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Efficiency and equity considerations in modeling inter-sectoral water demand in South Africa

By

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DECLARATION

I declare that this thesis which I submitted for the degree of Doctor of Philosophy (PhD) in Environmental Economics at the Department of Agricultural Economics, Extension and Rural Development, Faculty of Natural and Agricultural Sciences, University of Pretoria is original and has not been submitted by me for a degree at another university.

Signed:………………………………………………Date:………………………………..

James Sharka Juana

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This work is dedicated to the Strzepek family of Boulder, Colorado and to the loving memory of my late sister Sombo Miatta and my late parents Mr. and Mrs. Koroma Juana.

Efficiency and equity considerations in modeling sectoral water use in South Africa

By

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Department: Agricultural Economics, Extension and Rural Development

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ABSTRACT

Empirical studies have shown that while global per capita freshwater availability is declining, competition among production sectors for the withdrawal of this resource is rapidly increasing. This situation is exacerbated by the rapid population growth especially in developing countries, urbanization, industrialization, externality problems, environmental sustainability and the need to increase food production. At country specific levels, policies have been designed to institute water use efficiency, equity and sustainability. The need to promote sectoral water use efficiency from the demand-side management requires a study to investigate the responsiveness of different production sectors and sub-sectors to variations in water prices. In most instances however, efficient water allocation compromises social equity, especially in a country where there is widespread poverty and where the gap between the rich and the poor is so wide that policies aimed at promoting economic growth should be carefully investigated to find whether efficient water allocation can also address the issue of equity among the different population groups.

Review of empirical literature on the econometric approaches to sectoral water demand analysis shows that the agriculture sector has the least marginal value of water compared with the manufacturing, mining and services sectors. Based on this evidence it can be hypothesized that water reallocation from the agriculture to the non-agriculture sectors in South Africa can lead to growth in sectoral output.

However, in a country where there is a wide gap between the rich and the poor, equity issues are high on the development agenda. Therefore, the benefits derived from efficient water reallocation should be equitably distributed to improve the standard of living of the critical population. Hence, the second hypothesis is that water reallocation from the agriculture to the non-agriculture sector can lead to an increase in the income of the critical population. To investigate these hypotheses the study:

i) estimated the sectoral water demand functions and marginal values,

ii) used both social accounting matrix multiplier and computable general equilibrium analysis to investigate the impact of water reallocation from the agriculture to the non-agriculture sectors on output, factor payments on households' welfare and

iii) analyzed the households' welfare of the impact of global change on water resources in South Africa.

The study used the Global Trade Analysis Project (GTAP) and United Nations Industrial Development Organization (UNIDO) data, and adopted the marginal productivity approach, and the two-stage model to estimate the global sectoral water demand functions and marginal values for thirteen sectors.

This model is extended to the sectoral water demand analysis in South Africa. Thus, to validate the results of the global model, the study estimated sectoral water demand functions in South Africa by extracting data from STATSSA's census of manufacturing and agricultural and services activities, published for each of the nine provinces in South Africa and the 2002 water supply and use accounts published by the same institution. The study tests the policy relevance of the computed marginal values for South Africa by using these values to investigate the impact of reallocating water from the agriculture to the non-agriculture sectors on output growth, value added, employment and households' income generation.. To accomplish this objective, the study updates the 1999 social accounting matrix (SAM) for South Africa to reflect 2003 entries, computes the required multipliers and uses these to find how water reallocation on the basis of efficiency impacts sectoral output, households income generation and distribution. However, SAM multiplier analyses assume linearity, factor immobility and constant prices. The study therefore uses the computable general equilibrium analysis to investigate the households' welfare implications of sectoral water reallocation and reduction due to global change.

The SAM multiplier analysis shows that reallocation of water from the agriculture to the non-agriculture sectors leads to decrease in the output of the agriculture and the highly inter-dependent sectors. Specifically, output declines in the agriculture, food, beverages and tobacco and the services sectors, while it increases in the other sectors. However, if more than ten percent of the agriculture sector's water is reallocated to the non-agriculture sector, net output declines, implying that the decline in output in the agriculture, food, beverages and tobacco and services sectors is more than the increase in output in the other sectors. This has consequences for factor remuneration, employment and households' income.

The above decline in the agriculture sector's output leads to net job losses. Specifically the jobs lost in the agriculture sector are not countered by jobs created in the other sectors that benefit from the water reallocation. This is due to the fact that there are differences in skills requirements by the sectors. While the agriculture sector employs most of the unskilled workers, the other sectors require more medium and highly skilled individuals. This is reflected by changes in the wages paid to labourers. While the wages of unskilled labourers decline, there is an increase in the wages of medium and highly skilled labourers.

The simulation results of the computable general equilibrium analysis show that sectoral water reallocation and reduction adversely impact the least and low-income households' welfare, while improving the welfare of the high-income households. The interpretation is that with water reallocation or reduction, capital is substituted for water in the non-agriculture sectors and this increases the interest paid on capital, which goes to high-income households who are the owners of the capital. The adverse consequence can be reduced if food consumption by the poor households is maintained. To do this, some welfare measures are necessary. One such measure is the distribution of food stamps to the poor households.

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LIST OF ACRONYMS

Acronym	Meaning
AGI	Food, Tobacco and Beverage Manufacturing sector
AGR	Agriculture, Fishing and Forestry sector
CHM	Basic Chemical Manufacturing sector
CON	Construction sector
DWAF	Department of Water Affairs and Forestry
ELE	Electricity sector
ENG	Energy sector
FAO	Food and Agricultural Organization
GTAP	Global Trade Analysis Project
HEV	Metal Manufacturing sector
ISIC	International Standard Industrial Classification
MAC	Machinery and Equipment Manufacturing sector
MIN	Mining Sector
OHM	Other Manufacturing sector
PEC	Petroleum Extraction sector
PPP	Paper, Pulp and Publishing sector
SAM	Social Accounting Matrix
SARB	South African Reserve Bank
STATSSA	Statistics South Africa
SUR	Seemingly Unrelated Regression
TIPS	Trade and Industrial Policy Strategies
TXT	Textile, Leather Products and Wearing Apparel
UNIDO	United Nations Industrial Development Organization
WMA	Water Management Area

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

The world is currently facing severe and growing challenges to meet the rapidly growing demand for water resources. At the global level the average amount of water per person has substantially dropped from about 43 000 cubic meters per year in 1850 to about 9000 cubic meters per year in 1990 (Gleick, 1995). This results from the rapid population growth, which is not matched by an equivalent growth in the development of new water sources. New sources of water are increasingly becoming expensive to exploit; hence, the potential for expanding water supply has become limited. This problem is most visible in developing countries where national, regional and seasonal water scarcity poses a severe threat to economic development and poverty reduction. This threat is further exacerbated by the increasing cost of exploring new water supply sources, wasteful use of the already developed water supply, degradation of soil in irrigated areas, depletion of groundwater, water pollution, subsidies and other distorted incentives that govern water use, and inequitable access to water or its benefits by women, the poor and other disadvantaged groups (Rosegrant *et al*. 2002b).

The appropriate response to these threats requires the formulation of water management policies such that can maintain growth in agricultural production, facilitate the efficient and equitable inter-sectoral reallocation of water, reverse the ongoing degradation of water in irrigated land and water-related ecosystems, safeguard the rights and increase the incomes of the poor and socially excluded groups to the benefits from efficient water use and improve the effectiveness of water use in rainfed agriculture (Rosegrant *et al*. 2002a). These policy issues and concerns have led to water reforms in many countries.

1.2 ALTERNATIVE WATER ALLOCATION MECHANISMS

There are various strategies and principles used in allocating scarce water resources among the various sectors. Dinar *et al.* (1997) identified four major water allocation mechanisms which are generally practiced in different countries. These are marginal cost pricing, public allocation, water markets and user-based allocation mechanisms.

The first mechanism discussed by Dinar *et al.* (1997) is the marginal cost pricing, which involves an allocation strategy that equates the marginal value of water to the unit cost of water allocation. Sectors that have higher marginal values than the unit cost of water should be allocated more water than those with lower marginal values and higher unit costs of water supply. Economic efficiency or optimal water allocation is attained at the point where the ratio of the marginal value to the marginal cost (unit price) of water is the same for all sectors and is equal to unity (Beattie and Taylor 1993). This means that efficiency in inter-sectoral water allocation is achieved when the marginal benefit of a cubic unit of water is equal to the marginal costs of supplying that cubic unit. Although this mechanism is theoretically efficient and can easily be combined with pollution/effluent charges or taxes to solve the problem of externalities, it is difficult to define and correctly estimate the marginal costs of water allocation over time.

The second mechanism, which is the public water allocation strategy, is used when the state determines the quantity of water to be reserved for environmental sustainability and other priority use, while it allocates or distributes the balance water among different sectors of the economy. Public allocation mostly dominates industrial, municipal, agricultural and recreational sectors in many countries. The state's role is particularly strong in inter-sectoral water allocation as it is the only institution that has jurisdiction over all sectors of water use (Dinar *et al*., 1997). In addition to its objective of protecting the poor and the vulnerable population, sustaining environmental needs and providing a given level of water to meet minimal needs of the receiving sectors, public allocation also maintains prior legal rights which are based on historical facts. However, public water allocation can lead to waste and misallocation of water, and in many cases, does not support user participation. Most countries or river basins have some form of public allocation of water resources.

The third mechanism is the market-based allocation of water, which is referred to as "exchange of water-use rights". In a pure market-based allocation the demand for and the supply of water resources dictate the quantities to be traded as well as the unit price of water in the market. In such a situation water is reallocated from low to high marginal value uses; hence, makes the allocation mechanism efficient. However, market-based water allocation mechanisms sometimes require public intervention to define the original allocation of water rights, create the institutional and legal framework for trade and invest in the basic infrastructure to allow water transfers with low transactions costs.

The major advantage of the market-based allocation mechanism is the empowerment of water users to consent to any reallocation of water and compensation of any water transfer. This mechanism also induces water users to incorporate the full opportunity cost of water in their marginal cost analysis. It therefore allows users to easily and quickly respond to changes in commodity prices and water values. However, a purely market-based allocation mechanism often prices out of the water market the critical and most vulnerable population whose basic survival strategies depend on livelihoods that require the use of the resource.

The fourth mechanism, which is the user-based allocation, requires collective–action-institutions to make decisions on water rights. An example includes the former irrigation boards in South Africa. This mechanism's major advantage lies in its flexibility to adapt to water delivery patterns that meet local needs. On the one hand the allocation process becomes quite easy if those directly involved in water usage have adequate information on local conditions. On the other hand, the successful operation of user-based allocations depends on a transparent institutional structure, which may absent especially in developing countries.

All these four water allocation mechanisms aim at promoting economic efficiency, social equity and environmental sustainability.

1.2.1 Efficient water allocation

The allocation of an input is economically efficient if there is no other feasible allocation of that input that would make some sectors better-off without making others worse-off (Browning and Zupan, 2006). Hence, water allocation efficiency is a situation in which water is allocated among sectors, firms or individuals such that no further reallocation would provide gains in production or consumption to some firms, sectors or individuals without simultaneously imposing losses on others (Young 1996). Economic efficiency in water allocation or reallocation is also concerned with the amount of wealth that can be generated by a given quantity of water.

The equimarginal and the marginal cost-pricing principles are the two preconditions required to attain water allocation efficiency. The equimarginal principle requires that the marginal benefits of water should be the same for all users or sectors (Agudelo, 2001). Thus efficient water allocation means that the benefits from using an additional cubic unit of water in one sector should be the same for all the sectors. Once this is achieved, further redistribution of water resources can make no sector better off without making another worse off. The implication of this principle is that resources should be allocated in such a way that all the users and consumers derive equal value in using additional units of the resource.

The marginal cost-pricing principle requires that the benefits derived from the use of an additional unit of water should be equal to the cost of supplying the same unit of water. This means that the unit price of the resource should be the same as the marginal value of that resource. Thus, to efficiently manage a given quantity of water resource, it should be provided at the lowest cost and allocated in a way that makes the marginal benefits of users equal in all the economic sectors of a country, region or water management area (DWAF, 1998). Under efficiency consideration more water should be allocated to the sectors with higher marginal values of water than those with lower marginal values.

1.2.2 Equity

Equity objectives are particularly based on the principle of fairness of allocation across different economically diverse groups in the population of a country or water management area. This may not be compatible with the efficiency objective. Equitable water management requires that everyone has equal access to sufficient and affordable safe water to meet their basic needs or to the benefits generated from the use of a specific water resource (DWAF, 1998). This means that water allocation or reallocation should not only be concerned with deriving maximum benefits from the use of the resource, but also with how the allocation process improves the standard of living of the most vulnerable population. Most of the studies that have discussed the issue of equity in the past have concentrated on equity in access to water, which in most cases compromises the efficiency considerations of water allocation. Equity to the benefits from the use of the resource also needs considerable attention as a viable alternative to equity in access.

1.2.3 Sustainability

A sustainable water management strategy entails the use of the resource such that the resource stock is not depleted and that sufficient water is reserved for environmental needs. This may also be referred to as inter-generational equity where in the current generation's use of water resources or the benefits derived from using it does not compromise the future generations' use of the resource or its perceived benefits.

The attainment of efficient, equitable and sustainable water management requires weighing up the different social, economic and environmental objectives in the water management area.

1.3 WATER ALLOCATION REFORM IN SOUTH AFRICA

South Africa is in the process of implementing water reforms outlined in the 1998 National Water Act (DWAF, 1998). This legislation is internationally recognized as the most promising legal framework to address the country's water management problems. The framework is intended to repeal the 1956 Water Act which was based on the riparian principle, in favour of one that recognizes water as a national asset. DWAF (2005) stipulates the principle that "the national government is the custodian of the nation's water resources, as an indivisible national asset, and has ultimate responsibility for, and authority over water resource management, the equitable allocation and usage of water, the transfer of water between catchments and international water matters". This statement shows that South Africa has public inter-sectoral water allocation mechanism, based on the principles of efficiency, equity and sustainability. The framework for water allocation reform in South Africa provides detailed strategies and approaches to promote equity, sustainability and efficiency in water use. It recognizes that there are still significant inequities in access to and use of the country's water resources, as well as inequities in the distribution of the benefits that accrue from water use. The implementation of water allocation reform is designed to support government's poverty eradication strategies and economic development objectives (DWAF, 2005). The strategies for and objectives of water reforms in South Africa have been formulated into guidelines and approaches which are discussed below.

1.3.1 Guide lines for water allocation reforms in South Africa

The South African Department of Water Affairs and Forestry proposed in 2005 that water allocation process should:

i) Primarily redress the past imbalances in water allocations to the Historically Disadvantaged Individuals (HDI). This means that priority should be given to the poor and less privileged in the allocation of the available water resources.

ii) Have capacity-building programmes that support the use of water to improve livelihoods and to facilitate the productive and responsible use of water. This implies that both equity and economic growth objectives should be simultaneously addressed in the water allocation process.

iii) Contribute to the broad-based-black economic empowerment and gender equity, by facilitating black and women-owned enterprises access to water.

iv) Respond to local, provincial and national planning initiatives, and South Africa's international obligations and regional SADC initiatives. South Africa is a vast country with huge differences in regional water availability. It also has shared rivers. These regional differences and commitments to international obligations in allocating water resources must be taken into consideration in water resource management.

v) Be undertaken in a fair, reasonable and consistent manner, such that the existing lawful uses will not be arbitrarily curtailed.

vi) Give effect and support to the protection of water resources as outlined in the National Water Act, by promoting the phased attainment of both developmental and environmental objectives.

vii) Introduce innovative mechanisms that can reduce the administrative burden of authorizing water use, while still supporting its productive uses, and the effective management and protection of water resources (DWAF, 2005)

In summary, the guidelines for water allocation among the different sectors and users in South Africa are meant to promote efficiency, equity and sustainability.

1.4 PROBLEM STATEMENT

Water scarcity is increasingly becoming a pressing problem in developing countries. The demand for the world's water resources is rising rapidly, challenging its availability for food production and putting global food security at risk. Agriculture, upon which the majority of the world's population depends, competes with industrial, mining, domestic and environmental uses of the scarce water supply (Rosegrant *et al.*, 2002a). With increasing population growth, urbanization and the need to increase agricultural production, the demand for the scarce water resources is raising a growing concern about increasing the efficiency of water use. The number of countries facing the problem of water scarcity and insufficient water supply is rising. At the global level, while per capita availability of water is declining, water withdrawals are projected to increase more rapidly especially in developing countries (Webb and Iskandarani, 1998; Rosegrant *et al*., 2002). Therefore, the concept of water scarcity has received considerable attention in the last decade (Seckler *et al.*, 1998).

Generally, water scarcity raises two critical questions for development policies: i) to what extent can water resources be efficiently, equitably and sustainably allocated and used? and ii) what are the possible ways or means by which water scarcity can be alleviated or mitigated in support of further development? The answers to these questions will provide essential tools for water managers to design appropriate water development policies and allocation strategies. Previously, much concern has been about the agricultural (irrigation) sector to use water efficiently and release more water for other inter-sectoral needs. With the increasing concerns about the growing demand for water given the projected inelastic supply of the resource, efficient water use is now viewed as an inter-sectoral phenomenon, which can only be addressed from an integrated water resource management perspective.

In South Africa, as the economy grows, the competition for water among agriculture, mining, industry, domestic and environmental uses increases, while the long-run supply of water is projected to be inelastic. The rapid increase in the demand for water also increases externality problems. These factors increase the value of water; hence, the benefits from efficient water allocation among the user sectors. In the past, while attention was mainly focused on the development of new water resources, the efficiency and equity considerations were not given much attention as a viable alternative strategy to solving the problem of water scarcity. With the current water situation, the Department of Water Affairs and Forestry is looking for ways to ensure the most beneficial utilization of water in the country. These include the reallocation of water from lower to higher-value uses over time. Thus, the benefits from and the necessity of demand-side water management has significantly increased in importance.

While irrigation water requirements in South Africa account for about 62 percent of the total water requirements, agriculture accounts for less than four percent of the gross domestic product (GDP), and employs about 11 percent of the total number of employees in the country. Conversely, the mining and manufacturing sectors, which contribute about eight percent and 23 percent respectively to the GDP and employ about seven per cent and 19 percent of the total number of employees, account for only 15 percent of the total water requirements. Urban water requirements account for 25 percent of the total water use in the country (DWAF, 2004). Thus, there is an economic reason to reallocate water from agriculture to the non-agriculture sectors to promote sustainable economic growth and employment in the country.

From the economic perspective, the issue of reallocating water from low to high-value uses often emerges as rational under efficiency considerations. In most cases however, efficiency considerations alone fail to consider the backward and forward linkages among sectors, primary factors of production and institutions and the other non-economic uses of water, which if incorporated into the valuation framework addresses the issues of equity and sustainability. The question therefore is, not only how much does a particular sector contribute to the GDP, but how can a given quantity of water be used such that the standard of living of the critical mass of people is improved, both in the short and long-run. This addresses the issue of efficiency as well as equity and sustainability; hence, justifies the inclusion of social and environmental values of water into the economic valuation framework.

A number of studies in South Africa have tried to estimate the value of water in different sectors. Louw (2001) evaluated the impact of a potential water market on the efficient utilization of water in the Berg River basin. The study used a mathematical programming model to determine the true value of water. The estimated figures showed significant differences in the marginal value of water in different locations in the basin. However, the study estimated the marginal value of water for all industrial activities as a single sector. Therefore, the estimated marginal values for industries cannot be used as reliable base for workable policy decisions, because the demand for and the value of water vary from one industrial sub-sector to the other. For example, demand for or the value of water in agro-based industries (food and beverage manufacturing) is quite different from that of vehicle manufacturing.

In a different study, Farolfi and Perret (2002), through the use of standard environmental economics and an agent based simulation model analyzed the impact of reallocating water from farmers to mining sector in the Steelport sub-basin of the Olifants. While the study's use of a simple model is highly recommended for policy purposes, the use of only two sectors (irrigation and mining) when other sectors like different industrial sub-sectors, construction and services exist in the same study sub-basin is a major limitation. The model also used restrictive assumptions about water demand and output supply behaviour of competing users. In a related study, Hassan and Farolfi (2005) improved the initial model, by including industries and taking into consideration the ecological reserve. However, the study did not still consider the economy-wide benefits of water, which include the forward and backward linkages among the sectors as well as feedbacks from institutions. A recent study by Moolman *et al*. (2006) estimated the marginal revenue function of water for six irrigated crops in South Africa. The findings indicate that there are differences in the marginal revenue for different irrigated crops and in different locations and that the estimated marginal revenues can be used for intra-sectoral water allocation policies. While this is a good development in water management studies, focus on only a few crops and one production sector limits the policy relevance of the study. All the above studies contributed to the literature in water resources research in South Africa, but neglected the economy-wide contributions of inter-sectoral water use in the country.

Hassan (2003) estimated the economy-wide benefits from water-intensive industries in the Crocodile River Basin, using a quasi-input-output analysis. The study analyzed the contribution of irrigation agriculture and cultivated plantations in the Crocodile Catchment. While the study made a useful contribution to the understanding of water's contribution to economic development at a river basin level, the analytical framework was limited to the primary production impacts. Issues such as the contribution of water to household income generation, employment and output beyond the primary production sectors are not addressed in a traditional input-output analysis. Hence, this approach understates the full potential contribution of water to economic development and changes in households' welfare. Also, the study focus on the agricultural sector alone, while excluding other vital sectors like industrial sub-sectors, mining and the services sectors, which contribute more to the GDP and employment in the country's economy than agriculture, is major limitation to the policy relevance of the study.

The gaps and limitations of the above studies and the need to include feedback from factor inputs, institutions and the rest of the world in an analytical framework that assesses the economy-wide contribution of water to economic growth, poverty reduction and redressing the racial and income disparities in South Africa, necessitate a study that can include all the major production sectors and sub-sectors into the economy-wide water valuation framework. These issues and concerns require a detailed modeling technique that critically analyzes the structure of sectoral water uses in South Africa, with the view to recommending policies that maximize economic and social welfare benefits in the country. However, to effectively accomplish such a study, there is the need to understand the inter-sectoral demand for and the marginal value of water at both global and country specific levels, hence, the inclusion of global sectoral water demand estimation as the springboard for the country-specific water demand analysis.

1.5 THE OBJECTIVES OF THE STUDY

This study is designed to analyze the global and country specific (South Africa) sectoral demand for water and to analyze the efficiency and equity effects of inter-sectoral water reallocation strategies/ mechanisms based on the estimated marginal values in South Africa. Specifically, this study is designed to:

i) estimate the global and South African sectoral water demand elasticities and marginal values,

ii) update the existing South African social accounting matrix (SAM) and use the SAM approach to analyze the contribution of water to various inter-sectoral activities,

iii) using the market water allocation mechanism, investigate the impact of different sectoral water reallocation scenarios on households' welfare in South Africa.

iv) using the computable general equilibrium approach investigate the impact of global change on households' welfare in South Africa and

v) based on the simulation results, recommend policies that would promote water use efficiency and equity in South Africa.

1.6 HYPOTHESES TO BE INVESTIGATED

Various econometric studies have been carried out to investigate the relationship between water use as an intermediate input and sectoral output. The estimated results of these studies suggest that sectoral water demand is price elastic (Rees, 1969; Turnovsky, 1969; DeRooy, 1974; Grebenstein and Field, 1979; Babin *et al.*, 1982; Renzetti, 1988; Renzetti, 1992; Renzetti, 2002; Wang and Lall, 2002; Renzetti and Dupont, 2003). Empirical studies also show that water contributes positively to sectoral (Renzetti, 1988; Renzetti, 1992; Farolfi and Perret, 2002; Nieuwoudt *et al*., 2004; Hassan and Farolfi, 2005; and Moolman *et al*., 2006). The empirical evidence from these studies suggests that sectoral water allocation is efficient when water prices reflect the sectoral water marginal values of water. The empirical findings of Wang and Lall (2002) indicate that the agriculture sector has the least marginal value of water compared with the manufacturing, mining and services sectors. Based on this evidence it can hypothesize that water reallocation from the agriculture to the non-agriculture sectors in South Africa can lead to growth in sectoral output.

However, in a country where there is a wide gap between the rich and the poor, equity issues are high on the development agenda. Therefore, the benefits derived from efficient water reallocation should be distributed such that improve the standard of living of the critical population. Hence, the second hypothesis is that water reallocation from the agriculture to the non-agriculture sector can lead to an increase in the income of the critical population

The study estimates the sectoral price elasticities and marginal values of South Africa, updates the 1999 social accounting matrix for South Africa and uses both SAM multiplier and computable general equilibrium approaches to investigate how water reallocation from the agriculture to the non-agriculture sectors affects output growth, value added, job creation, and income generation and distribution among the income-stratified households.

1.7 OUTLINE OF THE STUDY

Chapter two provides a brief review of methodologies used in the economic valuation framework for water resources, while chapter three analyzes the global inter-sectoral water demand. In chapter three, the output elasticity, marginal value and price elasticity of water are computed for agriculture, mining, energy, manufacturing sectors. Since water use in the manufacturing sector differs for different manufacturing activities, this sector is divided into sub-sectors. The study uses the GTAP and UNIDO data to econometrically determine the demand functions for the different sectors.

