ELASTICITIES OF THE 45 SOUTH AFRICAN INDUSTRIES

Table A2.3: Statistical results from household expenditure elasticity estimation

Industry	*Coefficient*	*t-statistic*	*ADF*	*Cusum*[2]	*R^2*
Agric	0.99	9.73	-3.70	Pass	93.2
Coal	1.72	7.20	-2.68	0	80.0
Gold	0	0	0	0	0
Othmin	0	0	0	Fail	0
Food	0.96	15.17	-2.75	Pass	91.22
Bev	1	8.44	-2.04*	Fail	93.54
Tob	-0.1	-2.55	-2.21*	Fail	71.90
Text	0.43	3.13	-2.19*	Pass	85.39
Wear	0.25	2.75	-3.88	Pass	86.57
Leath	0.42	1.48	-1.65	Fail	73.17
Foot	0.68	11.39	-1.26	Fail	82.57
Wood	0.65	3.98	-4.85	Pass	91.13
Paper	1.11	5.13	-2.43*	Pass	48.14
Print	0.75	13.67	-3.44	Pass	93.02
Coke	1.62	15.54	-4.59	Fail	91.91
BasChem	1.69	8.13	-3.24	Fail	74.89
OthChem	1.17	15.82	-1.97	Fail	93.17
RubProd	0.35	4.57	-2.52	Fail	43.52
PlastProd	0.71	5.07	-2.71	Pass	90.31
Glass	0.83	4.13	-2.88	Pass	90.18
NonMetMin	1.58	6.68	-1.87	Fail	95.26
BasIrSt	0	0	0	0	0
BasNFer	0	0	0	0	0
MetProd	0.86	8.68	-4.00	Fail	91.90
Macheq	0.72	4.37	-3.23	Fail	81.13
ElecMach	0.03	0.20	-2.13	Fail	86.93
Telv	2.24	8.51	-3.95	Fail	96.07
ProfEq	1.2	3.49	-2.32*	Fail	71.34
MotVeh	1.2	3.49	-2.32*	Pass	71.34
OthTrnsp	1.41	3.31	-2.45*	Pass	81.45
Furn	1.85	4.83	-2.24*	Pass	79.13
OthInd	0.19	2.26	-4.45	Pass	15.66
Elect	1.46	8.58	-2.87	Fail	96.83
WatSup	0.62	2.70	-2.90	Fail	51.39
BuildCnst	0	0	0	0	0
Civil	0	0	0	0	0
WhSale	0.81	18.49	-3.28	Pass	92.20
CatAcc	0.9	8.15	-2.33*	Pass	85.85
TranspStor	1.68	30.93	-1.97*	Fail	97.15
Com	2.31	22.29	-3.04	Fail	94.97
FinIns	1.84	10.93	-2.44	Fail	92.76
BusServ	1.28	8.20	-2.46	Fail	96.54
MedDent	1.83	20.96	-3.87	Pass	96.22
OthComServ	0.72	18.35	-2.25*	Fail	92.09
OthProd	0.72			Fail	

APPENDIX 3

A STYLISED MACRO MODEL WHICH IS USEFUL FOR ANALYSING RESULTS FROM A CGE MODEL SUCH AS ORANI

(Source: Adams, 2003)

Level equations:

$$Y^{MP} = C + I + G + (X - M) \quad (1)$$

$$Y^{FC} = F_Y(L, K) \quad (2)$$

$$Y^{MP} = Y^{FC} + Y^{TAX} \quad (3)$$

$$P^C C = P^{FC}_{GDP} Y^{FC} \times \Omega \quad (4)$$

$$\frac{C}{G} = \Gamma \quad (5)$$

$$M = F_M(Y^{MP}, RER) \quad (6)$$

$$X = F_X(-RER) \times Y_W \quad (7)$$

$$\frac{I}{K} = G_I\left(\frac{ROR}{ROR^{REQ}}\right) \quad (8)$$

$$RER = \frac{P^{MP}_{GDP}}{(\phi P_w)} \quad (9)$$

$$P^{MP}_{GDP} = P^{FC}_{GDP}(1 + T) \quad (10)$$

$$TOT = \frac{1}{\{F_{TOT}(X) \times P_W\}} \quad (11)$$

$$\frac{P^C}{P^{MP}_{GDP}} = \frac{1}{F_{PGDP}(TOT)} \quad (12)$$

$$\frac{K}{L} = F_{KL}\left(\frac{RP_L}{RP_K}\right) \quad (13)$$

$$RP_L^{S_L} = RP_K^{-S_K} \quad (14)$$

$$RP_L = F_{RP_L}\left(RW, \frac{1}{TOT}, (1 + T)\right) \quad (15)$$

$$RP_K = F_{RP_K}\left(ROR, \frac{1}{TOT}), (1 + T)\right) \quad (16)$$