In chapter four, the global model is validated by using data from the census of manufacturing and agricultural activities, and water resource accounts compiled by STATSA (2004) and the time series data on manufacturing and agricultural activities, compiled by Trade and Industrial Policy Strategy (TIPS) for South Africa. The sectoral demand for water is further analyzed at the regional level to examine the extent to which sectoral marginal values of water differ from one region to the other. This is followed by updating the 1998 social accounting matrix developed by Thurlow and van Seventer (2002), to have 2003 entries and to replace the water accounts with the STATSA's 2004 water supply and use account for south Africa.. These data are used in chapter five to compute the coefficient matrix and multipliers, which are used to analyze the contribution of water to the economy and to assess the impact of sectoral water reallocation based on marginal values on inter-sectoral output growth, factor payments, job creation and household income generation in South Africa. In chapter six, because SAM impact analysis usually overstates or understates the simulation results, the study uses the computable general equilibrium analysis (CGE) to investigate the impact of global change and water reallocation from the agriculture to the non-agriculture sectors on households' welfare.

Chapter seven presents summaries of the empirical findings in the previous chapters and discusses some policy implications of these findings. It provides a brief general conclusion and highlights the areas for further and future investigation.

1.9 LIMITATIONS OF THE STUDY

The major limitation of this study is the unavailability of regional or basin level social accounting matrices in South Africa, because it is difficult to construct basin level SAMs for the nineteen water management areas within a short period. The water situation in South Africa varies from one catchment to the other. Analyses at the national may overstate or understate regional or basin level situations. For example, while mining may be an intensive water user in one catchment, in another catchment it might be agriculture or manufacturing. However, national level analyses are used as broad examples to show how reallocation of water from one sector to another on the basis of sectoral marginal productivity of water may not always simultaneously address efficiency and equity objectives.

Another limiting factor, which might affect the results, is the aggregated nature of the agriculture sector. Agriculture, forestry and fishing are aggregated into one sector. There is the need to disaggregate this sector to rainfed and irrigated agriculture, plantation and wild forestry. For effective policy implementation, there is the need to understand the value of water in these sub-sectors as in the disaggregated manufacturing sub-sectors.

CHAPTER TWO

ECONOMIC VALUATION OF WATER RESOURCES: AN OVERVIEW OF METHODS AND APPLICATIONS

2.1 INTRODUCTION

Water resources, like other natural resources are limited in supply. Studies show that at the global level, per capita water availability is declining due to population growth, urbanization, industrialization, climate change and poor governance. Additionally, the nonagricultural (domestic, industrial and environmental) demand for the scarce water resource is rapidly increasing (Rosegrant *et al.* 2002c). In the past, the need to meet the growing demand for scarce water resources was solved in part, by new investments in irrigation and water supply systems and through improved water management (Rosegrant 2003). Thus, the supply-side management of water resources received considerable attention in meeting the growing demand for scarce water resources. However, because of the rapid growth in the demand for water and the dwindling per capita water availability, investment in new water infrastructure and the heavy reliance on groundwater sources have become expensive. So water supply is projected to be inelastic in the future, due to the limitations put on the potential for expansion of new water supplies (Rosegrant and Cline 2003). Therefore, the switch from supply-side to demand-side management is now viewed as a viable option in water management policies. To efficiently institute demand-side management of the exiting water sources, users should pay its fair price, which reflects the scarce nature of the resource. Prices which reflect the marginal value of water are assumed to institute allocative efficiency of water use. With this development, water pricing policy is now viewed as an effective tool which can be used to stimulate socio-economic development. Nonetheless, there are major controversies over the socio-economic methods used to estimate inter-sectoral water prices, either because of distortions in water markets due to government intervention, or because existing prices do not reflect the scarcity value of the resource. Therefore, this chapter is designed to describe and analyze some of the existing methods of estimating the value of water in inter-sectoral economic activities. Agudelo (2001) categorized water valuation methods into three:

i) methods that infer value from information regarding markets of water and water-related benefits

ii) methods that estimate values from the derived demand for water, where water is used as an intermediate good, and

iii) methods that estimate the value of water from a direct consumer demand, as in the case where water is used as a final good.

As a market good, value is derived from rentals and sales of water rights or land in case of a riparian ownership of water. As an intermediate good, value is derived from the producers' demand function, residual imputation, value added or alternative costs of water use. If used as a final private good, the value of water is determined from the consumers' demand function. If water is used as a public final good, its value is derived from the embedded travel costs or as bundle of other goods in a hedonic property value or the use of contingent valuation method to determine the value consumers place on the its use (Agudelo 2001). This study focuses on the use of water as an intermediate good, used as an input in the production of other goods and services. It also attempts to analyze the benefits of inter-sectoral water use in a country where water markets are ill-defined and prices are distorted, because of government intervention or because of the absence of completely defined user rights.

When used as an intermediate good, the value of water must be assessed from the producers' point of view. The conceptual valuation framework for the welfare benefits of increases or decreases in water use is provided by the producers' demand for inputs, including water. The following valuation methods are among the many that could be used to assess the value of water as an intermediate input in an ill-defined or dysfunctional water market: i) estimating the producers demand function, ii) the residual imputation method, iii) the value added method and iv) the alternative cost method. Each of these methods is discussed in turn in the succeeding sections.

2.2 ESTIMATING THE PRODUCERS' DEMAND FUNCTIONS FOR WATER

In this approach, water demand function can be deduced from historical water use statistics or calculated from the analysis of optimum water consumption patterns, by mathematical programming to determine the schedule of increases or decreases in net income accruing from changes in the level of water use (Agudelo, 2001). From the estimated demand curve, the quantity of water demanded can be determined. If there are any changes in the level of water consumption, the area below the curve for the specified increase in the quantity of water demanded represents the maximum amount the producer is willing to pay to obtain the resource input. Where no information about the entire demand function exists, the price of water is used as the best estimate of the maximum willingness to pay for unit increase in the level of water use. The slope of the demand curve shows how the producer adjusts to changes in water price and this price indicates the marginal benefits of water use to the producer.

In estimating the producers' demands function, other variables such as the prices and quantities of other inputs are included. These variables generally cause the demand curve for water to shift over time, because the demand for water depends on the degree of variability in the demand for other inputs. The various methods that can be used to estimate the producer's demand function include the production function, assumed price elasticity, econometric modeling and mathematical programming.

2.2.1 Production function approach

In this approach the functional relationship between output and all the inputs including water is estimated.

$$Y = f(K, L, N, I \ldots, W) \tag{2.1}$$

Where Y is output, K is capital, L is land, N is labour, I is any other intermediate input except water and W is water. In an attempt to maximize profits, the producers select inputs such that the value of the marginal product is equal to the price of the product. That is;

$$P_K = P_Y x \frac{\partial Y}{\partial K}, \quad P_L = P_Y x \frac{\partial Y}{\partial L}, \quad P_N = P_Y x \frac{\partial Y}{\partial N},$$
$$P_I = P_Y x \frac{\partial Y}{\partial I}, \; P_W = P_Y x \frac{\partial Y}{\partial W} \tag{2.2}$$

The above implies that the level of water W is increased until the value of the additional unit of water used ($P_Y x \frac{\partial Y}{\partial W}$) just equals the cost of using an additional unit of water (P_W). Optimum condition requires that this must hold for all the inputs used and that the ratios of the marginal value to the marginal cost of an input must be the same for all inputs. As one of the main empirical estimation methods used in the study, this method will be fully discussed in chapter three.

2.2.2 Assumed price elasticity approach

This method assumes that the price elasticity of water is constant over a time and space. With constant elasticity, if the initial price (P) and quantity (Q) of water are specified, and assuming that the quantity of water changes to (Q_1) in response to a change in price from P to P_1, then the relationship between percentage change in the quantity of water demanded and the percentage change in the price of water could be integrated to obtain a demand function/curve for water within the specified range (Agudelo, 2001 and Young, 1996).

$$\int \frac{dP}{P} = \frac{1}{E}\int \frac{dQ}{Q} \Rightarrow \ln P = \frac{1}{E}\ln Q + C \qquad (2.3)$$

By taking the exponentials of both sides of equation 2.3 and setting the constant, the equation becomes;

$$P = P_1 \frac{Q_1^{1/E}}{Q^{1/E}} \qquad (2.4)$$

Therefore, the benefit gained by increasing the quantity of water used in response to an increase in the price of water is computed as;

$$B = \int_{Q_1}^{Q_2} PdQ = \int_{Q_1}^{Q_2} P_1 Q_1^{1/E} \frac{dQ}{Q_1^{1/E}} \qquad (2.5)$$

$$B = \frac{P_1 Q_1^{1/E}}{1 - \frac{1}{E}} \left[\frac{Q_2}{Q_2^{1/E}} - \frac{Q_1}{Q_1^{1/E}} \right] \quad (2.6)$$

If the assumed elasticity is not equal to unity, the integration becomes:But if the assumed elasticity is equal to unity, then the integration becomes:

$$B = P_1 Q_1 \ \ln \frac{Q_2}{Q_1} \quad (2.7)$$

Equations 2.6 and 2.7 represent the area under the demand curve for a change in the quantity of water demanded from Q_1 to Q_2, which is the value of incremental change in quantity of water demanded. King (2002) in Blignaut and de Wit (2004) used the constant elasticity concept to estimate the demand for, and the marginal value of domestic water use in South Africa.

The assumption of constant elasticity of water demand or supply over a period of time has been criticized. Water is an intermediate good used in the production of other goods and services. Therefore, the demand for water is dependent on the demand for the final goods or services produced. As such, assuming constant elasticity for a good that has a derived demand may be unrealistic and does not make economic sense (Kindle and Russel, 1994)

2.2.3 Econometric approach to estimating water demand functions

The econometric approach to estimating water demand functions involves making inferences from actual observation on quantities used and prices of water, along with corresponding data on other explanatory variables (Renzetti 2002; Agudelo 2001; Young 1996). In addition to the price of water, the prices of the other factors of production, type of technology, product mix and output levels are also required for a sound econometric modeling technique.

Many empirical studies apply econometric modeling techniques to estimate water demand functions for domestic, agriculture, industry and mining water uses. Earliest econometric methods used in modeling the demand for industrial water use focused on the estimation of single-equation demand functions/curves. Turnovsky (1969); Rees (1969) and DeRooy (1974) were among the first set of studies to estimate the demand for water use by the manufacturing sub-sectors. These studies estimated the single equation water demand functions, in which the ratio of total expenditure to the total quantity of water purchased was used as a proxy for water price. The use of average price as a proxy for water price is not consistent with economic theory. In optimum decision-making, firms equate marginal value to marginal cost (price) of inputs. Also the use of single demand equation to represent the demand function for all the categories of industries might be misleading. Some industries can treat and recycle water, while others often rely on freshwater intake for their production activities. The structure of water demand in different industries depends on the type of activities. For example, beverage industries use more freshwater and recycle less than electro thermal industries.

Subsequent studies extended the analyses of industrial water demand to the use of the cost function duality approach. The approach assumes that an industry’s productive technology can be represented by the cost function. Therefore, it uses the Cobb-Douglas’ cost function to estimate the derived demand functions for industrial water use (Nerlove, 1965). This approach assumes that manufacturing firms choose input levels to minimize their costs of production and use the estimated cost function to derive the input demand functions, from which the own and cross price elasticities of demand for the inputs can be computed. The Cobb-Douglas' production function is frequently criticized for its imposition of constant returns to scale, which violates the law of diminishing marginal returns and the assumption of strict separability of inputs (Beattie and Taylor, 1993).

An alternative to the Cobb-Douglas' cost function is the translog cost function which introduces flexibility in the returns to scale. This relaxes the constant returns to scale constraint imposed by the Cobb-Douglas' cost function. It also introduces weak separability of inputs and uses the dual approach in which production technologies are represented by multi-output cost functions.

Grebenstein and Field (1979) and Babin *et al.* (1982), used the translog cost functions to estimate the American manufacturing industries' demand for water using state-level cross-sectional observations. Renzetti (1988) used the Cobb-Douglas' cost function via the two-stage least squares approach to estimate the water demand by manufacturing firms in Canada; and Renzetti (1992) used the translog cost function and three-stage least squares approach to estimate the price effect of intake, treatment and recycled water use in the Canadian manufacturing industry.

As with the single equation estimation, the major flaw of this method is its use of average cost as a proxy for the price of water. Wang and Lall (2002) used the translog production function, via the seemingly unrelated regression (SUR) procedure to estimate the demand for industrial water use in China. The authors developed a model, which used the marginal value of water as a proxy for the price of industrial water. Generally, the results of these studies indicate that although the marginal value of water in industries is high, the demand for the input by the manufacturing firms is less responsive to changes in water prices.

2.2.4 Mathematical programming approach

The mathematical programming approach follows the linear programming model, which is an optimization model that combines unit processes of water utilization systems in the form of linear inequalities. The variables are the levels of the systems' operations and the inequalities express constraints of the overall system (Kindler and Russell, 1984; Carmichael and Strzepek, 1987). These models are developed to represent the optimum allocation of water and other inputs so as to maximize profits, subject to constraints on resource availability and institutional capabilities. The procedure usually follows the construction of a flow diagram of sectoral activities, linking up the components of the flow diagram, algebraically formulating linear inequalities and constraints, and estimating the coefficients of the decision variables. This approach articulates the links between water input alternatives, their prices, other input choices and output, and identifies the best or optimal input strategies or the profit maximizing production path that could be followed by firms. In effect, it identifies the most efficient water utilizing options by the production sectors in terms of cost effectiveness and output maximization. The objective function for a mathematical programming model is usually written as;

$$\begin{aligned} &\max \; f(\pi, X) \\ &\textit{subject to} \;\; A' X \leq B \end{aligned} \tag{2.8}$$

Where 'π' represents the net return per activity, 'X' is a vector of production activities, the elements of the 'A' matrix are the production coefficients and 'B' is the vector of production inputs such as labour, capital, natural resources including water, intermediate inputs and so on (Young 1996). The parameter 'π' is a measure of the marginal return to water in activity 'X'. The use of mathematical programming is quite advantageous in a situation where a wide range of technological options is to be studied. In such a situation, it is important that the marginal productivity, which is represented by the net profit coefficients, is accurately calculated. However, this valuation method requires detailed data at the firm/industry level and is most suitable for the individual sector or country level inter-sectoral water use analysis; but it is expensive and time consuming. Carmichael and Strzepek (1988) explained the use of mathematical programming in modeling and forecasting industrial water use and treatment practices.

2.3 THE RESIDUAL IMPUTATION METHOD

This method requires the subtraction of the economic cost of all the other production inputs except water from the sales revenue. The difference becomes the value of water in the production of commodity.

In the case where just one commodity is produced, the use of the residual imputation method is based on the theory that the sales revenue exactly equals the total cost of production. This implies that the sales revenue (price multiplied by the quantity sold) exactly equals the sum of the inputs used, multiplied by their respective prices. This relationship is expressed below as:

$$PQ = \sum K_i N_i + WP_w \qquad (2.9)$$

Where 'P' is the competitively determined commodity prices, 'Q' represents the quantity of the commodity produced and sold, while 'K_i' is a vector of competitively determined prices (equal to the marginal value product) of non-water factors, and 'N_i' is a vector of non-water inputs employed in the production process and 'W' and 'P_w' are the quantity and price of water respectively. If all the inputs, including water are exchanged in a competitive market and employed in the production process, the value of water (price multiplied by its volume used) will be;

$$WP_w = P_i Q_i - \sum K_i N_i \qquad (2.10)$$

This method can be extended to a multi-input and multi-product situation, in which different sectors compete for the use of the scarce resources (production inputs) and sell their products in a non-differentiated market. This implies that the firms are in perfect competition. The residual value of water in the i^{th} sector producing the j^{th} commodity is;

$$W_{ij} P_{w_{ij}} = \sum_{i=1}^{n} P_{ij} Q_{ij} - \sum_{i=1}^{n} W_{ij} N_{ij} \qquad (2.11)$$

Renwick (2001); Hussain *et al.* (2000) and Bakker *et al.* (1999) used this method to estimate water productivity in irrigated agriculture and reservoir fisheries. Renwick (2001) used the concept expressed in equation 2.11 to estimate both the implicit and explicit costs of securing water and the scarcity value of the resource use. Thus equation 2.11 can be broken into:

$$W_{ij}(P^* + \lambda) = \sum_{i=1}^{n} P_{ij} Q_{ij} - \sum_{i=1}^{n} W_{ij} N_{ij} \qquad (2.12)$$

Where 'P*' reflects both the implicit and explicit costs of securing water and 'λ' reflects the scarcity value of the resource use, hence:

$$P^* + \lambda = \frac{\sum_{i=1}^{n} P_{ij} Q_{ij} - \sum_{i=1}^{n} W_{ij} N_{ij}}{W_{ij}} \qquad (2.13)$$

However, Young, (1996) cautioned that the residual imputation method is only valid if i) all inputs and outputs are exchanged in markets that are both competitive and unregulated and ii) the production function is 'well behaved'.

Using the residual imputation method, Renwick, (2001) calculated the shadow price of water and by using discounting method, estimated the present value of water in irrigated agriculture and reservoir fisheries in Sri Lanka.

2.4 VALUE ADDED APPROACH

This approach could be used in any situation that requires the estimation of economic benefits derived from the use of water as an intermediate input in sectoral production activities. Value added refers to net payments to the primary factors of production such as wages and salaries, rents and other natural resources, interest or depreciation on capital. Value added is measured on a sector-by-sector basis through an input-output model representing the economic structure of a country, region or water management area. The framework of the input-output model, which is a static model, is used to estimate the direct and indirect impacts. This framework based on the linear structure of inter-industry production linkages, pioneered by Wassily Leontief in the 1930s. In it, the total input requirements matrix, also known as the coefficient matrix, is computed. The input-output coefficient matrix is used to calculate the direct and indirect intermediate inputs requirements per extra unit of output or value added in a specific sector. This coefficient matrix, which is also referred to as the Leontief inter-industry transactions matrix, defines the amount of the output from each production sector which is required as an intermediate input used to produce a unit of an output in a specific sector. The model illustrates the interdependence nature of the production sectors in an economy, hence the inter-sectoral forward and backward linkages. With the incorporation of water into the inter-sectoral production framework, the input-output model can be used to investigate the economy-wide contribution of water to inter-sectoral production activities and the impact of investment in water infrastructure on output growth and value added. It can also be used to evaluate the economy-wide impact of inter-sectoral water pricing, re-allocation and other managerial policies. Hassan (2003) used a quasi-input-output model to analyze the contribution of irrigated agriculture and cultivated forestry in the Crocodile River in South Africa. Despite its advantages, its ability to capture the forward and backward benefits of inter-sectoral activities, the use of the input-output model has been criticized for its exclusion of institutional framework inherent in an economy. It significantly fails to account for the equitable distribution of benefits derived from production activities.

To adequately address these limitations, the input-output or the Leontief model can be extended to the social accounting matrix (SAM) model by the inclusion of most of the final demand sector into the endogenous accounts. This inclusion facilitates the computation of an extended Leontief inverse, which aims at incorporating the feedbacks from rents to consumption, to new production that originates from an exogenous flow (Boughanmi *et al.,* 2002; Juana, 2006; Juana and Mabugu, 2005 and Sadoulet and de Janvry, 1995). From the coefficient matrix both the input-output and the SAM based production multipliers can be computed. Economic multipliers estimate the economy-wide impact of exogenous changes in related economic variables or policies in a specified economy. Four types of multipliers can be found in existing literature: the direct, indirect, induced and total impact multipliers. These are fully discussed in chapter five. These direct and indirect impacts of exogenous changes in final demand on output, employment and income are measured both in aggregate terms and for each sector of an economy. Kumar and Young (1996) incorporated water supply and demand functions into SAM framework for Thailand and investigated the economy-wide impact of water pricing policies on the economy of the country.

The SAM model can also be extended to computable general equilibrium (CGE) models, by imposing demand and supply functions and equilibrium conditions to the model. These relax the linearity conditions and introduce non-linear functions into the valuation framework. It also relaxes the assumption of constant prices in the factor and product markets and allows the market mechanism process to solve for competitive equilibrium. Berrittella *et al.*(2007) did a global CGE analysis of the economic impact of restricted water supply using the modified GTAP-E (Energy) version. The authors generated a GTAP-W (Water) model which is aggregated to include 17 sectors and 16 regions and included water as a non-marketed resource. Also, Letsoalo *et al.*(2007) used the CGE approach to analyze the benefits of water consumption charges in South Africa.

2.5 ALTRERNATIVE COST APPROACH

The alternative cost approach is appropriate when estimates of direct demand schedules or functions are difficult to be computed because of data unavailability or other reasons. This approach is based on the assumption that the maximum willingness to pay for a publicly supplied good or service is not greater than the cost of providing it. That is, if a given project, with a specified output costs is less than the next best project with the same output level, then the former is preferred to the alternative. The present value of the total costs of each alternative is calculated on the basis of commensurate planning period, price level, and discount rate (Agudelo, 2001). The analysis must verify that the highest-cost alternative would actually be constructed in the absence of the project under consideration.

The alternative cost approach is very useful when the demand for water is price inelastic and when the objective of a public project is to reduce the cost of producing an output which could otherwise be provided at a higher cost to the consumer. The approach has the advantage of permitting benefits evaluation without actual estimation of the demand curve.

2.6 OUTLINE OF THE APPLIED METHODS USED IN THIS STUDY

Given the above analyses of methods used to estimate the economic value of water, this section briefly discusses the methods applied in this study.

In Chapter Three, the study estimates the global inter-sectoral water demand functions for thirteen production sectors. Using the marginal productivity approach, the study estimates the output and price elasticities and marginal values of water for the different water user-sectors. The data for the global level analysis are extracted from the GTAP (2001) and UNIDO (2000) data bases. The modeling procedure follows the Wang and Tall (2002), by estimating the Cobb-Douglas' and translog production functions. Using the two-staged model the study estimates the elasticities and marginal values for the different aggregated sectors. The study uses the marginal productivity approach because the price of water is not shown in the available data. Therefore, the computed marginal values are used as a proxy for the price of water. In Chapter Four, the study extracts data from the census of manufacturing, agricultural, construction and services activities on the one hand

(STATSA, 2002), and from water resource accounts (STATSA, 2004) to estimate the sectoral water demand functions for South Africa. This is done in order to validate the global model. The regional water demand functions are computed by using the 1996 census of manufacturing activities data, and the DWAF's economic information system (EIS) and other regional data, to validate the national level parameter estimates.

In chapter five, the 1999 social accounting matrix (SAM) developed by Thurlow and van Seventer (2002) is updated to reflect 2003 entries by using data from TIPS (Trade and Industry Policy Strategy, 2004) and Statistics South Africa 2000 Water Accounts (STATSA, 2004). This SAM is used to compute the multipliers, which are interpreted to show the contribution of water to economic activities in South Africa. The multipliers are used to examine the economy-wide impact of water reallocation from agriculture to the non-agriculture sectors on the basis of the computed marginal values in Chapter Four. This shows how sectoral water reallocation based on the sectoral marginal contribution of water impacts output growth, factor payments and household income generation. If economic efficiency is mainly determined by marginal values, the study then examines the extent to which the equity criterion is also met. If not, then the study generates scenarios to find out which allocation strategy maximizes both economic and social welfare. However, when the assumptions of the SAM analysis are relaxed in a CGE model, the simulation results are usually significantly different from the SAM results. Therefore, the study uses the computable general equilibrium analysis to investigate various water policies on households' welfare.

2.7 SUMMARY AND CONCLUSION

This chapter surveyed the various methods for valuing water as an intermediate good. Four main valuation methods were briefly discussed. Among the various methods discussed the econometric demand estimation and the value added approaches will be extensively applied in this study.

The study applies the econometric approach to estimate the global inter-sectoral water demand functions and compute the output and price elasticities and the marginal value of water for specified sectors. Specifically, the study adopts the marginal productivity approach to estimate the translog production functions. This approach is preferred to the other econometric methods because of it being consistent with economic theory of optimum pricing. Since water prices are distorted either because of government regulations that favour one sector's use of water over the others, or because of the quasi public good nature of the resource, this study uses computed marginal values as the shadow price of water. Also, since water pricing is a controversial issue in water resource economics, policy analysts would like to recommend sectoral water prices that reflect the economic value of the resource to policy makers. The marginal productivity approach ensures that the marginal value of water is equal to the price of water. This method facilitates the estimation or computation of sectoral price and output elasticities and marginal values in water markets have distorted prices. It applies the duality approach which computes output elasticities directly from the estimated functions, and uses the estimated output elasticity to compute the marginal value, hence, the price elasticity of demand for water by the different sectors (Wang and Lall, 2002). Therefore the model is called the two-stage model. This approach is used because of the available data reports values of inputs and outputs, and not their prices. The method can be intuitively used to extrapolate the marginal value of water for the different sectors, which is then used as a proxy for water price in the different production sectors in the absence of global water markets. The data used for the global inter-sectoral water demand analysis is extracted from the Global Trade Analysis Project (GTAP) 2001 and UNIDO data sets. To validate the global model, the same method is used to estimate inter-sectoral water demand functions in South Africa. In this country-specific study, the marginal productivity approach is preferred to other approaches because water prices are currently distorted in the country, due to the extensive government intervention in the allocation and other policy implementation processes in order to protect the rights of the historically disadvantaged individuals. The study assumes constant price and output elasticities. This assumption is used to estimate the provincial inter-sectoral marginal values of water. The results obtained are used to compare and analyze cross-regional difference in inter-sectoral marginal values of water. The marginal productivity approach is discussed in details in chapter three.

To investigate the policy relevance of the computed or estimated marginal values, there is the need to ascertain the policy option for which the estimated figures are more appropriate: either for inter-sectoral water pricing policy or inter-sectoral water reallocation. To gauge the policy viability of the estimated inter-sectoral marginal values the study updates the already existing social accounting matrix of South Africa and uses this updated SAM to compute the coefficient and multiplier matrices, which are used to analyze the economy-wide impact of reallocating water among the production sectors on the basis the marginal value of water in each of these sectors in South Africa. The SAM multiplier analysis approach is used because the model is capable of explaining inter-sectoral linkages. Therefore, it can explain how changes in water allocation can impact sectoral production and value added on one hand, and how these impacts are transmitted to the institutions that own the factors of production on the other hand (Juana and Mabugu, 2005; Boughanmi *et al.*, 2002). Thus, the model accounts for both changes in output due to policy alterations and the distributional aspects of these impacts; hence, its appropriateness in assessing the economy-wide contribution of water and policy implications of investments and reallocation decisions. This method is discussed and applied in Chapter Five.

CHAPTER THREE

MARGINAL PRODCUTIVITY ANALYSIS OF GLOBAL SECTORAL WATER DEMAND

3.1 INTRODUCTION

Water use can be divided into two broad categories; residential and non-residential uses. Non-residential water use can be sub divided into agricultural, manufacturing, mining and environmental uses. Water's role in inter- sectoral productivity has received little attention in econometric studies of natural resource use. Of all the production sectors, the manufacturing sector has been the most understudied sector. The value of water in manufacturing processes has not been extensively studied as it has been in the other sectors. Extensive review of empirical literature suggests that a considerable number of studies have focused attention on the agricultural and residential water uses. Only a few of these studies have been applied to industrial water use. Available evidence shows that most of the studies on manufacturing water demand have focused attention on developed rather than developing countries.

Industrial or manufacturing water use makes up a significant share of total water withdrawals. In 1995, global industrial water demand accounted for about 20 percent of the total global water withdrawals (Shiklomanov, 1998). However, this figure differs across countries and regions depending on the level of industrialization and development. For example, while industrial water withdrawal accounts for 11 percent of the total water withdrawals in South Africa, the same sector accounts for 46 percent of the total water withdrawals in the United States of America (Gleick *et al.*, 2002). Also studies show that while irrigation water use is gradually declining in developing countries and countries in economic transition, industrial water use is steadily increasing. Specifically, Rosegrant *et al.* (2002a) show that while irrigation water use in Asia and the rest of the world is projected to decline from 51 percent and 29 percent in 1995 to 45 percent and 27 percent respectively in 2025, worldwide industrial water use is projected to slightly increase from nine percent in 1995 to 11 percent in 2025. These figures show that industrial water use, especially in developing and transitional economies is rapidly increasing. Therefore, the emphasis on water use efficiency has now become an inter-sectoral phenomenon.

Studies also suggest that industrial water use is linearly related to the level of water pollution, though Hettige *et al.* (1997) show that water pollution index initially increases with per capital income and then levels off, and that pollution intensity decreases with industrialization and development, before it levels off at some point.

The role of water in sectoral production activities stems from its function as an intermediate public good, which plays an active part in the production process by changing the unit cost of production. Generally, sectoral water use has four components: freshwater water intake, treatment of water prior to use, recirculation and discharge. These four components are important concepts to consider in the estimation of the value of water use in different productions sectors of an economy. Most sectoral activities use water as an input into the production process, though the purpose of water use varies from one sector to the other. For example, water may be used in beverage industries as a direct input, or for cooling in electro-thermal industries or used for transporting other inputs in the paper and pulp industries or generally as a sink for waste discharges. These different uses make sectoral water demand a multidimensional phenomenon; hence, applying a single modeling procedure to model the demand for inter-sectoral water use may not be accurate (Kindle and Russel, 1994). Extractive water use, for example, includes water used in irrigation, manufacturing and mining processes, and thermal electricity production, while non-extractive uses include hydroelectric power production, disposal of industrial effluent and commercial navigation.

Efforts to estimate sectoral water demand functions have been confronted with many challenges. These include the lack of clearly defined information on the price of bulk water sales or purchases, either because most self-supplied sectors pay little or nothing for their raw water input or because sectoral or sub-sectoral expenditures on water is reported as part of the overall expenditure on intermediate inputs or because the expenditure on water is negligible. The latter might be the case when the price that industries pay does not reflect the marginal value of the resource.

Despite these difficulties, because of the crucial role water plays in sectoral operations, there is the need to model the demand for water use in all the primary/secondary production sectors. Also, because of the growing evidence that freshwater availability is declining, while competition among sectors for the withdrawal of the scarce freshwater resources is increasing every year, there is the need to use the scarce water resources efficiently. Now while global irrigation water use is projected to decline industrial water use, especially in developing and transitional economies is increasing (Rosegrant *et al.*, 1995). As a result, current debates focus on improving the efficiency of sectoral water use.

Unlike the agriculture sector, the structure of water use in the industrial sector differs from one industry to the other. To improve sectoral water use efficiency, there is the need to understand the structure of water demand for the different production sectors and sub-sectors. Some questions of interest include these: can water pricing institute sectoral water use efficiency? If so, which pricing structure can best attain this objective? Which sectors require mandatory water policy to achieve water use efficiency? The answers to these questions and issues require a detailed empirical study to estimate the demand for inter-sectoral water use. Thus, this chapter investigates and estimates the global inter-sectoral water demand. The specific objectives of this chapter include:

i) Estimation of the global sectoral demand functions for water,

ii) Computation of the output and price elasticities of the demand for water by the various production sectors

iii) Estimation and comparison of the sectoral marginal values of water and

iv) Recommendation of policies that would promote sectoral water use efficiency.

Section two critically analyzes and discusses empirical method used to estimate the sectoral demand for water, Sections three and four present the empirical findings and policy implications, and summary and conclusions respectively.

3.2 THE EMPIRICAL MODEL AND THE MODEL ESTIMATION PROCEDURE

Given the available data the study estimates the Cobb-Douglas' and the translog production functions. This approach, first used by Wang and Lall (2002), models the value of aggregate output as a function of the values of labor, capital input, aggregate intermediate and water inputs. The estimation procedure assumes the existence of a twice differentiable aggregate Cobb-Douglas' production function and its translog transformation. The functional relationship is expressed as:

$$Y = \beta_0 L^{\beta_1} K^{\beta_2} W^{\beta_3} I^{\beta_4} \qquad (3.1)$$

Where 'Y' is the value of output measured in tens of billions of U S Dollars, 'L', 'K' and 'I' are the labour, capital and intermediate inputs respectively measured in tens of billions of US Dollars and "W' is the quantity of water input measured in million cubic meters. β_0 is the constant term, which represents the state of technology of the industry and $\beta_{1,}$ $\beta_{1,}$ β_3 and β_4 are the multiplicative indices of labour, capital, water and intermediate inputs. Each input's multiplicative index represents the output elasticity of that input. The above function can be linearly transformed by taking the natural logarithm of both the dependent and the independent variables:

$$\ln Y = \ln \alpha + \beta_1 \ln L + \beta_2 \ln K + \beta_3 \ln W + \beta_4 \ln I \qquad (3.2)$$

From the above function, the output elasticity (σ) and the marginal value (ρ) of water can respectively be computed as:

$$\sigma = \frac{\partial \ln Y}{\partial \ln W} = \beta_3 \text{ and } \rho = \sigma * \frac{Y}{W} \qquad (3.3)$$

The major limitations of this functional form are the assumptions of strict separability of inputs and the imposition of constant returns to scale. These imply that the sum of the multiplicative indices is unity and that the inputs are independent of each other. That is, the cross between any pair of the independent variables is zero (Browning and Zupan, 2006). Equation 3.3 can be extended to the translog production function which is given below in equation 3.4.

$$\ln Y = \beta_0 + \beta_1 \ln L + \beta_2 \ln K + \beta_3 \ln W + \beta_4 \ln I + \beta_5 \ln L \ln K + \beta_6 \ln L \ln W + \beta_7 \ln L \ln I + \beta_8 \ln K \ln W + \beta_9 \ln K \ln I + \beta_{10} \ln W \ln I + \beta_{11} \frac{\ln^2 L}{2} + \beta_{12} \frac{\ln^2 K}{2} + \beta_{13} \frac{\ln^2 W}{2} + \beta_{14} \frac{\ln^2 I}{2} \quad (3.4)$$

This functional form introduces the interaction between and the square terms of the pairs of independent variables. Therefore, it relaxes the constant returns to scale and the strict separability conditions imposed by the Cobb-Douglas' functional form. From equation 3.4 the output elasticity can be computed as:

$$\eta_y = \frac{\partial \ln Y}{\partial \ln W} = \beta_3 + \beta_{13} \ln W + \beta_6 \ln L + \beta_8 \ln K + \beta_{10} \ln I. = \frac{\partial Y}{\partial W} \cdot \frac{W}{Y} \quad (3.5)$$

The marginal value of water is then computed as:

$$\rho = \frac{\partial \ln Y}{\partial \ln W} * \frac{Y}{W} = \eta * \frac{Y}{W} \quad (3.6)$$

The study assumes that firms in each of the production sectors are perfectly competitive. Economic theory of production asserts that for profit maximizing perfectly competitive firms/ industries, the marginal value of an input is equal to the marginal cost and is the shadow-price of that input (Browning and Zupan, 2006; Agudelo, 2001). Therefore the price of water is assumed to be equal to the marginal value of water. According to Wang and Lall (2002), the price elasticity of water (ε_p) is computed as;

$$\varepsilon_p = \frac{\partial \ln W}{\partial \ln P} = \frac{\partial \ln W}{\partial \ln \rho} = \frac{\partial W}{\partial P} * \frac{P}{W} = -\frac{\eta}{\eta - \eta^2 - \beta_{13}} \quad (3.7)$$

The study estimates the Cobb-Douglas' and the translog production functions that are specified in equations 3.2 and 3.5. Once estimated, the marginal effects are computed to estimate the combined sectors output and price elasticities, and marginal value of water. To compute the sector specific elasticities and marginal values, the product of the sector specific dummies and their respective natural logarithm of water are imposed on the translog function as shown in equation 3.8.

$$\ln Y = \beta_0 + \beta_1 \ln L + \beta_2 \ln K + \beta_3 \ln W + \beta_4 \ln I + \beta_5 \ln L \ln K + \beta_6 \ln L \ln W + \beta_7 \ln L \ln I + \beta_8 \ln K \ln W + \beta_9 \ln K \ln I + \beta_{10} \ln W \ln I + \beta_{11} \frac{\ln^2 L}{2} + \beta_{12} \frac{\ln^2 K}{2} + \beta_{13} \frac{\ln^2 W}{2} + \beta_{14} \frac{\ln^2 I}{2} + \beta_3^1 S_1 \ln W_1 + \beta_3^2 S_2 \ln W_2 + \ldots\ldots\ldots + \beta_3^{13} S_{13} \ln W_{13} \quad (3.8)$$

The variables are defined as in equation 3.4, with the addition of the product of the sectoral dummies (S_1, S_2,……..,S_{13}) with their respective natural logarithms of water ($\ln W_1$, $\ln W_2$,……,$\ln W_{13}$), which are represented by the coefficients $\beta_3^1, \beta_3^2, \ldots\ldots\ldots, \beta_3^{13}$ for each of the production sectors whose water demand functions are estimated. These coefficients account for the differences in both the intercept and slope terms of their respective sectors (Wang and Lall, 2002). Equation 3.8 is therefore used to compute the sector specific elasticities and marginal value of water. The estimated results are presented in Table 3.1. The computed figures explain how sectors respond to percentage changes in the price of water. This estimation method is chosen over the single equation method, because it increases the degrees of freedom of the estimated equation. Therefore, the coefficients estimated using this method predict a more reliable relationship between the dependent and the independent variables. Single equation estimation for each of the thirteen sectors substantially reduces the degrees of freedom. This reduces the number of significant variables and the F-score (Wang and Lall, 2002). In econometric literature, this method is referred to as the two-stage model. During the first stage the economy-wide demand function is estimated and in the second stage, the estimated function is used to show how specific sectors deviate from the economy-wide estimated function (Greene, 2003).

Price elasticity shows the effectiveness of water pricing as a policy instrument to institute sectoral water use efficiency while the estimated marginal values serve as indicators of the water productivity in the various production sectors.

3.3 DATA SOURCES AND DESCRIPTION OF EXTRACTED DATA

Most of the data used for this study are extracted from the GTAP 2001 cross-sectional database which has 66 regions, 57 sectoral outputs and 5 factors of production measured in tens of billions of US Dollars (Rutherford and Paltsev, 2000). The 57 GTAP sectors are aggregated into 13 sectors using the international standard industrial classification (ISIC) codes, which include agriculture(AGR), food, beverages and tobacco manufacturing(AGI), basic chemical manufacturing(CHM), construction(CON), electricity (ELE), energy (ENG), heavy metal manufacturing (HEV), other manufacturing (OHM), machinery and equipment (MAC), mining (MIN), petroleum products (PEC), pulp and paper (PPP), and leather products and wearing apparel(TXT). Details of the extracted data from the GTAP5 are documented in APPENDIX 1

Sectoral industrial water use is generally not recorded at national level on in global data bases. Strzepek *et al* (2007 have developed a methodology for estimating industrial water use based on applying a correlation factor for industrial water use with employment statistics. The primary source of information for deriving employment/industrial use statistics for estimating industrial water use is the most recent Census of Manufacturing activities (US Bureau of Census, 1986). The census data were obtained from a special survey of 10 262 establishments. The coefficient for water use per employee per day is multiplied by the number of workers in industrial sector.

The method provides estimates that are most applicable for US industries in 1986. However, this work is looking global industrial water use in 2000. This includes industrial water use in both industrialized and industrialized countries. To address this issue, the authors applied the concept of national water-use intensity that varies from one country to the other; an approach that was successfully applied by Hettige *et al.* (1997) to estimate sectoral industrial water pollution. Based on this approach, sectoral water use is estimated as follows:

$$WU(Nation, Sector) = WUperEmpl(USA86, Sector) X\, Empl(Nation, Sector)\ X\ Intensity(Nation) \quad (3.9)$$

Where;

WU (Nation, Sector) is sectoral water use in nation 1997,

WUperEmpl (USA86, Sector) is USA sectoral water use in 1986,

Empl (Nation, Sector) is employee per sector in a country and

Intensity (Nation) is the ratio of national 1997 industrial water use to 1986 USA industrial water use.

For this analysis the nation scale has been aggregated to 66 regions of the GTAP5 (GTAP, 2006), which are combinations of single nations and regional aggregation of countries and 13 aggregated industrial sectors.

The data on employees per sector for each of the 66 regions was obtained from the United Nations Industrial Development Organization (UNIDO) INDSTAT3 2006 Industrial Statistics Database. Water use per sector was extracted from the Census of Manufacturing Activities (US Bureau of Census, 1986). The intensity factor was estimated by summing the total industrial water use over all sectors for each of the 66 regions. The information on total industrial water withdrawal for each region was extracted from the FAO AQUASTAT database (FAO, 2005). The AQUASTAT value was divided by the USA86 base estimates. As check for the validity of the estimates, the int6ensity factors are compared to the factors obtained by Hettige *et al.* (1997) for each region and following the trend that water use intensity increases with GDP. The estimated water data is in column 6 of Table A1.

3.4 PRESENTATION AND DISCUSSION OF ESTIMATED RESULTS

This section is divided into four sub-sections. The first sub-section presents and discusses the estimated coefficients of the three regression models. The second sub-section presents the computed output elasticities of water, while subsections three and four present and discuss the price elasticities and marginal values of water respectively.

3.4.1 Regression Results

The estimated regression coefficients of the three models are presented in Table 3.1. The estimated coefficients of the Cobb-Douglas' model are presented in Column 2, while the translog and the translog with sector specific dummies are presented in columns 3 and 4. In the Cobb-Douglas' model, the estimated coefficients show that all the inputs are positively and significantly related to output. The estimated translog function was tested against the null hypothesis that the interaction and square terms were not significantly different from zero. Based on the results of the test statistic, the null hypothesis was rejected. The third model, which included the product of the sectoral dummies and the water use for each sector, was estimated to account for the differences in the intercept terms and the slope coefficients across the different sectors. It therefore facilitates the easy and better estimation of the sectoral output and price elasticities and marginal value of water. This method has more degrees of freedom than the single equation estimation method for each sector. Therefore, it is a more reliable method of estimating the sectoral demand functions for water.

The third model is also tested against the null hypothesis that the coefficient of the product of the sectoral dummy and the natural logarithm of water use in each sector is not significantly different from zero. The results suggest that these coefficients are significantly different from zero and show that generally, water is a significant input in sectoral production activities. The coefficients of the product of the sectoral dummies with the water use for each sector indicate that water is a significant input in food, beverages and tobacco manufacturing, agriculture, construction, energy, heavy metal manufacturing, machinery and equipment, mining, and clothing and textile manufacturing industries. The last three rows of Table 3.1 present the test-statistics which assess the degree of predictability and appropriateness of the model.

The results of the Wald test show that the translog is the most appropriate functional form. The R^2 indicates that the estimated coefficients can highly predict the relationship between the output and the input variables. Durbin Watson statistics of 2.235, 2.014 and 1.987 respectively show that there were no serious problems of autocorrelation among the specified variables. The detailed estimated coefficient with their respective standard errors and t-values are reported on Tables A3, A4 and A5 in the appendix.

Table 3.1: The estimated coefficients of the global model

Variables (1)	Cobb-Douglas Production Function (2)	Trans-log Production Function (3)	Trans-log with sector dummies (4)
Constant	2.242*	2.757*	2.5808*
lnL (Natural logarithm of labour)	0.083*	0.262*	0.221*
lnK(Natural logarithm of capital)	0.227*	0.380*	0.344*
lnW(Natural logarithm of water)	0.215**	0.150**	0.092***
Natural logarithm of intermediate inputs)	0.633*	0.446*	0.346*
LnL*lnK (Interaction bewteen labour &capital)	-	-0.005	-0.005
LnLlnW (Interaction between labour & water)	-	0.0014	0.000
LnLlnI (Interaction between labour & intermediate)	-	-0.229*	-0.023*
LnKlnW (Interaction between capital & water)	-	-0.002**	-0.002
LnKlnI (Interaction between capital & intermediate)	-	-0.024*	-0.024*
LnWlnI (Interaction between water & intermediate)	-	0.011***	0.001
$0.5\ln^2 L$ (Square of natural log.of labour)	-	0.030*	0.277*
$0.5\ln^2 K$ (Square of natural log.of capital)	-	0.046*	0.399*
$0.5\ln^2 W$ (Square of natural log. of water)	-	0.001	0.016***
$0.5\ln^2 I$ (square of natural log. of intermdiate)	-	0.051*	0.042*
S1*ln(W) Beverage and Tobacco	-	-	0.051***
S2*ln(W) Agriculture	-	-	0.011**
S3*ln(W) Basic Chemicals	-	-	-0.002
S4*ln(W) Construction	-	-	-0.037**
S5*ln(W) Electricity	-	-	-0.010
S6*ln(W) Energy	-	-	-0.137*
S7*ln(W) Metal Manufacturing	-	-	0.358**
S8*ln(W) Machinery & Equipment	-	-	0.269**
S9*ln(W) Mining	-	-	-0.052**
S10*ln(W) Other manufacturing	-	-	0.0001
S11*ln(W) Petroleum products	-	-	-0.029
S12*ln(W) Paper and pulp	-	-	0.017
S13*ln(W) Clothing and textiles	-	-	0.027***
Number of observations	727	727	727
Degrees of freedom	(4, 720)	(14, 710)	(27, 700)
F Score	608.26*	224.46*	163.09*
Durbin Watson Test	2.235*	2.014*	1.987**
R^2	0.7486	0.7255	0.6971

The summary statistics of the estimated variables are reported on Table A2 in Appendix 1.

3.4.2 The computed output and price elasticities of water

This sub-section first presents and discusses the output elasticities computed for the combined sectors and for each sector as specified in equation 3.8. It then presents and discusses the price elasticity of the demand for water as specified in equation 3.5.

Table 3.2: The computed sectoral elasticities and marginal values of the global water demand model

Sectors (1)	Mean values of output (2)	Mean volume of water *(mm^3)* (3)	Output elasticity (4)	Marginal Value of water *(US\$/mm^3)* (5)	Price elasticity of water (6)
Beverage and Tobacco	407.85	29.81	0.26	3.50	-1.46
Agriculture	81.14	44.53	0.22	0.39	-0.89
Basic Chemicals	273.81	13.47	0.20	4.12	-1.39
Construction	1139.29	44.34	0.17	4.31	-1.35
Electricity	311.54	87.10	0.20	0.70	-0.78
Energy	22.34	3.55	0.07	0.43	-1.42
Metal Manufacturing	312.63	23.56	0.56	7.47	-2.44
Machinery & Equipment	19.83	1.91	0.47	4.92	-2.03
Mining	503.87	61.48	0.15	1.25	-1.34
Other manufacturing	620.65	30.72	0.20	4.14	-1.39
Petrol-coal	14.97	0.26	0.18	10.17	-1.36
Paper and pulp	62.28	10.12	0.22	1.36	-0.87
Clothing and textiles	17.36	0.74	0.23	5.47	-1.43
Combined sectors	368.59	56.32	0.20	1.34	-1.27

The computed sector specific results and the combined output elasticity of water are presented in column 4 of Table 3.2. Output elasticity measures the degree of responsiveness of changes in the value of output to a unit change in the level of water use. The results show an industry-wide output elasticity of water of 0.20. This implies that on the average, the value of output increases by 2 percent for every ten percentage increase in the level of water use. Generally, there is not much variation in output elasticity among the various sectors. The metal manufacturing industry, with an output elasticity of 0.56 has the highest value. This is followed by machinery and equipment with an output elasticity of 0.47, while the energy sector has the least output elasticity of 0.07. An output elasticity of 0.22 in the agriculture sector is higher than the combined sectors output elasticity, indicating that for every ten percent increase in level of water use in agriculture, the value of output increases by only about two percent. These results suggest that for every 10 percentage increase in the level of water, the percentage increase in the value of output in the metal manufacturing industry is more than the percentage increase in the value of output in any other sectors and that the energy sector has the least percentage increase in the value of output. The estimated industry-wide output elasticity of water, which is 0.20, is consistent with the findings of Wang and Lall (2002) with an elasticity measure of 0.17 and with sector-specific output elasticities varying from 0.04 to 0.26.

The computed price elasticities are reported in column 6 of Table 3.2. The sectoral price elasticity of the demand for water shows the degree of responsiveness of each sector's water use to changes in the price of water. The computed figures show that generally, sectoral water demand is price elastic, with elasticity measure of -1.27. From the computed elasticities, it could be seen that the price elasticity of demand for water in the agriculture sector (-0.89) is less than the combined sectors' price elasticity of demand for water. The computed elasticities also show that when the price of water increases by 10 percent, water use in the agriculture sector decreases by about nine percent, while all the sectors' water use decreases by about 13 percent. However, individual sectors differ in the degree of their responsiveness to changes in water prices as shown above in column 6 of Table 3. 2. For example, the demand for water is price elastic in the mining (-1.34), energy (-1.42), machinery (-2.03), construction (-1.35), metal manufacturing (-2.44), electricity (-1.38) and beverages and tobacco (-1.46) sectors. Relative to these sectors the demand for water is price inelastic in agriculture (-0.89), leather products and wearing apparel (-0.94), and pulp and paper (-0.87) sectors. In the mining sector for example, mine water can easily be recycled. Therefore, for some increase in the price of freshwater, mines can reduce freshwater intake and treat and recycle the wastewater. These results are also consistent with the findings of Wang and Lall (2002), with an industry-wide price elasticity of the demand for water of -1.03 and sector specific price elasticities ranging from -0.57 in power generation to -1.20 in leather manufacturing.

3.4.3 Estimated sectoral marginal values of water

This subsection presents and discusses the computed sectoral marginal values of water specified in equation 3.10.

The computed sectoral marginal values of water are presented in Column 5 of Table 3.2 and graphically illustrated in Figure 1. The marginal value measures the change in the value of output of a given sector, as a result of a unit change in the level of water use in that sector. In this study, the marginal value of water in a given sector shows the increase in the value of output due to a cubic meter increase in water use in that sector. This is an important concept in general production theory. The unit cost of an input (marginal cost) is compared with the unit contribution of that input to output or revenue, which in this study, is the marginal value. If the marginal value is less than the marginal cost, less of that input should be used until the marginal value is equal to the marginal cost. In a multi-input industry, the ratio of the marginal value to the price of the input must be the same for all the inputs and must be equal to unity (Beattie and Taylor, 1993). The combined sectors and the sector specific marginal values, including agriculture, are presented in column 5 of Table 3.2. The marginal values of water are computed at the mean values of the variables.

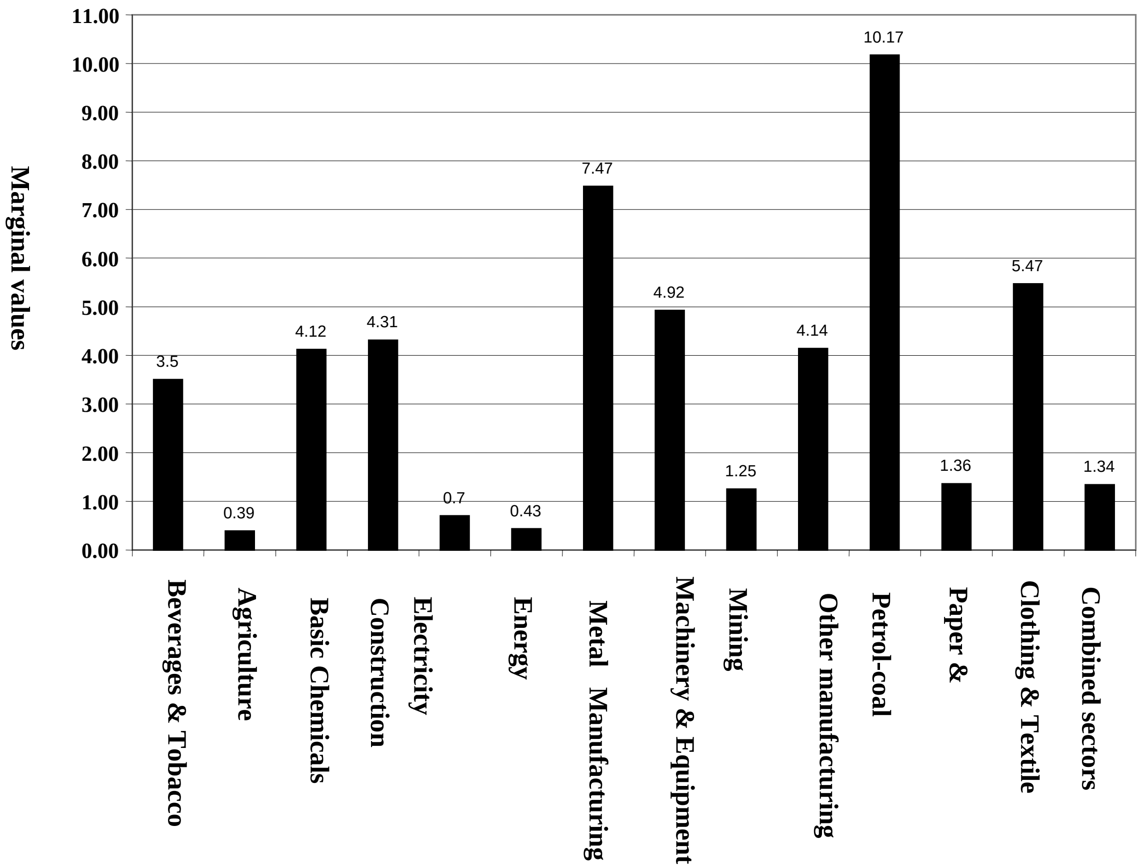

Figure 1: Global sectoral marginal values of water

On the average, combined sectors water use has a marginal value of US$1.34/m^3. This is higher than water's marginal value of US$0.39/m^3 in the agriculture sector. The petroleum sector has the highest marginal value of US$10.17/m^3. Next is the heavy metal manufacturing sector, with a marginal value of US$7.47/m^3. The energy sector, with a measure of US$0.43/m^3, has the least marginal value among the industrial sectors. These results imply that for the same cubic meter increase in the level of water use in each of the sectors, the value of output will increase more in the petroleum sector than the other sectors. Therefore, at the global level the marginal returns to sectoral water use is higher in the petroleum sector than in any other sector. The energy sectors' marginal value of water is the least, compared with the other sectors. Agriculture's marginal productivity of water is also low as compared to petroleum and metal manufacturing. These findings have policy implications which will be discussed in the concluding chapter.

The estimated sectoral marginal values in this study cannot be compared to the results of other studies because of differences in currency units and other socio-economic factors. Also, the concept of sectoral marginal values of an input should be interpreted with caution in terms of its policy relevance. For a workable policy decision, the economic approach to the concept should be used in conjunction with some technical considerations. For example, the marginal value of water in petroleum industry is the highest (see Figure 1). An additional unit of water to this sector may dramatically reduce the marginal productivity of the input in this sector. Therefore, it is necessary to consider the absorptive capacity of the sector.

The model used to estimate global sectoral water demand functions can be used to compute the sectoral marginal values of water in the GTAP countries. The modeling approach assumes constant output elasticities, but varying marginal values, which depend on the level of water application and the sectoral output in each of the GTAP regions/countries. It follows that, at all levels of water use, while output and price elasticities remain constant, the marginal value of water varies from one level of water use to the other. Therefore, intensive water use sectors have lower marginal values than non-intensive water sectors.

3.8 SUMMARY AND CONCLUSIONS

The need to institute sectoral water use efficiency necessitated a study to investigate how different production sectors respond to changes in water prices. The data used for the study were extracted from the GTAP and UNIDO databases. The data on the values of sectoral output, labour, capital and intermediate inputs were extracted from GTAP in GAMS. The volume of water used by each sector was extracted from the UNIDO data set which has sectoral water use per employee. This was converted to sectoral water use by using equation 3.13 and checking for consistency with the FAO sectoral water use.

Following Wang and Lall (2002), the translog production function was estimated, and used to compute the combined sectoral output and price elasticities and marginal value of water. The translog production function with sectoral dummies was then estimated. This estimated model was used to compute the sector specific output and price elasticities and marginal value of water for thirteen production sectors (see Table 3.2). The results indicate that sectoral water demand is generally price elastic, although there are varying degrees of price elasticities of sectoral water demand. While some sectors respond to small changes in the price of water, others only respond to substantial changes in price. Therefore, in order to improve sectoral water use efficiency, sectoral water prices should be designed such that each sector's price adequately facilitates reduction in water use. These results also confirm that water pricing could be a workable policy instrument to promote sectoral water use efficiency. However, the responsiveness to changes in water prices is not the same for all the sectors. For example, the price elasticity of demand for water in the paper and pulp industry is -0.87 and that for metal manufacturing is -2.44. These imply that when the price of water increases by 10 percent, paper and pulp industry reduces the quantity of water use by about nine percent, while the metal manufacturing industry reduces water use by about twenty four percent. Therefore, charging the same price for all the sectors may not achieve the policy target because of variations in their responsiveness to changes in water prices.

Furthermore, countries differ with respect to water availability, agro-climatic zones, water use patterns and the demographic composition of the population. These differences explain the differences in economic and water policies. Because of these differences, globally computed sectoral price and output elasticities and marginal values of water could not be used as appropriate country-specific water policy tools. To formulate national water policies that address both the issues of equity and efficiency, there is the need to investigate sectoral water demand functions at specific country levels. This also helps to validate the global level analysis. Also, because water is used in conjunction with other inputs there is the need to investigate whether water is a compliment or a substitute to the other inputs. Therefore, the next chapter will estimate the sectoral water demand functions in South Africa.

CHAPTER FOUR

MARGINAL PRODUCTIVIVTY ANALYSIS OF SECTORAL WATER DEMAND IN SOUTH AFRICA

4.1 INTRODUCTION

In the preceding chapter, the global sectoral water demand functions were estimated for thirteen production sectors. In summary, the estimated results show that sectoral water demand is generally price elastic, although sector-specific elasticities as well as their marginal values vary from one sector to the other. The findings suggest that water pricing could be a workable policy instrument to achieve sectoral water use efficiency. To be consistent with economic theory, the study recommended sectoral water prices which reflect the marginal value of water. However, global sectoral water demand functions may not accurately reflect country specific water situations. The estimated global sectoral price and output elasticities of demand for water, and their respective sectoral marginal values of water may either be understated or overstated when compared to country specific water demand functions. Country and sector specific water demand functions depend on both the availability of the resource and the intensity of sectoral water use. Therefore, there is a need to validate the estimated results of the global level analysis of sectoral water demand functions at country specific levels and investigate the consistency of the global and country specific water demand functions. Water demand functions have been estimated for a number of developed countries like Canada by Renzetti (1988; 1992); Renzetti and Dupont (2003); France by Reynaud (2003), South East England by Rees (1969) and the United States by Grebenstein and Field (1979). In developing countries and countries in economic transition some studies have estimated the sectoral water demand functions.

These include studies by Wang and Lall (2002) in China; Onjala (2001) in Kenya; Kumar (2004) in India and Feres and Reynaud (2003) in Brazil. As discussed in the problem statement in section 1.4 of chapter One, various studies carried out in South Africa to estimate the value of water have either concentrated on a single sector or a few sectors. They therefore lack inter-sectoral comparative anlysis of the estimated marginal values of water. Thus, there is a need to validate the global water demand analysis by using South Africa as a case study. South Africa is selected for the validation study because the country is in the process of implementing an internationally recognized water reform policy that entails efficiency, equity and sustainability considerations. Moreover, the existence of fairly reliable data sets on sectoral production activities and water use makes the country a suitable option among the many developing countries or countries in economic transition.

Historically, water resource management in South Africa has focused on developing water supply sources through the establishment of complicated engineering supply-side solutions. Due to the increasing cost of such engineering processes, the potential future inelastic nature of water supply and perceived declining per capita water availability in South Africa, supply-side solutions alone no longer viewed as a viable option. This necessitates the switch to demand-side management options to complement the already developed supply-side engineering solutions. However, demand-side solutions to the potential water scarcity in South Africa require knowledge about the value of water in various sectors of the economy. The identified gaps and requirements for a comprehensive assessment of sectoral water use make it necessary to estimate sectoral water demand functions in the country.

The DWAF (2005) document sets the principles and framework for water reform that moves the country from water allocation based on the "riparian" principle to one that is based on the principle of efficiency, equity and sustainability. These principles and framework of water reforms in South Africa are outlined and explained in section 1.3 of chapter one. To achieve these objectives, there is the need for extensive research aimed at providing workable water pricing and allocation policies that can simultaneously address efficiency of water use, equity to access and to the benefits that accrue from the use of the resource, and environmental sustainability, such that the resource is available to future generations. Generally, all the estimated marginal values show that agriculture has the least marginal value of water. However, the exclusion of some of the vital sectors and the lack of consideration for inter-sectoral and institutional linkages in the former studies, and their failure to adequately disaggregate especially the manufacturing sector into sub-sectors requires further investigation into the problem.

Manufacturing water use differs from one sub-sector to another. It is also assumed that there are spatial differences in the sectoral marginal value of water in South Africa because of differences in agro-climatic zones. For efficient and successful policy design and implementation, there is the need to understand how agricultural and non-agricultural sectors respond to price changes and the contribution of water to output in each of these sectors. Against this background, this chapter is designed to critically analyze sectoral water demand in South Africa and make comparative analysis of the sectoral marginal values of water at provincial level. Specifically, this chapter is designed to:

i) Estimate the sectoral water demand functions in South Africa,

ii) Compute the output and price elasticities of water demand for the various production sectors,

iii) Estimate and compare the sectoral marginal values of water at both national and provincial levels, and

iv) Recommend policies that would promote sectoral water use efficiency.

The next section explains the model specification and estimation, and the description and sources of data used for the study. Section 4.3 presents and discusses the estimated results at national and provincial levels of the country, while section 4.4 provides the chapter summary and concluding remarks.

4.2 MODEL SPECIFICATION, ESTIMATION AND DATA SOURCES

This section is divided into two sub-sections. The first sub-section discusses the model specification and estimation procedure and the second sub-section explains the data sources and data extraction procedure.

4.2.1 Model specification and estimation procedure

This chapter applies the modeling procedure which was described in chapter three. To estimate the Cobb-Douglas', the translog and the translog with sectoral dummies production functions, the study uses equations 3.4, 3.6 and 3.8. The Cobb-Douglas' production function is estimated to test how consistent the data is with the model. The translog production function is estimated to compute the combined sectors' output and price elasticities and marginal value of water. The translog model with sectoral dummies is then estimated to facilitate the computation of sector specific elasticities and marginal value of water use. As explained in chapter three, the product of the natural logarithm of water use in each sector and the sector specific dummy accounts for differences between both the intercept and the slope of the combined sectors' water demand function and each sector's water demand functions. This model is referred to as the two-stage model. In the first stage, the overall output and price elasticities and marginal value of water are computed. In the second stage, the coefficient of the product of the sector specific dummies and the natural logarithm of water use are used to compute the sector specific elasticities and marginal values of water.

4.2.2 Description and sources of data

For the estimation of the sectoral water demand functions in this chapter, the study uses three sources of data. The first source is the 1996 census of manufacturing, agricultural, mining, construction and services activities, published by STATSA (2002) in ten volumes, one for each province and one with a national coverage. The information collected from this source included value of output produced by each sector or sub-sector, depreciation in capital stock, the value of intermediate input, and wages and salaries paid to employees. All these variables are measured in millions of Rand. Information on the same variables for the agriculture sector was extracted from the census for agriculture activities for each province and for the whole country.

The second set of data is extracted from the water resources accounts, also published by Statistics South Africa (STASA, 2004). This data source contains information on sectoral water availability and utilization in million cubic meters for each of the nineteen water management areas (WMA) and for the whole country. Using the same procedure in chapter three sectoral water use per employee is converted to water use in each sector by multiplying this ratio by the number of employees in each sector. This figure is compared to the sectoral water use in water resource account. Where a substantial difference exists between the two figures, the conversion factor is adjusted, until the converted figures are consistent with sectoral water use (see equation 3.9). Details of the extracted data can be found on Table B1 in appendix 2.

To compute the marginal value of water over time for each sector, the Trade and Industrial Policy Strategies (TIPS) time series data set is used. The extracted data included the value of sectoral output, total expenditure on wages and salaries, other intermediate inputs, depreciation on capital and new capital investment. To isolate the impact of fluctuations in the value of the currency the values are measured in millions of 1996 Rand. The information on water in millions of cubic meters was extracted from the same source. The study uses the quantity and not the value of water because of current distortions in the municipal prices of water.

For the purpose of this study, data are extracted for the period 1970 to 2004. In the data set there are 43 disaggregated sectors according to the international standard industrial classification (ISIC). Considering the nature of water use by the different sectors, the 43 sectors in the TIPS time series data were aggregated to 13 sectors. The aggregated sectors are agriculture (AGR), which consists of crop production, animal husbandry, forestry and fisheries; agro-based industries (AGI), consisting of beverages, tobacco, and food manufacturing; mining (MIN), which comprises coal mining, gold mining, uranium and other mining, Leather products and wearing apparel (TEX), consisting of textile, wearing apparel, leather and leather products and footwear; wood, paper and paper products (PPP), consisting of wood and wood products, paper and paper products, printing, recording and recorded media; petroleum products (PET); chemicals (CHM), consisting of basic chemicals and other chemicals; heavy manufacturing (HEV), made up of non-metallic minerals, basic iron and steel., basic non-ferrous metals and metallic products excluding machinery; machinery and equipment (MAC), including machinery, electrical machinery and apparatus, television, radio and communications equipment, motor vehicles, and spare parts and professional and scientific equipment, electricity (ELE); construction (CON) including building, civil engineering and other construction; and services (SER) consisting trade services, catering and accommodation, transport and storage, communication, business, medical, dental and veterinary services, other professional and general government services and other manufacturing (OHM) like furniture, rubber and rubber product. These aggregated sectors are consistent with those extracted from the other sources.

4.3 PRESENTATION AND DISCUSSION OF ESTIMATED RESULTS

This section is divided into four sub-sections. These include presentation of:

i) the coefficients of the three estimated models (the Cobb-Douglas', the translog and the translog with sectoral dummies)

ii) the computed elasticities;

iii) sectoral marginal values of water;

iv) sectoral marginal values of water by province and over time

4.3.1 Presentation of the estimated coefficients

Table 4.1 presents the estimated coefficients of the three models. A correlation matrix showed a high degree of correlation between water and intermediate inputs. Since the focus is on water, the intermediate input variable was dropped, while capital, labour and water are retained and their coefficients estimated in the three models.

In the first model, the Cobb-Douglas' production function was estimated and the estimated coefficients are shown in Column 2 of Table 4.1. The estimated coefficients show a one percent level of significance for capital and labour and a five percent level of significance for water. All the estimated coefficients are positive, indicating a positive relationship between the inputs and output. Because the variables are expressed in natural logarithms, their coefficients are interpreted as output elasticities.

The translog production function was then estimated and tested against the null hypothesis that the interaction and square terms are not significantly different from zero. Based on the result of the test statistic, the null hypothesis was rejected. The coefficients of the translog model with their respective significance levels are presented in Column 3 of Table 4.1. The labour variable is significant at one percent level, while capital and water are significant at five percent.

The third model, which imposed the product of the sectoral dummies and the mean level of water use in each sector on the translog model, was estimated, and the coefficients are reported in column 4. This model is estimated to show that both the intercept and slope coefficients differ for the different sectors. It thus facilitates the easy and better estimation of the sectoral elasticities and marginal values. The results for all the variables, including the sectoral dummies, generally indicate that water is a significant input in sectoral production activities. The standard errors, t-scores and p-values of the estimated coefficients are documented on Tables B2,3 and 4.

Table 4.1: Estimated coefficients of the South water demand models

Variables (1)	**Model 1 Cobb-Douglas'** (2)	**Model 2 Translog Production Function** (3)	**Model 3 Translog with Sector Dummies** (4)
Constant	1.0828*[1]	2.0556**	2.0905*
lnK (Capital)	0.1959*	0.1140**	0.2463**
lnL (Labour)	0.2165*	0.1271*	0.8125*
lnW (Water)	0.0665**[2]	0.0665**	0.4731*
lnK*lnL(Capital * Labour)		-0.0065	0.0712
lnK*lnW (Capital*Water)		0.0774	-0.0182
lnL*lnW (Labour*Water)		-0.0052	0.0197
LnKsq (square of capital)		0.0129	-0.0309
LnLsq (square of labour)		-0.0463***[3]	-0.0426
lnWsq (square of water)		-0.0514***	-0.0545***
S1lnW(Beverage and Tobacco)			0.1758*
S2lnW(Agriculture, Fishing and Forestry)			0.0035*
S3lnW(Basic Chemical manufacturing)			0.3019
S4lnW(Construction)			0.4421**
S5lnW(Electricity and Gas)			-0.0134*
S6lnW(Metal Manufacturing)			0.0990**
S7lnW(Machinery and Equipment)			0.5371*
S8lnW(Mining and Quarrying)			0.0569***
S9lnW(Other Manufacturing)			0.0635
S10lnW(Petroleum Products)			0.5434*
S11lnW(Paper, Pulp and Printing)			0.1037**
S12lnW(Services)			0.5371*
S13lnW(Leather Products and Wearing Apparel)			0.6339*
Number of observations	117	117	117
Degrees of freedom	(3, 114)	(9, 108)	(22, 95)
F Score	362.12*	193.35*	97.34*
Durbin Watson Test	2.138	1.975	2.189
R^2	0.65324	0.6157	0.5817
Ajusted R-squared	0.64528	0.6082	0.5743

The coefficients of the product of the sectoral dummies with the mean level of water use for each sector was then tested against the null hypothesis that the differences in water use

[1] Significant at one percent level

[2] Significant at the five percent level

[3] significant at the ten percent level

by the sectors is not significantly different from zero. The test results show that sectors significantly differ from each other with respect to their various levels of water use.

The last three rows of Table 4.1 present the results of the test-statistics which assess the degree of predictability and appropriateness of the model. The results of the Wald test show that the translog is the most appropriate functional form. An adjusted R^2 of 65% of the translog functional form with sector dummies indicates the model's predictability of the relationship between the output and the input variables. The Durbin Watson statistics of 2.138, 1.975 and 2.189 respectively show that there were no serious problems of autocorrelation among the specified variables.

4.3.2 Computed output elasticities

Output elasticity of water measures the degree of responsiveness of output to a unit change in the level of water application in each sector. It measures the percentage change in the value of output when the level of water application increases by one percent.

The sectoral elasticities and marginal values are computed on the means of the variables. These sectoral means of the estimated variables are presented in Table 4.2. The combined sectors and the sector specific output elasticities are reported in column 2 of Table 4.3. The results show that the combined sectors' output elasticity of water is 0.19. This result indicates that for all the sectors, the value of output increases by 1.9 percent when sectoral water use increases by ten percent. This means that although the value of output increases with increase in the volume of water used by all the sectors, the percentage increase in the value of output is not proportional to the percentage increase in the level of water use. However, output elasticity varies from one sector to the other, although the computed figures indicate that none of the sectors has output elasticity greater than unity. For example, the leather products and wearing apparel sector has the highest output elasticity of 0.82, while electricity records the lowest output elasticity of 0.18. Figure 2 displays the computed output elasticity for each sector.

Table 4.2: Means of estimated variables

Sector (1)	Output (R m) (2)	Capital (R m) (3)	Employment (R m) (4)	Intermediate (R m) (5)	Water (m m^3) (6)
Beverage and Tobacco	1713.54	69.80	183.68	1294.67	2.98
Agriculture	958.84	98.79	153.88	439.72	1403.00
Basic Chemicals	1145.39	46.01	139.00	855.33	18.24
Construction	1361.85	26.90	243.43	945.78	0.15
Electricity	525.88	153.52	126.13	287.51	37.22
Metal Manufacturing	1752.69	97.79	408.79	1253.45	46.33
Machinery & Equipment	2067.08	56.51	316.72	1556.18	0.88
Mining and Quarrying	1874.12	200.02	475.60	812.84	68.00
Other Manufacturing	975.71	23.55	492.33	593.52	29.27
Petroleum Products	598.04	63.52	30.75	416.65	3.49
Paper, Pulp and Publishing	671.08	43.82	163.40	604.71	32.68
Services	13564.92	964.43	4383.42	5497.30	106.19
Leather products & wearing apparel	554.90	17.68	115.91	391.24	0.85
Combined Sectors	2133.42	143.14	555.87	1147.82	134.39

The computed sectoral output elasticities indicate that for each of the production sectors the value of output increases with increase in the volume of water, but the percentage increase in the value of output is not proportionate to the percentage increase in the volume of water. The figure below indicates that when water use increases by one percent in each of the production sectors, the percentage increase in the value of output in the leather products and wearing apparel sector is greater than that in any other sector. However, the policy relevance of the concept of output elasticity needs to be critically investigated before recommending its implementation. Firstly, one percent increase in the volume of water use in the agriculture sector may not be the same as one percent increase in the volume of water use in the other sectors. Secondly, a percentage increase in the value of output in agriculture may be more or less than a percentage increase in the value of output in the beverage and tobacco manufacturing industry. Therefore, direct comparison of the sectoral output elasticities may be misleading. In spite of the differences in percentage changes, the sign and magnitude of the sector specific output elasticity indicate the direction and productivity of water in that sector alone.

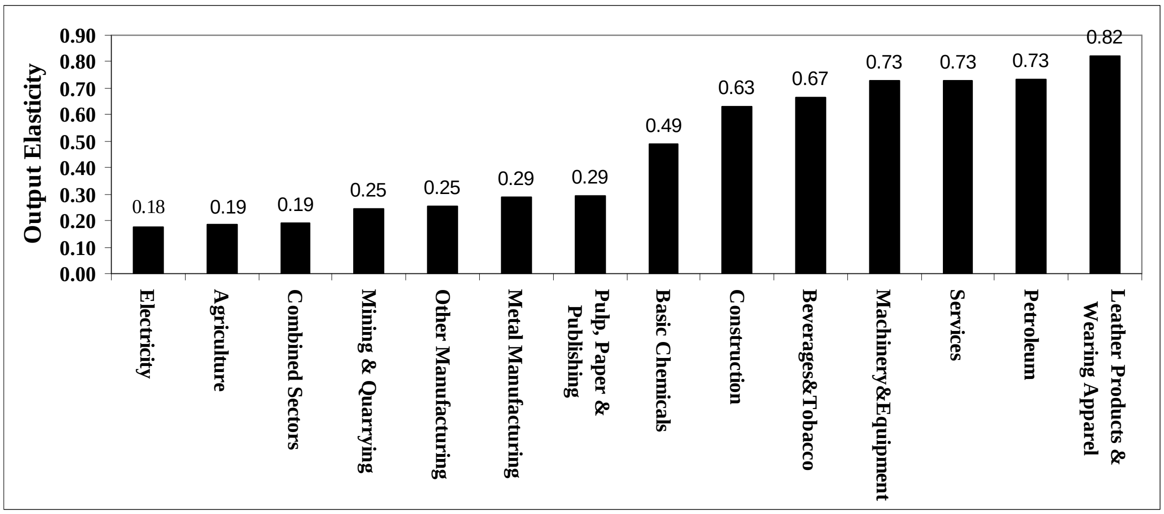

Figure 2: Computed sectoral output elasticities of water in South Africa

This concept indicates that the percentage change in the value of output is positive in all the sectors, but not proportionate to the percentage change in the level of water use. However, the disproportionate relationship between percentage increase in output and percentage increase in the volume of water use is more in the electricity sector than the other sectors.

The above results are also consistent with the findings of Wang and Lall (2002), which show that the sectoral output elasticity is less than unity in all the sectors. They are also consistent with the findings of the global level water analysis in chapter three. The general implication from the findings is that percentage changes in output do not proportionately correspond to percentage changes in the level of water use by the production sectors.

4.3.3 Computed sectoral price elasticities of the demand for water

The sectoral price elasticity of demand for water shows how the production sectors change their demand for water due to a unit change in the price of water. It measures each sector's degree of responsiveness of changes in the volume of water to a unit change in the price of water. The computed price elasticities of water for each and every sector which are reported in column 4 of Table 4.3 indicate that combined sectoral water demand is price elastic, with elasticity measure of -1.03.

Table 4.3: Computed sectoral price elasticities and marginal values of water in South Africa

Sectors (1)	Output Elasticity (2)	Marginal Value (Rand/m^3) (3)	Price Elasticity (4)	10% Increase in the price of water (5)
Beverages &Tobacco	0.67	38.25	-1.44	(14.4)
Agriculture	0.19	0.13	-1.03	(10.3)
Basic Chemicals	0.49	3.08	-1.23	(12.3)
Construction	0.63	58.98	-1.39	(13.9)
Electricity	0.18	2.49	-1.02	(10.2)
Metal Manufacturing	0.29	10.91	-1.08	(10.8)
Machinery & Equipment	0.73	17.16	-1.52	(15.2)
Mining & Quarrying	0.25	6.79	-1.05	(10.5)
Other Manufacturing	0.25	8.43	-1.06	(10.6)
Petroleum	0.73	12.55	-1.53	(15.3)
Pulp, Paper & Publishing	0.29	6.02	-1.08	(10.8)
Services	0.73	9.28	-1.52	(15.2)
Leather products & wearing apparel	0.82	53.68	-1.67	(16.7)
Combined Sectors	0.19	3.01	-1.03	(10.3)

Column 4 of the above table shows that generally, a 10 percent increase (decrease) in the price of water leads to 10.3 percent decrease (increase) in the quantity of water demanded by all the sectors. Since the percentage decrease (increase) in the quantity of water demanded is slightly more than the percentage increase (decrease) in the price, sectoral water demand is said to be price elastic. As with output elasticity of water, the price elasticity demand for water also varies from one sector to the other. This implies that the responsiveness to the same percentage change in the price of water varies from one sector to the other.

For example; a 10 percent increase in the price of water reduces electricity's demand for water by 10.2 percent, while it reduces the demand for water in the leather product and wearing apparel sector by 16.7 percent. The impact of a 10 percent increase in the price of water on the quantity of water demanded by each and every sector is shown in column 5 of Table 4.3.

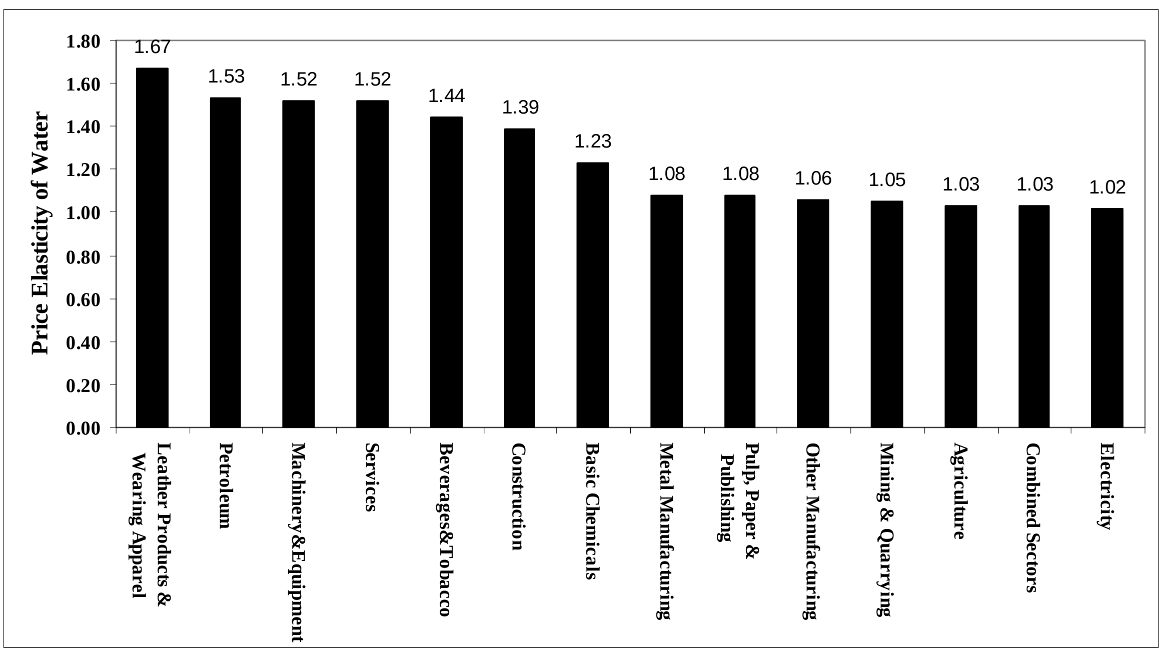

Figure 3: Sectoral price elasticity of water in South Africa

Figure 3 presents a graphical illustration of the absolute values of sectoral price elasticities of demand for water in order of magnitude, showing leather products and wearing apparel with the highest price elasticity and electricity with lowest price elasticity of demand for water. These figures indicate that the overall, production sectors' demand for water is price elastic. Therefore, the percentage decrease in the volume of water demand by each sector is more than the percentage increase in the price of water for that sector. The computed elasticities are fairly consistent with those estimated in the global water demand analysis. These findings have some policy implications which will be discussed in chapter seven.

4.3.4 Presentation of the computed sectoral marginal values of water

Marginal value of water measures the change in the value of output due to a cubic meter change in the volume of water. The marginal value of water in a sector shows the increase or decrease in the value of output per cubic meter change in the volume of water used in that sector. The marginal value of input is an important concept in general production theory. The unit cost of an input (marginal cost) is compared with the unit contribution of that input to output or revenue, which in this study, is the marginal value of water. Where the marginal value is less than the marginal cost, less of that input should be used until at least the marginal value is equal to the marginal cost. In a multi-factor industry, the ratio of the marginal value to the price of the input, must be the same for all the factors and must be equal to unity. The combined sector' and the sector specific marginal values of water are reported in column 3 of Table 4.3. The marginal values are computed at the means of the variables. The combined sectors water use has a marginal value of R3.01/m^3 of water. This implies that on the average, the value of sectoral output increases by R3.01/m^3 of water. As with output elasticity, the marginal value of water varies from one sector to the other. The construction sector, with R58.98/m^3 has the highest marginal value of water in South Africa. This is followed by the leather products and wearing apparel sector with a marginal value of R53.68/m^3. Again, the agriculture sector, with a measure of R0.13/m^3, has the least marginal value of water. Figure 4.2 presents a graphical illustration of the sectoral marginal values of water in order of magnitude.

This implies that in South Africa, the same cubic meter of water is more productive in the construction sector than in all the other sectors, with agriculture being the least productive in terms of marginal returns to water use. However, since the magnitude of a sector's marginal value of water depends on both the level of water use and output, more water-intensive sectors have lower marginal values than the less water-intensive sectors. The marginal value of water in the agriculture sector is lower than the one estimated by Moolman *et al.* (2006:86) which ranges from R25.43/m^3 for mango to R1.67/m^3 for sugar cane. However, it is higher than the one estimated by Nieuwoudt *et al.* (2004:180) which

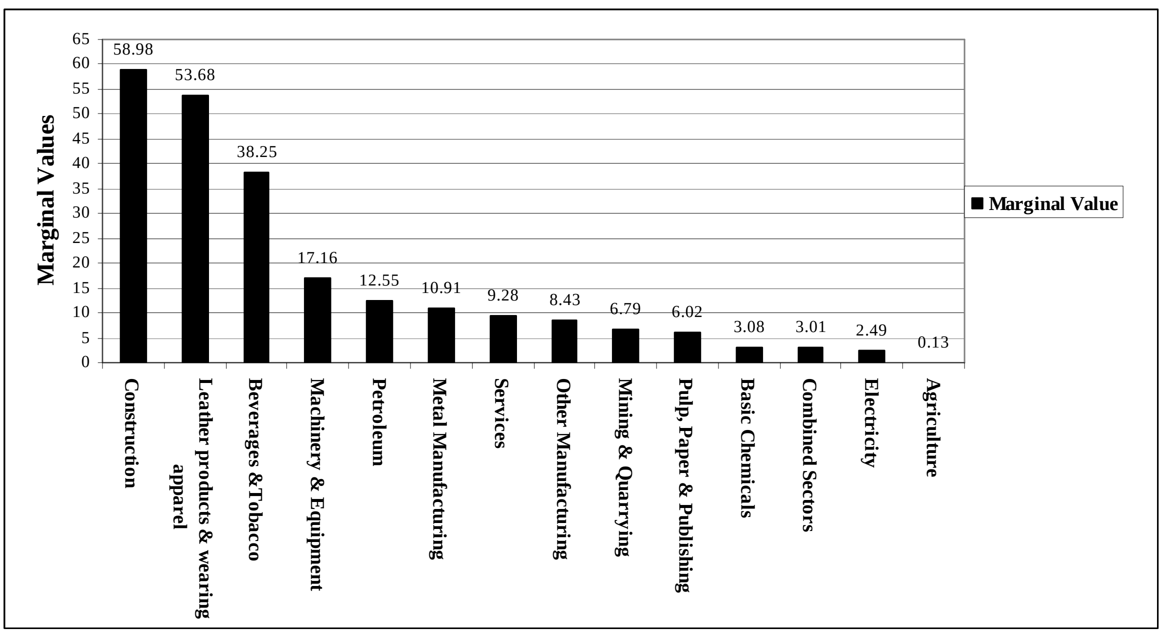

Figure 4: Sectoral marginal values of water in South Africa

varies from R0.0011/m^3 to R0.2115/m^3. These comparisons show that the marginal values of water differ with different valuation methods. These marginal values can not be compared with studies done in other countries because of differences in currency units.

The concept of marginal value of water, unlike that of output elasticity, has more practical policy relevance, which will be discussed chapter seven. Generally, in South Africa, the issues of equity, efficiency and sustainability are high on the water policy agenda. The institution of water use efficiency is based on the principles of water pricing and inter-sectoral water transfer/trading. However, the modeling and computational techniques applied in this study imply constant elasticities, but varying marginal values. Therefore, the computed marginal values vary from one province to the other, depending on the level of water use, output and the use of other inputs, including changes in the level of technology.

4.3.5 Provincial sectoral marginal values of water

To investigate spatial variations in inter-sectoral marginal values of water the study computed the marginal values of water for each sector in all the nine provinces of South Africa. Table 4.4 presents the computed results. The data for this exercise were extracted from STATSA's 1996 census of manufacturing, agricultural, construction and services activities published for each of the nine provinces. The information on sectoral water use is reported in these documents in million cubic meters. To make sure that the extracted data is consistent, the water data was compared with the sectoral water use data also published by resource Statistics South Africa (STATSA, 2004).Comparing the country-wide sectoral marginal values presented in Column 3 of Table 4.3 and the provincial sectoral marginal values presented in Table 4.4 it is shown that although country-wide estimations put machinery and equipment manufacturing as the sector with the highest marginal value of water, the situation is different for different provinces. For example, in the Eastern Cape, Free State and North West provinces, construction has the highest marginal value of water, while in KwaZulu Natal, Mpumalanga, Northern Cape and Western Cape provinces beverage and tobacco manufacturing has the highest marginal value of water and metal manufacturing has the highest marginal value of water in the Limpopo provinces.

The marginal value of water in the beverage and tobacco manufacturing sector is highest in the Western Cape and least in Free State, while agriculture commands a higher returns in Gauteng and the least in Western Cape. Also, the marginal value of water in construction sector is highest in the Eastern Cape and least in the Northern Cape.

Table 4.4: Provincial sectoral marginal values of water in South Africa

Sectors	Eastern Cape	Free State	Gauteng	Kwa-Zulu Natal	Mpumalanga	North West	Limpopo Province	Northern Cape	Western Cape
Beverage and Tobacco	30.61	12.59	40.15	39.70	34.38	33.72	48.27	42.07	53.69
Agriculture	1.32	0.94	4.26	1.21	0.65	0.87	3.27	1.09	0.58
Basic Chemicals	1.74	4.48	21.82	8.84	5.04	0.44	20.01	2.13	0.27
Construction	51.04	38.99	14.88	13.26	11.50	33.94	31.86	4.23	8.35
Electricity	6.49	7.13	3.93	4.48	3.72	6.42	21.52	12.87	4.12
Metal Manufacturing	1.67	0.67	26.02	13.16	13.43	1.73	60.37	10.45	0.42
Machinery & Equipment	4.35	1.27	11.24	27.95	19.92	5.22	15.59	18.10	0.66
Mining and Quarrying	1.56	4.77	6.87	1.63	6.45	7.27	1.56	10.52	1.93
Other Manufacturing	9.34	5.53	36.35	9.57	0.95	40.91	17.59	2.84	15.72
Petroleum Products	3.13	0.61	12.81	3.68	0.35	17.71	1.75	0.89	4.89
Paper, Pulp and Publishing	2.52	0.19	63.67	12.49	0.39	22.31	44.54	1.01	6.16
Services	30.21	2.44	5.15	3.24	3.72	6.67	9.13	17.13	6.93
Leather Products and Wearing Apparel	0.78	0.14	9.49	12.18	0.21	18.17	21.66	1.23	4.05

Generally, the marginal value of water for the same sector varies from one region to the other, though the price and output elasticities are assumed to be constant. This is because of variations in sectoral mean production and availability use of water. Sectors that are high intensive water users usually have lower marginal values than those which use less water.

4.5 SUMMARY AND CONCLUSIONS

The need to validate global sectoral water demand analysis and to institute inter-sectoral water use efficiency in South Africa necessitated a study to investigate the responsiveness of industries to water prices, using the data extracted from STATSA's census of manufacturing, construction agricultural and services activities, and water resource accounts..

Adopting the model used by Wang and Lall (2002) and applied in chapter three, the Cobb-Douglas' translog production function was estimated, with sectoral dummies for 13 production sectors, from which the price and output elasticities and the marginal values of water were computed for the different sectors.

The results indicate that generally, water use by industries is price elastic in South Africa, implying that industries do respond to changes in water prices. However, there are varying degrees of price elasticities of industrial water demand for the different sectors. The results also suggest that, to improve industrial water use efficiency, water prices should at least reflect the marginal value of water in the different industrial sectors. This policy should be used in conjunction with other mandatory policies like fixed quantity of freshwater intake by industries, water treatment and recycling and effluent charges.

Since water is combined with other inputs, there is the need to investigate whether water and each of the other inputs are either compliments or substitutes. This will produce some interesting results for water policy makers. South Africa has different ecological and climatic zones, so water situation in the country varies from one climatic zone to the other. Therefore, national figures estimated in the study may not be reflective of each and every agro-ecological or climatic zone. Thus, there is a need for a detailed study at the catchment level to estimate the inter-sectoral demand for water use.

The results of this study show that agriculture is among the sectors with lower marginal values of water. From the economic point of view and the concern to maintain a sustainable economic growth, the study recommends an inter-sectoral water reallocation based on marginal values. However, efficiency considerations in inter-sectoral water transfer may undermine the country's principle of equity in water use. Based on the principle of efficiency, water should be reallocated from agriculture to the sectors that have higher marginal values of water. This is likely to affect employment and the income of the poor rural population, the majority of who depend on agriculture for their livelihood because the agriculture sector employs more than 50 percent of the employed unskilled labour (Thurlow and van Seventer, 2002). This requires an investigation of the impact of inter-sectoral water reallocation, on the basis of sectoral marginal values, on sectoral output, factor remuneration, employment and household income generation.

CHAPTER FIVE

SECTORAL WATER USE IN SOUTH AFRICA: EQUITY VERSUS EFFICIENCY

5.1 INTRODUCTION

The issue of water scarcity and the challenge to increase the efficiency of sectoral water use has been discussed in detail in the preceding chapters. In chapters three and four the sectoral water demand functions were estimated and the sectoral price and output elasticities and marginal values of water computed. From the estimated sectoral elasticities and marginal values of water, water pricing and allocation policies that can potentially improve water use efficiency were recommended at both global and South Africa levels. However, the analytical procedure in both cases made no attempt to investigate equity issues together with the efficiency considerations discussed. In the realm of institutional analysis of critical natural resource use, socio-economic criteria for efficient resource management require that the interest of all the stakeholders involved in the use of the resource must be taken into consideration. As a result, there is the need to investigate the economy-wide socio-economic consequences of implementing inter-sectoral water reallocation policies on the basis of efficiency considerations.

As the population is growing in South Africa, the need to increase food production and to maintain a sustainable economic growth and environment increases the demand on the nation’s water resource, while the supply of this resource is projected to be inelastic.

Irrigation water requirement in South Africa accounts for about 62 percent of the total water requirements, while the agriculture sector as a whole accounts for only about four percent of the GDP, and employs about 11 percent of the total number of employees (DWAF 2004). Moreover, empirical results from chapters three and four indicate that agriculture has the lowest marginal value of water, while manufacturing, mining and the services sectors comparatively have higher marginal values.

From the above indications the policy of reallocating water from the agriculture to the non-agriculture sectors on the basis of their respective marginal values might be seen as a viable policy to promote sustainable economic growth and employment. However, the rationality of this policy may be questioned if the forward and backward inter-sectoral linkages, as well as transmission mechanisms to different household categories, through factor payments are not incorporated into the valuation framework. The question is therefore, not only how much does a particular sector contribute to the GDP of an economy, but also how best can scarce water resources be allocated to improve the standard of living of the critical population. This addresses the issue of efficiency, as well as equity and sustainability. It thus justifies the inclusion of social and environmental values of water into the economic valuation framework. Against this background, this chapter is designed to critically analyze the economy-wide inter-sectoral water reallocation on the basis of economic efficiency in South Africa. Specifically, using the social accounting matrix framework, the study:

i) analyzes the contribution of water to the various economic activities,

ii) estimates, using marginal values of water, the economy-wide impact of reallocating water from agriculture to the non-agriculture sectors

iii) recommends the water allocation strategy that is likely to promote efficiency and social equity.

The purpose of this chapter is to investigate whether a trade-off exists between efficiency and equity policies of inter-sectoral water use in South Africa and to investigate the socio-economic consequences of this trade-off.

The next section briefly describes the general features of a social accounting matrix (SAM) and the generic SAM for South Africa. It also explains how the 1999 SAM for South Africa was updated and aggregated for the purpose of this study. Section 5.3 explains the theoretical framework and the modeling procedure, while section 5.4 presents and discusses the model results, and section 5.5 presents a brief summary and conclusions of the chapter

5.2 THE FEATURES OF THE SOUTH AFRICAN SAM

This section briefly describes the generic features of the South African SAM. It then explains how the 1999 South African SAM was updated to reflect 2003 accounts and how these accounts were aggregated for the purpose of the current study.

5.2.1 The features of the SAM

The SAM constructed for this study is an updated version of the generic 1998 SAM developed by Thurlow and van Seventer (2002). The 43 activities and 43 commodities were consistent with time series data compiled by South Africa's Trade and Industrial Policy Strategies (TIPS). Therefore the 1998 entries for activities and commodities were updated to reflect the 2003 using the supply and use tables extracted from the TIPS data set.

The factor inputs entries were also updated to reflect the 2003 figures from the TIPS data set. The information on household income and expenditure patterns was provided by Statistics South Africa from the 2003 census. Information on government's income and expenditure accounts, investment and international trade was provided by the South African Reserved Bank's publications (SARB, 2002). The detailed structure of the generic SAM for South Africa is found in Thurlow and van Seventer (2002). Because most sectors have self water supply source, the water supply information from the municipalities' billing records grossly understates the use of the resource by the production sectors and households. These entries were therefore replaced by the water resource management strategy (WRMS) registration information and the information from Statistics South Africa's water resource accounts STATSA (2004).

For the purpose of this study the updated SAM was aggregated to 14 activities or commodities, three primary factors of production, enterprises account, five household categories, government account, investment and the rest of the world.

The agriculture sector, consisting of agriculture (crop production and animal husbandry), forestry and fishing accounts, were aggregated to agriculture, while coal, gold, uranium and other mining were aggregated to mining activities/commodities. The manufacturing sector, consisting of 43 activities and 43 commodities were aggregated to 12 activities/commodities accounts comprising agro-industries (food, beverage and tobacco manufacturing); leather products and wearing apparel (textile, wearing apparel, leather and leather products and footwear); paper and paper products (paper, paper products, printing, recording and recorded media); petrol; chemicals (basic and other chemicals); heavy manufacturing (non-metallic minerals, basic iron and steel, basic non-ferrous metals and metals products excluding machinery); machinery and equipment (machinery and equipment, electrical machinery and apparatus, television, radio and communication equipments, motor vehicles and spare parts and professional and scientific equipments); electricity; water; construction (building, civil engineering and other construction); services (wholesale and retail trade, catering and accommodation, transport and storage, communication, business, medical, dental and veterinary, other professional and general government services); and other manufacturing. The aggregations reflect the structure of water use intensity by the sectors and sub-sectors.

The capital; three labour (unskilled, medium-skilled and high-skilled); and enterprises accounts in generic SAM were retained; but the 14 household accounts in the original SAM were aggregated to five accounts. The highly disaggregated household accounts do not show much differences in the income structure between one category and the one immediately below or above it. The first two deciles reflect the households earning below 20 percent of the national income. The third and fourth deciles show those earning between 20 and 40 percent of total income, while the fifth and sixth deciles reflect middle-income households that are between 40 and 80 percent of the total income in South Africa. The rich households earn more than 80 percent of the total household income in South Africa. The majority of the population of South Africa is in the first two categories, and less than three percent is in the tenth deciles. Most of the poor households' income comes from the wages of unskilled labourers and transfers from semi-skilled labour (Thurlow and van Seventer, 2002). These households are the historically disadvantaged individuals, whose past and current economic situation can hardly enable them to get out of the poverty trap.

This explains why this category of households highly depends on welfare programmes and various levels of subsistence activities for their economic survival.

Government accounts, which were broken down into expenditure and income accounts (four accounts) in the original SAM were aggregated to net government account. Savings and investment and the rest of the world accounts were retained. Table 7D in the appendix presents the aggregated SAM used in this study.

5.3 THE THEORETICAL FRAMEWORK AND MODELING PROCEDURE

This section explains the theory which underlies the use of input-output and social accounting matrices. It also explains how the model can be applied to investigate economy-wide impact of economic policies with specific reference to the impact of inter-sectoral water reallocation on sectoral output, value added and households' income distribution in South Africa.

5.3.1 The theoretical framework

Input-output and social accounting matrix models have been extensively used in the early literature to analyze inter-sectoral growth linkages in an economy (Juana, 2006; Juana and Mabugu, 2005; Bautista *et al.* 2002; Delgado *et al.* 1998; Sadoulet and de Janvry, 1995). The analysis of this type of interaction among sectors and institutions require economy-wide frameworks (Sadoulet and de Janvry 1995). The SAM framework can be used to analyze the impact of an exogenous shock on the economy. In this chapter the SAM framework is used to assess the impact of water reallocation from low to high values uses on output growth, factor remuneration or gross value added, job creation/losses, and households' income generation and distribution.

The study computes the SAM multipliers using the material balance equation, developed in Sadoulet and de Janvry (1995); and used by Bautista *et al.* (2002); Juana (2006) and Juana and Mabugu (2005). The basic materials balance equation can be specified as:

$$Y^l = AY^l + F \tag{5.1}$$

Where 'Y^{l}' is an nx1 column vector of total sectoral output, 'A' is an n x n matrix of direct technical coefficients for the endogenous factors and 'F' is an nx1 column vector of final demand. The dimension of the 'A' matrix coincides with the number of accounts considered for the purpose of SAM analysis. Solving for 'Y^{l}' from equation 1 leads to:

$$Y^l = (I - A)^{-1} F \tag{5.2}$$

Where 'I' is the identity matrix and '$(I\text{-}A)^{-1}$' is the Leontief inverse. The input-output model is concerned with solving for the sectoral output levels (Y) that satisfy final demand for those output levels (F), given the inter-industry structure of production or the intermediate input requirements of the production sectors (A). Given the inter-sectoral transactions matrix (A), the model is used to determine the production plan which is consistent with a desired final demand vector (F). The above equation can be used to derive various types of multipliers, the most common of which are the production and income multipliers. Equation 2 can be reduced to:

$$Y^l = M^l F \quad where\ M^l = (1 - A)^{-1} \tag{5.3}$$

Therefore, 'M^{l}' is the input-output multiplier matrix, referred to in literature as the Leontief inverse. The vectors 'Y^{l}' and 'F' represent sectoral output and final demand respectively. Equation 5.3 can be used to calculate the endogenous incomes associated with any changes in the total exogenous accounts, given the multiplier matrix. It can also be used to analyze the effects on output arising from exogenous shocks, such as changes in investment or government expenditure or the rest of the world. Each cell in the multiplier matrix 'M^l' interprets the total income change in the row account induced by an exogenous income injection in the column account. In the production sectors, the multipliers indicate how a unit increase in the sector's production due to exogenous shocks stimulates economy-wide output growth.

Equation 5.3 can be extended to the SAM multiplier matrix by the inclusion of the primary factors and the consumption accounts into input-output accounts. The inclusion of these accounts aim at incorporating feedbacks from rents to consumption to new production originating from an exogenous inflow. Let 'A_m' be the enlarged square matrix of direct propensities computed from the SAM and 'M^s' the enlarged inverse (SAM multiplier) matrix. Then 'M^s' can be computed as:

$$Y^s = M^s F, \; where \; M^s = (I - A_m)^{-1} \tag{5.4}$$

Equation 5.4 solves for the equilibrium level of all endogenous accounts which result from a shock or exogenous injections, from changes in the elements of the exogenous accounts. The multiplier matrix 'M^s' measures the direct and indirect impacts of the incorporated endogenous links and reduces to 'M^l' when the dimension 'm' of the 'A_m' matrix corresponds to 'A' (Boughanmi *et al.* 2002). Any difference between 'M^s' and 'M^l', is due to the induced effect which is taken into account by 'M^s', but not by 'M^l' (Juana, 2006 and Juana and Mabugu, 2005:250).

Economic multipliers estimate the economy-wide impact of a change in an exogenous account on intermediate and final demand. This induces changes in sectoral output levels, value added and income generation in a specified economy, such as a state or a province. These changes suggest a strict cause-effect relationship (Tanjuakio *et al*., 1996). In this study, the model estimates the economy-wide impact of reallocating water among the production sectors on the basis of their respective marginal values of water. Water reallocation on the basis of marginal values is an exogenous policy shock, aimed at improving the efficiency of sectoral water use.

There are four types of multipliers in the existing literature: i) the direct or production multiplier, which captures the immediate impact of the initial change in the output level of the industry or industries being analyzed; ii) the indirect or income multiplier, which captures the increased purchase of inputs required by industries to produce the additional output to meet the change in final demand; iii) The induced multiplier, which measures changes in household spending, resulting from the changes in employment generated by the direct and indirect multipliers; and iv) the total impact multiplier, which is an aggregate of the direct, indirect and induced effects (Boughanmi *et al*. 2002).

Given the multiplier matrix $(1\text{-A})^{-1}$ and the final demand for goods and services, the output level that satisfies the demand can be computed by multiplying the multiplier matrix by the final demand. That is

$$(1 - A)^{-1} * F = Y^{1} \qquad (5.5)$$

Equation 5.5 is used to validate the computed multipliers and also shows the impact of exogenous shocks to the entries in the social accounting matrix on output, through its impact on the coefficient matrix, hence the multipliers. To capture the changes in output, the former level of output before the shock is subtracted from the new level of output after the exogenous shock. The difference shows the change in output resulting from the shock, which alters the level of intermediate demand in different ways for the various sectors, hence the different elements in the coefficient matrix. The change in output resulting from the reallocation of water from one sector to the other is shown as:

$$\Delta Y_i = (1 - A_2)^{-1} * F - (1 - A_1)^{-1} * F = [(1 - A_2)^{-1} - (1 - A_1)^{-1}] * F \qquad (5.6)$$

Where ΔY_i represents the change in sectoral output for sector 'i' which results from the change in the level of water allocation and its impact on the technical coefficients matrix (A_1 to A_2) that result from the shocks applied to the SAM. Equation 5.6 shows the change in output arising from changes in the entries due to policy implementation, which in turn lead to increases or decreases in intermediate input requirements. The technical coefficients change because the shocks lead to a change in the input requirements. This has consequences for the production sectors. This framework is used to investigate the impact of reallocating water from agriculture sector to the non-agriculture sectors on output, employment, factor payments and households' income generation and redistribution.

Reallocation of water from agriculture to the non-agriculture sectors directly leads to a decline in the output of the agriculture sector. This leads to a decrease in the technical input requirements for the agriculture sector, which is directly or indirectly transmitted to the other production sectors. Firstly, all the sectors that produce these inputs are impacted directly, the intermediate demand for their output declines, resulting in the decline in the production of those intermediate inputs, and consequently the output from these non-agriculture sectors are expected to decline. Secondly, sectors that directly depend on the output of the agriculture sector for their intermediate input requirements are also impacted. A decline in the production of these inputs leads to a decrease in the use of these inputs or a switch to their importation from more expensive sources. The degree of impact depends on the inter-industry dependency between these sectors and the agriculture sector. For example; the food, beverages and tobacco manufacturing sector, which uses inputs from agriculture and the services sector, which supplies the intermediate inputs for agriculture are impacted more by a decline in agriculture's output than the mining, electricity and construction sectors.

The changes in output that result from water reallocation from low to high-value uses have some significant impact on the use of primary factors. However, within the short-run the use of capital is assumed to be constant, but the employment of labourers is immediately impacted by the level of change in sectoral output. The increase or decrease in output will lead to hiring or firing labourers respectively in the production sectors. The outputs of sectors that gain from the water reallocation are expected to increase, while those of agriculture and the highly inter-dependent sectors are expected to decline. Workers are laid-off in sectors with declining outputs and hired by the sectors with increasing output. The net effect leads to either job creation or losses. The wage is assumed to be constant and the quantity /value of output per worker is used as the coefficient to determine the number of workers hired or fired by every sector as result of the policy implementation (Sadoulet and de Janvry 1995). This relationship is explained by equation 5.7.

$$L = \kappa Y \quad (5.7)$$

Where 'L_i' is the number of labourers employed by sector 'i', 'Y' is the output produced by this number of labourers (other primary factors are assumed to be constant in the short-run) and k the coefficient indicating the number of labourers required to produce a unit of output. Therefore, any change in output (ΔY) affects the number of labourers employed by the constant coefficient k.

$$\Delta L = \kappa \Delta Y \quad (5.8)$$

Using this, the study investigates the number of jobs created or lost due to the reallocation of water from low to high-value uses.

5.3.2 The simulation techniques

The main purpose of this chapter is to investigate whether water reallocation from the agriculture (which has the least marginal value of water), to the other sectors on the basis of sectoral marginal values of water will simultaneously promote water use efficiency and social equity. Efficiency in this context refers to growth in output and value added at factor cost, while social equity refers to job creation and the income generation and redistribution in favour of the low-income households. This study considers equity to the benefits of efficient water use and not equity in access to the physical asset. Therefore, after computing the social accounting matrix multipliers using the steps explained in section 5.3.1, a specified quantity of water is experimentally reallocated from the agriculture sector to the non-agriculture sectors using the computed sectoral marginal values of water as coefficients of this reallocation mechanism. These sectoral marginal values were estimated in chapter four and are reported in column 3 of Table 4.3. Water is reallocated from the agriculture sector because agriculture has the least marginal value of water. The following experiments are carried out.

Scenario 1: Forty percent of total water used in the agriculture sector is reallocated to the other production sectors on the basis of their respective marginal values. This is done by multiplying the total quantity to be allocated by the coefficient in column 2 of Table 5.1. These coefficients are based on the sectoral marginal values computed in chapter four and reported in column 3 of Table 4.3. The total coefficient is 1.000. Sectors with higher coefficients like leather and wearing apparel, and construction receive more of the reallocated water from agriculture than those with lower coefficients. The simulation results of this experiment are presented in Tables 5.1, 5.2, 5.3, 5.4 and 5.5.

Scenario 2: This follows the same procedure in scenario 1, but instead of 40 percent of total volume of water, only 20 percent is reallocated and distributed among the other production sectors on the basis of the estimated sectoral marginal values of water.

Scenario 3: Follows all of scenario 1, but only 10 percent of water used in the agriculture sector is transferred and distributed among the other production sectors on the basis of the estimated sectoral marginal values of water.

Scenario 4: The same procedure as in scenario 1, but only five percent of the total water used in the agriculture sector is transferred and distributed among the other production sectors on the basis of the estimated sectoral marginal values of water.

All the simulation results of these experiments are presented in Tables 5.1, 5.2 and 5.3, 5.4 and 5.5

5.4 PRESENTATION AND DISCUSSION OF SIMULATION RESULTS

The section is divided into two parts. The first part discusses the contribution of water to output growth, factor remuneration and households' income generation, while part two discusses the impact of reallocating water from agriculture to the other on output growth, job creation/losses, factor remuneration and households' income generation under the different scenarios discussed in sub-section 5.3.2

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The marginal values which are used in the simulation were econometrically estimated and computed in chapter four, using the two-stage model and marginal productivity approach. The computed marginal values show that the machinery and equipment manufacturing sector has the highest marginal value of water, followed by petroleum, heavy manufacturing, services, and mining respectively. The marginal value of water in the chemicals, leather and wearing apparel, and agriculture sectors are among the least.

5.4.1 Contribution of water to economic activities in South Africa

Column 13 of Table C2 in Appendix 3 presents the contribution of water to the economy generally, and specifically to output growth, factor remuneration and households' income generation. The multipliers show that for every Rand increase in investment in the water sector, output grows by about R6.67, while payments to the primary factors of production increase by R1.49 and R1.01 is generated as households' income. In terms of output growth, water contributes more to the services sector than the others; followed by agro-industries. The agriculture sector is again among the sectors that have the least direct contribution from water, although it is the most intensive user of water.

Water's contribution to factor remuneration is highest for capital, followed by unskilled, medium-skilled and skilled labour respectively. Overall, water does not contribute as much to value added as it does to output growth. Since the contribution of water to agriculture and the marginal value of water in this sector are minimal, there is enough justification to reallocate water from agriculture to the other sectors.

5.4.2 Reallocating water among the production sectors on the basis of efficiency

The simulation results of the experiments described in sub-section 5.3.2 are presented in the Tables 5.1 and 5.2. The study first discusses the impact on output growth, followed by the impact on employment and value added at factor costs and finally, households' income generation and redistribution.

5.4.2.1 Impact of water reallocation on output

The simulation results show that the reallocation of 40 percent of water from agriculture to the non-agriculture sectors can potentially lead to an overall decline of R1028.34 million in sectoral output. However, output increases in some sectors, while it declines in the others. It declines by R3516.88 million in the agriculture sector, R226.90 million in the food, beverages and tobacco manufacturing sector and R93.51 million in the services sector. Conversely, output increases by R1020.55 million in the mining sector, R889.41 in the leather and wearing apparel sector and R531.8 million in other manufacturing. Details about the absolute changes in output due to water reallocation from agriculture to the other sectors are presented in Column 4 of Table 5.1. The overall net decline in output is about

0.03 percent, which suggests that the decline in agricultural and the allied sectors' output are not offset by the increase in the receiving sectors' output. Output declines by 3.27 percent in the agriculture sector. Details about the percentage changes in output due to 40 percent water reallocation from agriculture to the non agriculture sectors are reported in Column 3 of Table 5.2.

Table 5.1: The contribution of water to sectoral output under different allocation scenarios

Sectors	Coefficients (2)	Base output (Rm) (3)	Water reallocation scenarios and changes in sectoral output			
			40% (4)	20% (5)	10% (6)	5% (7)
Agriculture(1)	-	107 549.3	(3516.88)	(2296.01)	(1231.43)	(410.42)
Mining	0.0298	18 6475.6	1020.55	853.41	736.62	299.36
Agro-industry	0.1680	23 8395.7	(226.90)	(156.40)	-89.6	45.85
Leather & wearing	0.2358	80 312.64	889.44	436.42	350.55	125.80
Paper, pulp & printing	0.0264	79 506.52	65.48	50.69	9.69	4.15
Petroleum	0.0551	82 195.24	44.71	27.88	17.33	2.29
Chemicals	0.0135	148 622.5	7.36	6.058	5.94	4.97
Heavy manufacturing	0.0479	175 957.8	45.84	35.99	24.58	2.95
Machinery& equipments	0.0754	295 222.1	36.34	44.17	28.33	3.62
Other manufacturing	0.0370	100 214.2	531.83	409.9	497.86	249.97
Electricity	0.0109	57 311.97	131.50	13.04	1.28	1.07
Water	-	18 218.11	0.05	0.53	0.52	0.43
Construction	0.2591	150 434.8	35.91	26.47	25.95	15.17
Services	0.0408	1 824 883.0	(93.51)	7.5	32.73	479.73
Total change in sectoral	**1.0000**	**3 545 299.03**	**(1028.34)**	**(540.37)**	**410.62**	**824.90**

In the second scenario where only 20 percent of water in the agriculture sector was reallocated to the non-agriculture sectors on the basis of their respective marginal values, overall output declines by R540.37 million. This figure represent about 0.015 percent decline in output from the base figure. Output declines in the agriculture and food, beverages and tobacco manufacturing sectors. The potential decline in the agricultural sector's output is R2296.01 million or 2.135 percent of the base output of this sector. In the food, beverages and tobacco manufacturing sector output declines by R156.40 million, which accounts for 0.066 percent of the sector's base output. However, the services sector is not significantly affected by this experiment.

Table 5.2: Impact of water reallocation on sectoral output under different scenarios

Sectors	Base output	Water reallocation scenarios and percentage changes in sectoral output			
		40%	20%	10%	5%
(1)	(3)	(4)	(5)	(6)	(7)
Agriculture	107 549.30	(3.270)	(2.135)	(1.145)	(0.382)
Mining	186 475.60	0.547	0.458	0.395	0.161
Agro-industry	238 395.70	(0.095)	(0.066)	(0.038)	0.019
Leather & wearing apparel	80 312.64	1.107	0.543	0.436	0.157
Paper, pulp & printing	79 506.52	0.082	0.064	0.012	0.005
Petroleum	82 195.24	0.054	0.034	0.021	0.003
Chemicals	148 622.50	0.005	0.004	0.004	0.003
Heavy manufacturing	175 957.80	0.026	0.020	0.014	0.002
Machinery& equipments	295 222.10	0.012	0.015	0.010	0.001
Other manufacturing	100 214.20	0.531	0.409	0.497	0.249
Electricity	57 311.97	0.229	0.023	0.002	0.002
Water	18 218.11	0.000	0.003	0.003	0.002
Construction	150 434.80	0.024	0.018	0.017	0.010
Services	1 824 883.00	(0.005)	(0.000)	0.002	0.026
Total change in sectoral output	**3 545 299.03**	**(0.029)**	**(0.015)**	**0.012**	**0.023**

As in the first experiment the outputs of most of the receiving sectors increase as expected, though this increase does not offset the decline in the losing sectors. Specifically, the output of the mining sector increases by R853.41 million, which is 0.46 percent of the base output, while the leather and wearing apparels output increases by R436.42 million. Details about the absolute output increase or decrease is reported in column 5 Table 5.1 and the percentage increases or decreases are reported in column 4 of Table 5.2.

The third experiment investigates the possible impact of a ten percent water reallocation from agriculture to the non-agriculture sectors on the basis of their marginal values. Unlike the first and second scenarios, this result of this experiment shows a net increase in output of R410.62 million. This indicates a 0.012 percent increase in output from the base output. As in the first two scenarios the outputs of the agriculture and food, beverage and tobacco manufacturing sectors decline by R1 231.01 million and R89.62 million respectively. The output decline in agriculture is approximately 1.145 percent of the base output, while that of food, beverages and tobacco manufacturing accounts for 0.038 percent of the base output. However, the outputs of the other non-agriculture sectors increased. The most prominent potential increase is recorded in the mining sector of R736.62 million, which accounts for 0.395 percent of the base output in that sector. This is followed by increases in the output of other manufacturing and leather products and wearing apparel sectors. These recorded R497.86 million and R350.55 million increases in output respectively. Overall the result of the experiment indicates a net increase of R410.62 million, which is 0.012 percent of total base sectoral output.

The results of the fourth scenario, which investigates the impact of a five percent reallocation of water from the agriculture sector to the non-agriculture sectors, are presented in Column 7 of Table 5.1 and the percentage interpretations are presented in Column 6 of Table 5.2. The results show a possible decline in agricultural output by R410.42 million which is 0.382 percent decline in base output. However, unlike the other scenarios, this experiment records an increase in the output of all the other non-agriculture sectors including services and food, beverages and tobacco manufacturing sectors. The overall impact records a net increase in output of R824.90 million, which is 0.023 percent increase in total base output. While the decline in agricultural output is minimal at thus level of water transfer, the increase in the output of the non-agriculture sectors leads to high net increase in overall output, though the percentage reallocation of water was minimal.

There are two possible reasons for the experimental results reported in Tables 5.1 and 5.2: the inter-sectoral linkages and the absorptive capacity of the receiving sectors. Firstly, the agriculture sector has forward and backward linkages with the other sectors in the economy. Output from the agriculture sector serves as input in the other sectors. The most prominent of these is the food, beverages and tobacco manufacturing. A decline in the output of the agriculture sector means that the intermediate inputs it provides for the food, beverages and tobacco manufacturing also declines, which reduces the production capacity of this sector as indicated by the results of the first three experiments. This is true for all the other sectors, except that this forward linkage is not strong enough to alter the production pattern of the other sectors. Agriculture also buys intermediate inputs from the other sectors. The most prominent of these is the services sector. Hence, any decline in the output of the agriculture sector implies that less intermediate inputs from the services sector are used, leading to a decline in the output of the services sector. Therefore, though these highly inter-dependent sectors receive water from the agriculture sector, their outputs decline. This is explained by the results of the first two scenarios. If the decline in the output of the agriculture sector is not quite significant to alter the production activities of these highly dependent sectors, they sectors can absorb the shock and still maintain a net increase in the output, to supply other sectors. This is explained by the results of the third and fourth scenarios.

Secondly, while some sectors have high marginal values of water, they are not intensive users of the resource. Hence, their capacity to absorb the reallocated water from the agriculture sector is quite limited. Therefore, the addition to output resulting from the addition of water is likely to be minimal when the receiving sectors' absorptive capacities are exceeded. This is true for machinery and equipments, chemical manufacturing, construction and heavy metal manufacturing sectors. The increase in the output of these sectors resulting from the reallocation of water from the agriculture sectors does not offset the decline in the output of the agriculture sector. To institute water use efficiency, the experimental results show that the percentage of agricultural water to be reallocated should not exceed ten percent. When this is exceeded the allocation is inefficient, as it leads to net output decline.

5.4.2.2 Impact of water reallocation on factor remuneration

This sub-section explains the impact of water reallocation from the agriculture to the non-agriculture sectors on payment to the primary factors of production. As output falls, the remuneration to the factors of production is affected. Within the short-run capital investment is not as significantly affected as the remuneration to employees.

A forty percent transfer of water from the agriculture sector to the non-agriculture sectors significantly alters total remuneration to both skilled and unskilled labourers.

Table 5.3: Impact of water reallocation on factor remuneration under the different scenarios

Primary factors	Base remuneration	Water reallocation scenarios			
		40%	20%	10%	5%
(1)	(2)	(3)	(4)	(5)	(6)
Capital	370 416.37	0.713	0.691	0.478	0.07
		0.000%	*0.000%*	*0.000%*	*0.000%*
Unskilled labour	141 514.46	(765.57)	(420.03)	(217.005)	50.00
		(0.541%)	*(0.287%)*	*(0.153%)*	*0.035*
Medium skilled labour	169 071.87	331.17	256.45	226.27	80.58
		0.196%	*0.152%*	*0.134%*	*0.048%*
High skilled labour	86 538.55	24.43	16.08	3.07	0.03
		0.028%	*0.019%*	*0.004%*	*0.000%*
Total impact on factor remuneration	**767 541.25**	**(409.256)**	**(146.801)**	**12.815**	**130.688**
		(0.053%)	***(0.019%)***	***0.002%***	***0.017%***

This experiment records a reduction in total wage bill to unskilled labourers by R765.57 million, which is 0.54 percent of the base wage bill, while the wage bill of both medium and high skilled labourers increase by R331.17 million (0.2 percent) and R24.43 million (0.03 percent) respectively. However, the overall effect shows a decline in factor remuneration by R409.26 million, which is 0.05 percent of the base remuneration package. Similarly, the transfer of twenty percent of water from agriculture to the non-agriculture sectors shows that total factor payments decline by R146.80 million. As in the first scenario, the wages of unskilled labourers decline by R420.03 million (0.29 percent), while those of medium and high skilled labourers increase by R256.45 million and R16.08 million respectively indicating 0.15 percent and 0.019 percent increase from the base figures.

Unlike the first and second scenarios, the third scenario indicates a net increase in factor remuneration by R12.82 million, which is 0.002 percent of the base remuneration. As in the first and second scenarios, the wages of unskilled labourers decline, but this is offset by the increase in the total remuneration to medium and high skilled labourers.

The fourth scenario shows the same pattern but with a higher net increase in factor payments of R130.69 million, which shows a percentage increase of 0.02 percent in the total base remuneration.

The possible reason for this pattern of change in factor remuneration is that the majority of the employees in the agriculture sector are unskilled labourers. When output in this sector declines, most of those laid off are these unskilled labourers and the non-agriculture sectors cannot absorb all those laid-off by the agriculture sector. The manufacturing sector for example requires medium level skilled individuals for most of the technical operations. The mining sector alone cannot absorb most of the laid-off labourers. This leads to a significant decline in the unskilled labour remuneration.

The fourth experiment indicates that with a minimum reallocation of water, the number of labourers laid-off in the agriculture sector is absorbed by the non-agriculture sectors that benefit from the reallocation, leading to net increase in factor remuneration.

5.4.2.3 Water reallocation and employment in the economy

The alterations in output due to water reallocation from the agriculture to the non-agriculture sectors have consequences for job creation or losses in an economy characterized with a high level of unemployment. As explained in the theoretical framework, a decline in sectoral output leads to loss of jobs in that sector and an increase in sectoral output stimulates job creation. As already shown in section 5.4.2.1 with a significant transfer of water from agriculture to the non-agriculture sectors, the outputs of the agriculture, food, beverages and tobacco manufacturing and the services sectors decline while the output of the other non-agriculture sectors increase. The potential jobs that will be created or lost due to the experiments are reported in Table 5.3.

In the first experiment, a 40 percent reallocation of water from agriculture to the non-agriculture sectors results in a potential loss of 7081 jobs. Because of the decline in the agriculture sector's output, 24 427 jobs are lost in this sector, while most of the non-agriculture sectors create jobs as result of the increase in their outputs. The potential job losses outweigh the potential jobs created. This results in a net job loss. Details are reported in Column 2 of Table 5.4.

The second scenario shows a net job loss of 2127, with 15 367 jobs lost in the agriculture sector and 406 potential job losses in the food, beverage and tobacco manufacturing sector. The other sectors record a potential of 13 646 jobs created. The potential job losses outweigh the potential jobs that can be created by this experiment. Details are reported in column 3 of Table 5.4

The third experiment records 143 net jobs created. The agriculture sector records 12 551 job losses, but the jobs created by the other sectors outweigh the job losses. This implies that a ten percent water reallocation from the agriculture sector to the non-agriculture sectors can lead to job losses in the agriculture sector and job creation in the non-agriculture sectors. In the last experiment, reallocation of five percent of water from agriculture to the non-agriculture sectors potentially leads to 260 net jobs.

Table 5.4: Water reallocation and job creation under different scenarios

Sectors	Water reallocation scenarios and Job losses/creation			
(1)	40% (2)[4]	20% (3)	10% (4)	5% (5)
Agriculture	(24 427)	(15 367)	(12 551)	(7 452)
Mining	7 587	5 672	4 032	1 639
Agro-industry	(589)	(406)	30	119
Leather & wearing apparel	8 278	6 062	5 262	1 171
Paper, pulp & printing	237	184	35	15
Petroleum	38	24	15	2
Chemicals	14	11	11	9
Heavy manufacturing	169	133	91	11
Machinery& equipments	76	92	59	8
Other manufacturing	1 698	1 209	2 733	798
Electricity	365	36	4	3
Construction	222	163	160	94
Services	(749)	60	262	3843
Total change in sectoral output	**(7 081)**	**(2 127)**	**143**	**260**

[4] Numbers in parenthesis are negative

The experiments show that when a minimum quantity of water is reallocated from agriculture to the non-agriculture sectors on the basis of marginal values, the potential exists for jobs to be created. If these minimum quantities are exceeded, the sectoral output and factor payments are expected to decline, leading to net job losses. The job losses in the agricultural sector are not necessary taken up by the non-agriculture sectors because of differences in skill requirements in these sectors. While the agriculture sector employs more unskilled labourers, the manufacturing, mining and construction sectors require more medium and high skilled labourers.

5.4.2.4 Water reallocation and households' income generation and distribution.

The potential alterations in output and the possible impacts on factor payments and job creation/losses have some implications for the generation and distribution of households' incomes. The potential impact of each of the four experiments on households' income generation and distribution is analyzed for the five household categories in South Africa, according to their economic status. The results are reported in Table 5.5

The results of the first experiment show a net decrease in households' income by R304.826 million, which is 0.051 percent of the total households' base income. This means that a forty percent reallocation of water from the agriculture to the non-agriculture sectors can possibly lead to total decline in households' income by R304.286 million. The analysis shows that the least-income and low-income households' incomes decline by R169.879 million (0.961 percent of base income) and R467.723 (1.394 percent of base income) respectively.

Table 5.5: Impact of water reallocation on households' income under different scenarios

Household category (1)	Base household Income (2)	Water reallocation scenarios			
		40% (3)	20% (4)	10% (5)	5% (6)
Least-income households	17 674.926	(169.879)	(145.035)	(72.724)	(47.017)
		(0.961%)	*(0.821%)*	(0.411%)	*(0.266%)*
Low-income households	33 553.951	(467.723)	(402.002)	(257.937)	(126.001)
		(1.394%)	*(1.198%)*	*(0.769%)*	*(0.376%)*
Middle-income households	281 996.433	220.936	179.332	115.366	102.158
		0.078%	*0.064%*	*0.041%*	*0.036%*
High-income households	146 835.814	101.388	93.983	130.727	96.315
		0.069%	*0.064%*	*0.089%*	*0.066%*
Highest-income households	114 287.263	10.992	8.765	6.926	3.357
		0.010%	*0.008%*	*0.006%*	*0.003%*
Total impact on households income	**594 348.035**	**(304.286)**	**(264.957)**	**(77.642)**	**28.812**
		(0.051%)	***(0.045%)***	***(0.013%)***	***0.005%***

While the incomes of the two lowest-income households decline, the potential exists for the incomes of the middle, high and highest-income households to increase. However, this increase is not enough to dampen the effect of the decline in the incomes of the lowest-income households. Detailed potential impact of the experiment on households' income is presented in Column 3 of Table 5.5.

A similar pattern of result is displayed for a twenty percent reallocation of water from the agriculture to the non-agriculture sectors. This shows a potential decline in households' income by R264.957 million. The income of the two low-income households declines by R145.035 million and R402.002 million. The middle and high-income households' incomes is expected to increase, although the potential increase is less than the decline in the lowest-income households' incomes. Column 4 of Table 5.5 records the detailed potential impact.

Although the magnitude of net decline in households' income is not as much as in the first and second experiments, the third experiment also records similar pattern of impact. This implies that even with only ten percent reallocation of water from the agriculture to the non-agriculture sectors, poor households are still expected to loss income, while the gain in income by the middle and high-income households is not enough to generate a net increase in households' income.

The results of the fourth simulation record a net increase households' income, although the incomes of the poor households decline. In the fourth scenario, where only five percent of water is reallocated to the non-agriculture sectors, the middle and high-income households' incomes has the potential of increasing more than the decline in the lowest-income households' income. This can only lead to a welfare gain if the winners are ready to adequately compensate the losers.

When output falls in the agriculture sector, the sectors that use agricultural output as intermediate inputs and those that supply the required intermediate input for agriculture are directly affected. The outputs of the non-dependent sectors are expected to increase. Whether the increase outweighs the decrease, the net effect depends on both the quantity of water reallocated from agriculture to the non-agriculture sectors and the absorptive capacity of the receiving sectors. The experimental results show that this leads to a decline in the output of these sectors. The results also indicate that for a positive net increase in output water transfer from the agriculture sector should not exceed ten percent. Five percent reallocation has a greater positive impact on output than ten percent.

Alterations in output have direct consequences for factor remuneration, employment and households' income generation and distribution. Sectors that potentially benefit from the water reallocation experience output growth, while the potential losers experience output decline. Those with the potential to increase output employ more labourers, while the sectors with a potential decline in output lay-off labourers. The net effect may lead to job creation if the winners create more jobs than the number of jobs lost, or job losses if the winners cannot absorb all the labourers laid-off by agriculture and its allied sectors. The simulation results show that at if the ten percent level of water reallocation is exceeded more jobs are lost than created. This impact, when translated into monetary terms, indicates the alterations in wages, and consequently households' income. The experimental results indicate that the total wage bill for unskilled labourers declines in the first three scenarios and has minimal increase of 0.035 percent in the last experiment. The total wage bills for the medium and highly-skilled labourers increase in all the scenarios. This increase is not large enough to compensate for the decrease in the wage bill of the unskilled labourers in the first two experiments, leading to a net decline in labour remuneration. This is directly transferred to the households' income generation. Because the majority of the unskilled labourers are the lowest-income households, a decline in unskilled labourers total wage bill leads to a decline in the income of the lowest-income households although in some of the scenarios, there is a positive net household income generated. This may be due to increased remittances from the middle-income earners, the majority of whom are medium skilled labourers.

5.5 SUMMARY AND CONCLUSIONS

Using the traditional SAM multiplier analysis, this study analyzed the contribution of water to the various sectoral activities and estimated the potential impact of reallocating water from agriculture to the non-agriculture sectors on the basis of the marginal revenue of water in the various non-agriculture sectors.

The findings show that although agriculture's marginal returns to water use in South Africa is not as high as the manufacturing and mining sectors; it plays a major role in income generation and creating jobs for the low-income households in the country. It has forward and backward linkages in the economy, which are not captured in the direct impact analysis. Therefore, any water reallocation strategy that significantly alters the production structure in this sector will be transmitted to the most vulnerable population in the economy. All the simulation results show that any level of water transfer from agriculture to the other sectors significantly alters agricultural output and consequently leads to a decline in the incomes of most vulnerable households (least-income and low-income households), making them poorer. The results also show any level of water transfer from agriculture leads to net job losses. This means that the number of jobs lost in the agriculture sector are not created in the non-agriculture sectors to effect a not job creation.

The simulation model used assumes strict linearity and constant prices are constant. It also assumes that causal relationships among sectors, factors of production and institutions are purely demand determined. The simulation results could be different if a combination of linear and non-linear relationships is used in the modeling procedure. Also by relaxing the assumption of constant prices and allowing price flexibility in both the factor and output markets may lead to different simulation results. There is also the need to show how households respond to changes in the level of income by altering their expenditure patterns. These require the use of a Computable General Equilibrium model to investigate the impact of inter-sectoral water allocation policies on the economy.

CHAPTER SIX

A COMPUTABLE GENERAL EQUILIBRIUM APPROACH TO ANALYSE THE HOUSEHOLDS' WELFARE EFFECTS OF CHANGES IN SECTORAL WATER USE IN SOUTH AFRICA

6.1 INTRODUCTION

In Chapter Four, the econometric analysis showed that the agriculture sector has the least marginal value of water when compared to the other sectors. Using the computed marginal values as coefficients in a SAM multiplier analysis, chapter five investigated how water reallocation from the agriculture sector to the non-agriculture sector impacts output, value added, households' income generation and job creation. The simulation results show that any level of water transfer significantly alters output in the agriculture sector, which leads to a decline in poor household's income and net job losses. However, SAM analyses assume linearity, constant prices, no substitution of inputs and that the model is demand driven. Therefore, it is highly possible that the SAM multiplier analysis of the preceding chapter may have overstated or understated the overall impact of water reallocation from the agriculture to the non-agriculture sector. Thus, a Computable General Equilibrium (CGE) analysis, which relaxes the assumptions of SAM analysis, is required to investigate the impact of alterations in current sectoral water allocation on sectoral output, value added and households' welfare. Studies show that the agriculture sector uses a higher percentage of South Africa's freshwater resources than the mining, manufacturing and service sectors, but has the least percentage contribution to GDP (DWAF, 2005). Using this information and the empirical findings of chapters four and five, it is hypothesized that water reallocation from agriculture to the non-agriculture sectors can lead to an increase in GDP and an improvement in the welfare of the low-income households. Berrittella *et al.* (2007) developed the GTAP-W version from the GTAP-E data and applied the CGE model to investigate the economic impact of restricted water supply. The results suggest that there are regional winners and losers from water supply constraints and that because of the distortions of agricultural markets, water supply constraints could improve allocative efficiency and that the welfare gains more than offset the loses from such constraints. The findings shed light on a critical international water use constraints, but global models are often not reflective country specific situations. Therefore, the need exists to investigate these findings at country specific, while examining the role of international water market in national water use efficiency. In a related study, Letsoalo *et al.* (2007) used the CGE model to analyze the proposal of the South African government to reduce water consumption by introducing water resource management charges. They authors also investigated the effectiveness of tax reforms in efficient water management in the country. The simulation results show that a budget-neutral combination of water charges, particularly in irrigated agriculture and coal mining, and reduced indirect taxes, particularly on food would yield triple dividend, which include reduced water use, more rapid economic growth and a more equal income distribution, hence, reduces the level of poverty in the country. The analytical results of the study are quite novel and have relevant policy implications for a country where poverty reduction is high on the development agenda. However, limiting the number of sectors to only irrigated agriculture and mining, while industrial water use intensity is increasing in the country is a crucial limitation to the findings. These oversights and limitations need a more detailed country level study. Therefore, this chapter is designed to:

i) make adjustments to the social accounting matrix that was used in chapter five

ii) include the industrial, construction and services sectors in analyzing critical water issues in South Africa, and

iii) investigate the impact of global change and water reallocation from agriculture to the non-agriculture sectors on sectoral output, value added and general households' welfare.

The next section explains the theoretical and empirical modeling framework of the computable general equilibrium model and its application in this study. It also discusses the different experimental simulations carried out by the study. Section 6.3 presents simulation results while 6.4 discusses the empirical finding and Section 6.5 summarizes the empirical findings and provides conclusions of the study.

6.2 DATA, THEORETICAL FRAMEWORK AND SIMULATIONS

This section is sub-divided into the description of data and its sources, the theoretical framework and modeling procedure.

6.2.1 Description and sources of data

The study uses an updated version of 1999 social accounting matrix the 1999 for South Africa, which was developed by Thurlow and van Seventer (2002). The 43 activities and 43 commodities are consistent with the time series data compiled by South Africa's Trade and Industrial Policy Strategies (TIPS). Therefore the 1999 entries for activities and commodities were updated by using the figures of 2003 supply-use tables extracted from the TIPS data set. The information on household income and expenditure patterns were extracted from Statistics South Africa 2001 census figures. The SAM has four factors of production; capital, unskilled labour, medium skilled labour and highly skilled labour.

There are three main institutions; comprising fourteen household categories, firms and government. The remaining accounts are the net savings-investment accounts and the rest of the world.

6.2.2 Treatment of water and SAM aggregations

As a key factor in this study, the treatment of water is given special attention, hence, a detailed description of the sources of water data. The water supply information is from the municipalities' billing records. This grossly understates the actual water used by the different sectors, because most sectors use self-supplied water, which is not accounted for in the current SAM.

In Thurlow and van Seventer (2002), water is treated as a production sector, with the row accounts showing water used as a fixed intermediate input by each of the other production sectors and as a final good by households. It also shows payments received from the other production sectors and institutions to the water sector. The column entries show payments by the water sector to the other sectors for the use of other intermediate inputs and to the factors of production for the use of the factors services. However, the allocation of water as a fixed intermediate input cannot be studied in a standard CGE framework. Therefore, to make the data compatible for a CGE analysis, water is modeled as a factor of production and not as a fixed intermediate input.

As a factor of production, the row accounts represent distribution of water among the production sectors and the respective tariffs paid by these production sectors. Domestic water use and the ecological reserve are exogenously determined by the water distribution authorities before the residual is distributed among the production sectors. This is in accordance with Schedule 1 which stipulates that each person is entitled to 25 liters per day, as a basic right for all South Africans and that the ecological reserve requirement of at least 10 percent (DWAF, 2005).

All water tariffs paid by the production sectors accrue to the municipalities, which are the local representatives of the national government, the custodian of the nation's water resources. Conversely, the amount received by each municipality as the national government's representative is used to pay for water delivery services. Government also pays the rest of world for the use of water from sources outside South Africa. This transformation of water account from a production sector to a factor of production generally leads to decline in households' income by six percent and sectoral output by 5.3 percent, while it leads to an increase in value added by seven percent.

To ensure that the SAM balances after the transformation the row total for each account is subtracted from the corresponding column total. A zero difference between each row account and its corresponding column account shows that the SAM is balanced (See appendix 4 for the adjusted SAM). The column coefficients for each account sum up to unity.

For the purpose of this study the updated SAM was aggregated to 13 activities/commodities, five factors of production, enterprises account, five household categories, government account, investment and the rest of the world. The agriculture sector, consisting of agriculture (crop production and animal husbandry), forestry and fishing accounts, were aggregated to agriculture; while coal, gold, uranium and other mining were aggregated to mining activities/commodities. Using the three-digit ISIC codes the manufacturing sector, consisting of 41 activities and 41 commodities were aggregated to 12 activities/commodities accounts consisting of agro-based industries (food, beverage and tobacco manufacturing); textile and wearing apparel (textile, wearing apparel, leather and leather products and footwear); wood, paper and paper products (wood and wood products, paper, paper products, printing, recording and recorded media); petroleum products; chemicals (basic and other chemicals); heavy manufacturing (non-metallic minerals, basic iron and steel, basic non-ferrous metals and metal products excluding machinery); machinery and equipments (machinery and equipment, electrical machinery and apparatus, TV, radio and communication equipments, motor vehicles and spare parts and professional and scientific equipments); electricity; construction (building, civil engineering and other construction); services (wholesale and retail trade, catering and accommodation, transport and storage, communication, business, medical, dental and veterinary, other professional and general government services); and other manufacturing. The aggregations reflect the structure of water use by the sectors and sub-sectors.

The capital and three labour categories in generic SAM were retained. After the transformation of water from a production sector to a factor of production five main factors of production are recorded in the updated SAM; capital, unskilled labour, medium-skilled labour and high-skilled labour, and water.

The fourteen household accounts in Thurlow and van Seventer (2002) are aggregated to five accounts, with the first two deciles reflecting the households that earn below 20 percent of the total income, the third and fourth deciles reflecting those that earn between 20 and 40 percent of total income, while the middle income households earn between 40 and 80 percent of the income structure and the rich (high and highest-income) households earning above 80 percent of the total income of the country. In South Africa, the majority of the people fall in the first two categories, and less than three percent is in the last two categories. Most of the poor households earn their income from the wages of unskilled labour and transfers from semi-skilled labour (Thurlow and van Seventer, 2002: 13). These households are the historically disadvantaged individuals (HDIs), whose past and current economic situation can hardly enable them get out of the poverty trap, hence their high dependence on welfare programmes and various levels of subsistent activities for their economic survival.

Government accounts, which were broken down into expenditure and income accounts (four accounts) in the disaggregated micro SAM are aggregated to net government accounts.

6.2.3 The theoretical framework and the empirical modeling procedure

This section is divided into the theoretical framework, households' welfare analysis and the modeling or experimental procedure.

6.2.3.1 The theoretical framework

The Computable General Equilibrium model is used to present a counterfactual picture of the impact of water scarcity on households' welfare in South Africa. The study adopts the

CGE framework used in Strzepek and Carbone (2007). Water scarcity for sectoral production activities results from climate change, population growth, externality problems and wasteful use of the resource. In the CGE model, water is presented as a factor of production and not a production sector as documented in the 1998 SAM for South Africa. The model has 13 production and consumption sectors, five primary factors of production and five consumer categories.

The model uses a set of multi-level nested CES production functions to determine the level of production. Consumption is also modeled as a set of CES nested expenditure functions. A CES function is also specified to establish the relationship between the unskilled, medium-skilled and high-skilled labour categories. While the short-run use of capital is assumed to be fixed and sector specific, water and the three labour categories are freely mobile across sectors except where specified. This allows the functioning of a competitive market for the factors. Thus factors move to sectors where there have higher marginal values. Details are documented in Strzepek and Carbone (2007). Water is assumed to have zero price at the benchmark situation or no cost to the production sector, but has a shadow price to each production sector equal to its marginal value in that sector. The free movement of these factors of production enhances the adjustment of wages for each of the three labour categories and water tariffs. The factor prices are the adjusting variables which lead to the market clearing equilibrium prices of these factors.

The SAM has four main institutions; firms, households, government and the rest of the world. There are five household categories according to the proportion of national income that they receive. While the incomes of the three labour categories and capital accrue to households, the study assumes that all water tariffs water accrue to government, which is used to pay for water delivery services.

Households receive income from labour wages, interest on capital and from both local and international transfers. Their disposable income is allocated to consumption after transfers, taxes and savings. Consumption expenditure is obtained by maximizing their utility function subject to the prevailing market prices. The model further assumes that households' propensity to save is fixed. Households' save a fixed proportion of their income, while investments adjust to the level of savings. This means that investment is driven by the level of savings. Interest rates adjust to equate savings to investments.

Sectoral output is sold to production sectors as intermediate input, consumed domestically, or exported. The model uses the constant elasticity of transformation function to formulate the imperfect substitution between domestic consumption of sectoral output and export. The same constant elasticity of substitution function is used to model the imperfect substitution of domestically produced goods and imported goods. The imperfect substitutability modeled above enhances the importation and exportation of the same goods and also investigates the impact of external forces on domestic prices.

The factor market for water is closed by assuming that the quantity of water used is fixed and that total sectoral water use is equal to the total sectoral water supply, hence no reserves except under the experimental simulations. The capital and labour markets are closed by assuming that the demand for these factors is equal to their supply. These assumptions imply full employment of the factors. The saving-investment closure assumes that savings equal investment and that government income is equal to the government spending.

The study uses the MPSE/GE software written by Rutherford and has MCP solver in GAMS, which can write and calibrate all CES and CET functions to three levels of nesting.

6.2.4 Household welfare analysis

The study uses the concept of equivalent variation (EV) to discuss and analyze the impact of the different water reallocation and global change scenarios on households' welfare. This concept is used to measure changes in welfare by comparing the level of households' utility at the given price and income in the base level to the level of utility achieved after a specific water reallocation or global change scenario (Chitiga and Mabugu, 2006). In principle, equivalent variation can be interpreted as the minimum amount of money that has to be given to the households to renounce a utility increasing project. For negative values, it is the maximum amount that households are willing to give up to prevent a utility decreasing change. As used in this study, equivalent variation (EV) is defined as the maximum amount households are willing to pay to prevent a decline in consumption levels due to water shortages. Alternatively, it is the minimum amount they are willing to accept to forgo an increase in consumption levels such that the same level of utility is maintained after the global change or sectoral reallocation of water. Functionally, equivalent variation is denoted as:

$$EV = \left(\frac{P_1^0}{P_1^1}\right)^{\gamma} \left(\frac{P_2^0}{P_2^1}\right)^{1-\gamma} Y^1 - Y^0 \qquad (6.1)$$

Where P_1^0 is the price of good 1 in the base model,

P_1^1 is the price of good 1 after the simulation,

P_2^0 is the price of good 2 in the base model

P_2^1 is the price of good 2 after the simulation

Y^0 is the income in the base model and

Y^1 is households' income after the simulation.

When EV is greater than zero, it implies welfare improvement and welfare deterioration when EV is less than zero. In discussing the experimental results, the words households' income and expenditures are used interchangeably to mean the same, since households spend their disposal income on consumption goods (Varian, 1992). An increase in households' expenditures or income implies welfare improvement, while a decrease implies welfare deterioration.

6.2.5 The experimental simulations

This chapter investigates the impact of different water allocation scenarios on households' income and expenditure. There are two scenarios that need detailed explanation.

i) Benchmark scenario

The benchmark situation is the one documented in the SAM, which reflects market distortions in South Africa. This implies that the price paid by the production sectors does not reflect the opportunity cost/shadow price of the resource. This situation results from the apartheid Riparian Act of 1956 which inter-links the ownership of land with water resources (DWAF, 2005). Column 2 of Tables 6.1 and 6.2 reports the current sectoral water allocation, which is referred to as the "benchmark allocation" in the analysis. This situation shows that the agriculture sector consumes more than 60 percent of the water available for sectoral production activities. Therefore, the incentive exists for a more pareto-optimal sectoral allocation of the resource.

Base scenario: The new water act makes water a national asset and the government is the custodian of all ground and surface water resources. As such, the efficient and equitable allocation of the resource is the policy option that the government seeks to attain. The study therefore allows a pareto-optimal allocation of water to attain market equilibrium. This situation is referred to as the base situation. That is, a pareto-optimal sectoral use of available water. In the experiments that follow, two base situations are recorded. Under the global change scenario the base scenario requires a pareto-optimal allocation for all the production sectors, but under the water reallocation experiments, agriculture sector's water remains in agriculture, while water in the non-agriculture sectors is allocated to pareto-optimum. This is referred to as the base scenario in this set of experiments.

Further simulations: Two sets of experiments are done. The first set of experiments is based on possible reductions in water availability for sectoral production activities, due to climate change, population growth, water policies and increased externality problems.. Climate change models on South Africa predict a 70 percent reduction in mean annual runoff (MAR) by 2050 in extreme circumstances. However, other models predict a milder MAR reduction of between 10 and 30 percent (Turpie *et al.*, 2002). It is also projected that domestic water use will increase in the future due to population growth and urbanization. This implies reduction in water availability for sectoral production activities. In addition to these factors, the current trend of industrialization and mining will increase the externality problems of water use. Furthermore, because of the concerns for a sustainable environment, South Africa has legislated that a certain percentage of water be reserved to meet the ecological needs of the environment. Currently, the ecological reserve is 10 percent, implying that 10 percent of water should be reserved for environmental use. There are debates to increase this reserve. All these projections, assumptions and legislation indicate that in the future, water use by the production sectors will decline. Therefore, the study simulates the impacts of a 10 percent, 20 percent and 30 percent reduction in total sectoral water use in South Africa. After the reduction in sectoral water use, the market allocates the remaining sectoral water to pareto-optimum.

The second set of experiments assume that the total quantity of sectoral water use remains constant and the sectoral water is either used in agriculture or the non-agriculture sectors. Water in agriculture is allowed to stay in agriculture, but the non-agriculture sectors' water is allowed to be allocated by the market mechanism among the non-agriculture sectors until a competitive equilibrium is achieved. This implies that non-agriculture water is mobile among the remaining twelve sectors. This situation is recorded as the base scenario. In the experimental simulations, five percent, 10 percent, 20 percent, and 40 percent of the agricultural sector's water is reallocated to the non-agriculture sectors. The reallocated water is redistributed among the non-agriculture sectors by the market mechanism. In addition, there is a run which simulates the impact of transferring ten percent of water from the non-agriculture sectors to the agriculture sector. In both sets of experiments, the counterfactual results are relative to the base scenario, which is the ideal scenario.

Both sets of experiments are run under two separate assumptions. The first assumption is that food consumptions levels are not maintained at the base level. The second assumption is that food consumption is maintained at the base level. For the second assumption to be realistic, the study assumes the distribution of food stamp among the poor households, which is equivalent to the welfare loss.

6.3 PRESENTATION OF SIMULATION RESULTS

The simulation results are presented in four sub-sections: Changes in sectoral water use under different global change and sectoral water reallocation, changes in households' consumption levels under the water reduction scenario and changes in households' consumption under the different water reallocation scenario.

6.3.1 Sectoral water use under different global change scenarios

From the experimental procedures explained in the last section, this section presents sectoral water use situation under different global change scenarios. The above experiments are counterfactual global change situations which form the basis for experimental simulations, hence, investigate the impact of these changes on water availability for sectoral use and its subsequent impact on households' welfare.

The table on the next page shows the quantity of water in each sector after the various simulations. Column 2 of Table 6.1 shows the benchmark distribution of water among the various sectors in South Africa. Column 3 shows the base sectoral water use situation after allowing the market mechanism to efficiently distribute water among the various sectors until a competitive equilibrium is achieved. Columns 4, 5 and 6 show the sectoral water use situation after the various global change simulations. Column 7 presents the counterfactual sectoral water use situation of possible increase in water availability due to infrastructural development and/or international in-transfer of water.

The captions m30, m20, and m10 imply 30 percent, 20 percent and 10 percent reduction in total sectoral water use in South Africa and allowing the market process to adjust the remaining sectoral water to a competitive equilibrium. The caption p10 in Column 7 implies increasing total sectoral water use by 10 percent. These simulations have consequences for household consumption/income and agriculture exports and imports which will be discussed under the household welfare and different food policy scenarios.

Table 6.1: Sectoral water use under different global change scenarios

Sectors (1)	Bench mark (2)	Base (3)	m30 (4)	m20 (5)	m10 (6)	p10 (7)
Agriculture	12.34	12.07	8.33	9.07	10.53	12.39
Mining	0.43	0.87	0.47	0.57	0.79	0.88
Agro-industry	0.22	0.21	0.28	0.24	0.22	0.20
Leather & wearing apparel	0.06	0.06	0.04	0.04	0.06	0.06
Paper, pulp &printing	0.09	0.08	0.09	0.09	0.08	0.08
Petroleum	0.02	0.01	0.01	0.01	0.01	0.01
Basic chemicals	0.07	0.09	0.08	0.08	0.09	0.09
Heavy manufacturing	0.12	0.15	0.18	0.17	0.16	0.15
Machinery & Equipment	0.02	0.02	0.03	0.03	0.03	0.02
Other manufacturing	0.03	0.03	0.04	0.04	0.04	0.03
Electricity	0.12	0.09	0.07	0.07	0.09	0.09
Construction	0.09	0.05	0.05	0.05	0.05	0.05
Services	2.08	1.95	2.12	2.10	1.98	1.94
Total	15.69	15.69	10.98	12.55	14.12	15.69

6.3.2 Sectoral water use under different water reallocation scenarios

In the second experiment, the simulations hold total sectoral water availability constant, maintain water use in the agriculture sector, and allow water in the non-agriculture sectors to be distributed by the market process. After the market allocation process, the study investigates the impact of reallocating water from agriculture to the non-agriculture sectors on households' welfare.

Table 6.2: Sectoral water use under different water reallocation scenarios

Sectors (1)	Bench-mark (2)	Base (3)	m40 (4)	m20 (5)	m10 (6)	m05 (7)	p10 (10)
Agriculture	12.34	12.34	7.41	9.88	11.11	11.73	12.68
Mining	0.43	0.42	2.05	1.54	1.29	0.89	0.38
Agro-industry	0.22	0.19	0.26	0.19	0.22	0.21	0.17
Leather & wearing apparel	0.06	0.06	0.25	0.16	0.09	0.06	0.05
Paper, pulp &printing	0.09	0.09	0.38	0.26	0.18	0.16	0.08
Petroleum	0.02	0.01	0.21	0.17	0.12	0.08	0.01
Basic chemicals	0.07	0.1	0.18	0.11	0.09	0.09	0.09
Heavy manufacturing	0.12	0.21	0.15	0.15	0.15	0.15	0.19
Machinery & Equipment	0.02	0.03	0.27	0.21	0.18	0.12	0.03
Other manufacturing	0.03	0.04	0.27	0.13	0.07	0.04	0.04
Electricity	0.12	0.09	1.12	0.79	0.48	0.19	0.08
Construction	0.09	0.05	0.25	0.15	0.09	0.08	0.05
Services	2.08	2.06	2.89	1.95	1.62	1.89	1.85
Total	15.69	15.69	15.69	15.69	15.69	15.69	15.69

The table above illustrates the sectoral water use under the different water reallocation scenarios.

Unlike the global change scenarios in the previous experiments, these experiments investigate the impact of percentage water transfers from the agriculture to the non-agriculture sectors on households' welfare. Column 2 of Table 6.2 shows the benchmark allocation and Column 3 presents sectoral water use situation after achieving market equilibrium for non-agriculture water, while maintaining the level of water use in the agriculture sector. Columns 4, 5, 6, 7, 8 and 9 show the sectoral water situation after different percentage water transfers from agriculture to the non-agriculture sectors. For example, m40 means 40 percent water transfer from agriculture to the non-agriculture sectors. Similarly, m20, m10, m05, m02 and m01 imply 20 percent, 10 percent, five percent, two percent and one percent transfer of water from the agriculture to the non-agriculture sectors respectively. In addition to these simulations, a 10 percent transfer of water from the non-agriculture to the agriculture sector is also investigated. This is documented in column 10. The results are also relative to the base scenario. These simulation results also have consequences for households' welfare and for net agricultural exports, which will be discussed in section6.

6.3.3 Changes in sectoral output under the different global change scenarios

As explained in the theoretical framework and modeling procedure the market process was allowed to reallocate the initially market-distorted sectoral water to achieve competitive equilibrium. It then investigates the impact of the different global change scenarios on sectoral output. Table 6.3 shows the percentage changes in sectoral output when there is a reduction in water availability for sectoral activities.

Table 6.3: Sectoral output under the different global change scenarios

Sectors (1)	Base (2)	m30 (3)	m20 (4)	m10 (5)	p10 (6)
Agriculture	-27.32	-30.98	-24.87	-12.76	2.66
Mining	26.73	-16.58	-14.47	-9.40	0.84
Agro-industry	-0.83	-17.53	-16.43	-6.81	1.93
Leather & wearing apparel	0.04	-21.74	-15.19	-6.91	0.46
Paper and pulp	-0.47	6.35	3.16	2.44	-0.51
Petroleum	-1.08	-16.27	-12.64	-0.30	0.19
Basic chemicals	2.03	-10.46	-9.33	-0.17	0.16
Heavy metal manufacturing	3.12	19.88	13.68	6.10	-0.75
Machinery & equipment	0.13	3.88	2.02	2.20	-0.33
Other manufacturing	0.38	7.54	4.20	4.88	-0.95
Electricity	-2.98	-22.49	-19.53	-4.05	0.27
Construction	-4.66	2.72	1.34	0.48	-0.05
Services	-13.18	-8.96	-7.96	-1.75	0.11
Total	**24.62**	**-24.97**	**-19.45**	**-11.37**	**2.05**

The base situation, which is presented in column 2 of Table 6.3, shows that with market allocation of water resources agricultural output falls by 27.32 percent. The services sector also shows a significant decline in sectoral output by 13 percent. On the contrary, the mining sector records a significant increase in output of 26.73 percent. Heavy metal and basic chemical manufacturing industries also record increases in output. Overall, sectoral output increases by about 25 percent. This implies that market allocation of available water resources generally leads to increased sectoral output in South Africa, although output in some sectors decline. Therefore market allocation of water resources leads to efficient use of the resource. With market allocation, sectors pay the competitive market price of water, which makes some sectors to reduce the use of the resource while others increase its use. This impacts sectoral output, but the overall impact shows increased output and indicates efficient use of water.

Generally, under `the global change scenarios, total sectoral output declines by about 25 percent, 19 percent and 11 percent with 30 percent, 20 percent and 10 percent respective reductions in sectoral water availability. However, while some sectors experience significant percent decreases in sectoral output, others experience increase in output. For example, under all the global change scenarios, the agriculture, mining, food, beverages and tobacco manufacturing, clothing and textile, petroleum, basic chemical manufacturing, electricity and services sectors experience significant output decline, the pulp and paper, heavy metal manufacturing, machinery and equipment and construction sectors experience output growth. Columns 3, 4 and 5 of Table 6.3 present the possible changes in sectoral output resulting from the global change scenarios.

The last simulation investigates the possibility increasing of 10 percent sectoral water use under the best global change scenario. The result shows that total sectoral output can increase under this scenario. However, it is interesting to note that the output of some sectors decline. The possible reason is that substitution of the factors of production. While some sectors can easily substitute capital for water, others like agriculture, mining and food and beverage manufacturing can not, hence, reduction in output which impacts the heavily inter-dependent sectors' outputs.

6.3.4 Changes in factor payments under the different global change scenarios

Changes in sectoral outputs due to water reduction under the different global change scenarios have direct impact on factor payments. With a reduction in sectoral water availability, the immediate action taken by the production sectors is to substitute water with other factors. Therefore, the impact on the remuneration packages of the different factors differs from one factor to the other.

Table 6.4: Changes in factor remuneration under the different global change scenarios

Primary factors	Base remuneration	Global change scenarios			
		m30	m20	m10	p10
(1)	(2)	(3)	(4)	(5)	(6)
Capital	8.73	6.27	3.91	2.58	0.000
Water	17.68	(48.53)	(25.73)	(13.89)	8.52
Unskilled labour	22.80	(23.05)	(15.76)	(9.82)	5.63
Medium skilled labour	22.58	(3.92)	(1.75)	(.0.65)	0.42
High skilled labour	16.35	0.93	0.78	0.00	0.01
Total Impact	**14.89**	**(26.47)**	**(13.19)**	**(5.93)**	**2.17**

Firstly, market allocation of water to achieve competitive equilibrium increases total factor payments by about 15 percent. Column 2 of Table 6.4 shows that the wages of both unskilled and medium skilled labourers increases by 22.8 percent and 22.58 percent respectively. Similarly, the wages of high skilled labourers and the returns on capital and water significantly increase. These imply that market allocation of water resources enhances both output growth and growth in factor payments.

Secondly, reduction in water availability under the adverse global change conditions, results in a decrease in total factor remuneration. Column 3 of Table 6.4 shows that with a 30 percent reduction in sectoral water availability, total factor remuneration falls by 26.47 percent. Columns 4 and 5 of Table 3 also record percentage decreases in total factor payments in response to 20 percent and 10 percent reduction in sectoral water availability respectively. However, although total factor payments decline under the adverse global change conditions, returns on capital increase. The possible economic reason is that reduction in sectoral water availability encourages the production sectors to substitute more capital for the lost water. Hence, returns on capital increases on the average, while payments to the other factors fall. Specifically, the total wage bills for the unskilled and medium-skilled labourers decline because of adjustments in wages to clear the labour market. Conversely, an increase in sectoral water availability under the best global change scenario leads to a growth in total factor payments. Details are presented in Column 6 of the above table.

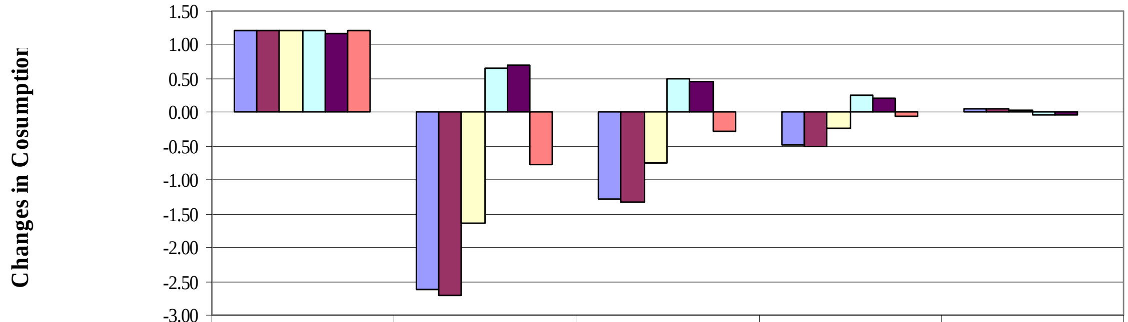
6.3.5 Households' welfare analysis under the different global change scenarios

Under this experiment, the study investigated the impact of possible reductions in sectoral water use due to climate change, population growth, urbanization and improvement in living standards (leading to an increase in domestic water use) and environmental sustainability.

Figure 5 shows the percentage changes in households' base consumption/income or expenditure when sectoral water use reduces by 30 percent, 20 percent and 10 percent respectively, which are recorded as m30, m20 and m10. There is also one simulation which investigates the impact of a 10 percent increase in sectoral water use due to increased investment in water infrastructure or international water transfer into the country. This is recorded as p10. The figure also shows that total households welfare deteriorates by 0.77 percent with a 30 percent reduction in sectoral water use. However, the results record a higher percentage decline in consumption expenditures by the least and low-income households than for the middle income households.

It is interesting to note that the consumption expenditures for the high and the highest-income households increase. The same trend follows the 20 percent and 10 percent reductions in sectoral water use. These results imply that any percentage reduction in sectoral water use will have more adverse consequences for the poor than the rich households. The possible interpretations of these results are that reduction in sectoral water use leads to a decline in output, hence, an increase in output prices. The lower-income households can not cope with these price increases. Therefore, they reduce their consumption of basic items, including food. It could also be the result of a general decline in the total wage bills of unskilled and medium skilled labourers, which is transmitted to the incomes of the poor and middle income households, hence, their consumption levels decline. The results show a decrease in overall households' consumption expenditures, indicating an overall decline in households' welfare.

An increase of sectoral water use by 10 percent leads to a minimal increase in total households' level of consumption. The increase in consumption expenditures is prominent for the least, low and middle-income households, while the consumption expenditures of rich households decline.



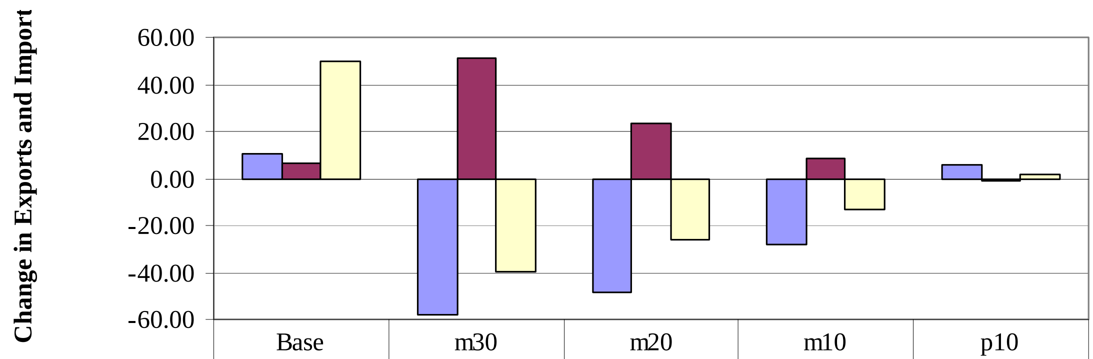
	Base Index	m30	m20	m10	p10
Least-income	1.21	-2.61	-1.29	-0.48	0.05
Low-income	1.21	-2.70	-1.34	-0.50	0.05
Middle-income	1.22	-1.64	-0.74	-0.25	0.02
High-income	1.20	0.65	0.49	0.25	-0.03
Highest-income	1.17	0.69	0.45	0.21	-0.03
Total	1.21	-0.77	-0.29	-0.07	0.01

Global Change Scenarios

Figure 5: Households' welfare analysis under the global change scenarios

The above results have consequences for agriculture supply, exports and imports of agricultural commodities. Figure 6 illustrates the impact of a reduction in sectoral water use on agricultural supply, exports and imports of agricultural commodities. The simulation results show that with a thirty percent reduction in total sectoral water use, agricultural exports fall by 57.7 percent and the corresponding agricultural imports increase by 51.2 percent, while domestic supply of agricultural commodities falls by 40 percent. The same trend of changes in agricultural exports, imports and domestic agricultural supply are seen for 20 percent and 10 percent reduction in sectoral water use.

A 10 percent increase in sectoral water use records a 5.59 percent increase in agricultural exports, a decrease of 0.76 percent in agricultural imports and an increase in domestic agricultural supply of 1.79 percent. Figure 6 reports the details of the impact of global change on domestic supply of agricultural commodities, and exportation and importation of agricultural commodities



	Base	m30	m20	m10	p10
Agric.Export	10.44	-57.70	-48.51	-28.23	5.59
Agric.Import	6.13	51.17	23.48	8.18	-0.76
Agric.Supply	49.84	-39.59	-26.42	-13.22	1.79

Figure 6: Agricultural exports and imports under the global change scenarios

These results generally show that a reduction in sectoral water use due to global change can lead to a decline in agricultural supply/output, which results in a decline of agricultural exports and an increase in agricultural imports. These results have implications for households' incomes, hence their consumption expenditures, especially those of the lower-income categories. These results also have implications for food security policies which will be discussed in section 6.5.

6.3.6 Changes in sectoral output under the different water reallocation scenarios

Table 6.5 reports the changes in sectoral output under the different water reallocation scenarios. The base scenario, in which agricultural water use was maintained at the benchmark level and allowing the market mechanism to reallocate the water in the non-agricultural sectors, indicate growth in sectoral output by 10.63 percent. Although there is a general increase in sectoral output, some sectors had a decline in output. For example, the agro-industry, paper and pulp, petroleum electricity and services sectors record an output decline, while the others show an output growth.

Table 6.5: Changes in sectoral output under the different water reallocation scenarios

Sectors (1)	Base (2)	M40 (3)	M20 (4)	M10 (5)	M5 (6)
Agriculture	0.00	-39.16	-21.32	-12.91	-4.36
Mining	14..63	16.12	14.57	9.40	7.84
Agro-industry	-0.21	-6.73	-4.95	-2.87	-1.92
Leather & wearing apparel	0.04	1.81	1.09	0.97	0.46
Paper and pulp	-0.13	6.35	3.16	2.44	1.51
Petroleum	-1.75	-6.27	-2.64	-0.30	1.19
Basic chemicals	2.48	-4.46	-2.33	-0.17	0.16
Heavy metal manufacturing	3.62	19.88	13.68	6.10	0.59
Machinery & equipment	0.03	3.88	2.02	2.20	1.47
Other manufacturing	0.75	7.54	4.20	4.88	3.26
Electricity	-0.93	-2.49	-1.53	-0.05	0.27
Construction	-1.37	2.72	1.34	0.48	0.05
Services	-8.56	-8.96	-7.96	-1.75	0.11
Total	**10.63**	**-5.97**	**2.39**	**5.68**	**6.05**

Forty percent water reallocated from the agriculture sector to the non-agriculture sectors leads to a decline the agriculture sector's output by about 39 percent. This is followed by a decline in the output of highly inter-dependent sectors like services, and agro- industry. The output of the other sectors increased, but the simulation results show an overall decline in sectoral output by about six percent. From the figures, one can infer that the gains from this reallocation are not large enough to offset the loss in the agricultural and its highly inter-dependent sectors' output. The other simulation results recorded in Columns 4, 5 and 6 of Table 6.5 show a similar trend of sectors that gain and those that loss from water reallocation from the agriculture to the non-agriculture sectors. However, these experiments show an overall increase in sectoral output. This highest percentage increase is overall sectoral output is only recorded for a five percent water reallocation. With further reallocation the percentage increase in output declines until it becomes negative. The possible reason is that some sectors are not intensive users of water like the agriculture sector. When their water use capacities are exceeded the additional water received from the reallocation process is not productive enough to lead further increase in sectoral output.

6.3.7 Changes in value added under the different water reallocation scenarios

Alterations in sectoral output has consequences for factor payments, because to clear the factor markets factor prices have to keep adjusting until a competitive equilibrium is achieved.

As with the other experimental results, market allocation non-agricultural sector water leads to a significant increase in factor payments. In general the experiment shows a potential increase of about 11 percent increase in overall factor remuneration. The percentage increase in higher for water, followed by high-skilled labour.

After the market allocation mechanism, further reallocation of water from agriculture to the non-agriculture sectors leads to a decline in interest payments on capital and wages to unskilled labourers. However, there is an increase in water tariffs and wages paid to medium skilled and high-skilled labourers leading to an increase in overall value added at factor cost..

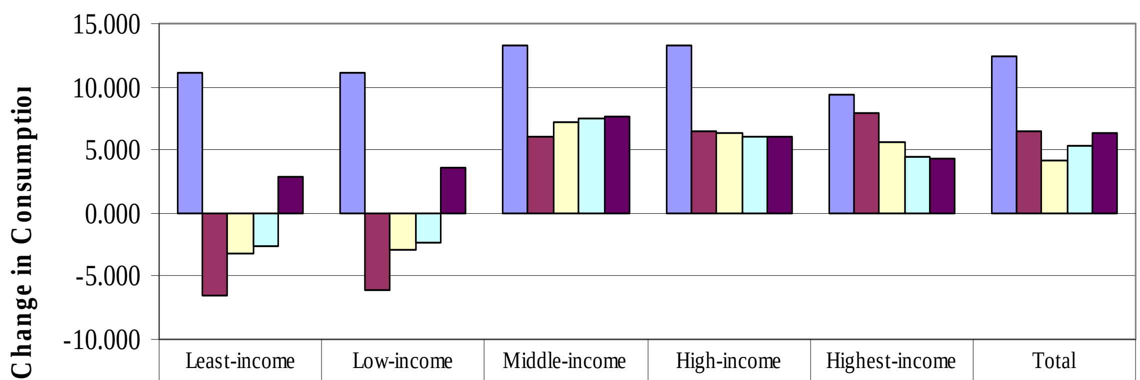
Table 6.6: Changes in factor payments under the different water reallocation scenarios

Primary factors	Base remuneration	Global change scenarios			
		M40	M20	M10	M05
(1)	(2)	(3)	(4)	(5)	(6)
Capital	4.72	(3.27)	(1.91)	(1.58)	0.000
Water	14.81	8.15	5.83	3.94	2.93
Unskilled labour	8.74	(10.37)	(8.37)	(4.95)	1.88
Medium skilled labour	10.43	3.92	1.75	1.65	1.49
High skilled labour	12.35	2.73	1.04	0.96	0.37
Total impact on factor	**10.89**	**1.39**	**2.56**	**2.94**	**3.17**

Water reallocation from the agriculture to the non-agricultural sectors leads to a weak substitution of water for capital. To clear the capital market, its price falls, which leads to a decrease in total interest payments on capital. Water reallocation from agriculture leads to decline in agricultural output as shown in Table 6.5. This sector is the highest employer of unskilled labour, hence, the accumulation of excess unskilled labourers, all of whom can not be absorbed by the non-agriculture sectors because of differences in skill requirements. Therefore, to absorb the excess unskilled labourers, the wages of this factor category should keep adjusting downwards until the market is cleared, leading to a decline in total wage bill for unskilled labourers. Although all the water reallocation scenarios show possible increases in factor payments, wages paid to the unskilled labourers and returns on capital decline.

6.3.8 Households, welfare analysis under the different water reallocation scenarios

The figure below shows the impact of water reallocation from agriculture to the non agriculture sectors.



	Least-income	Low-income	Middle-income	High-income	Highest-income	Total
Base	11.044	11.152	13.265	13.241	9.407	12.346
m40	-6.490	-6.113	6.047	6.474	7.978	6.518
m20	-3.174	-2.905	7.259	6.258	5.608	4.148
m10	-2.641	-2.399	7.543	6.081	4.430	5.255
m05	2.812	3.580	7.635	5.986	4.347	6.278

Water Reallocation Scenarios

Figure 7: Households' welfare analysis under the different water reallocation scenarios

The base figures show that when water is allocated by the market mechanism to achieve competitive equilibrium, there is a general improvement in welfare. The level of consumption or households’ expenditure on goods and services increases as compared with the benchmark consumption indices. However, the level of improvement is not as much as when the market process allocates water in all the production sectors including agriculture. While total consumption level increases by 12.35 percent in the former experiment, it increases by 20.49 percent when water is allocated by the market mechanism in all the sectors.

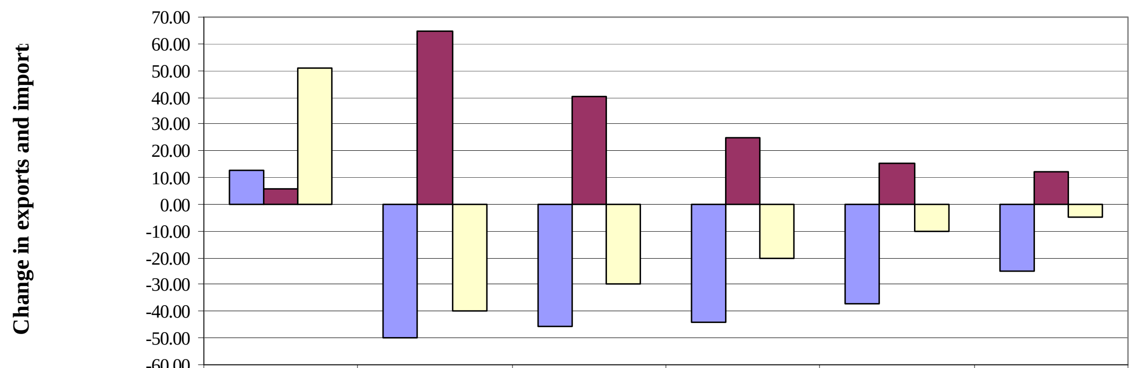
All the water reallocation scenarios show a general potential increase in households' welfare. However, while there is general welfare improvement for the middle, high and highest-income households, the welfare of the least and low-income households decline when more than five percent of water in the agriculture sector is transferred to the non-agriculture sectors.

Reallocation of water from the agriculture sector to the non-agriculture sectors leads to a decline the agriculture production, and consequently a decline in agricultural total wage bill paid to the unskilled labourers. This leads to a decline in the welfare of the least and low-households who largely depend on wages from unskilled labourers and transfer payments. Conversely, the improvement in the welfare of the middle, high and highest-income households results from increased medium and high-skilled labourers whose wages are transmitted to these household categories.

6.3.9 Changes in agricultural imports and exports under the different water reallocation scenarios

The above analyses show a decline in agricultural output and the outputs of the sectors that highly depend on agriculture for their intermediate input requirements. This output decline has consequences for agricultural exports and imports.

The base scenario records an increase in the exportation of agricultural commodities and a mild increase in the importation of same commodities leading to an increase in the aggregate agricultural supply. Under all the water reallocation scenarios the study records a significant decline in the exportation of agricultural commodities, with a corresponding significant increase in the importation of the same agricultural commodities, leading to an increase in domestic commodity prices.



	Base	m40	m30	m20	m10	m05
Agric. Exports	12.74	-49.83	-45.75	-43.88	-37.42	-25.07
Agric. Imports	5.54	64.66	40.35	24.98	15.49	12.23
Agric. Supply	50.99	-40.00	-30.00	-20.00	-10.00	-5.00

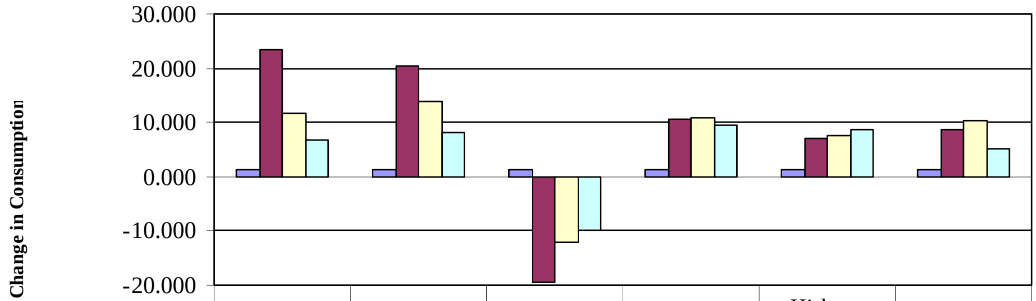
Water Reallocation Scenarios

Figure 8: Agricultural exports and imports under the water reallocation scenarios

Consequently, the poor households' welfare due to decline in their consumption expenditure..

6.3.10 The impact of a welfare program on changes households' consumption

In both the global change and the water reallocation from agriculture to the non-agriculture sectors experiments, it has been shown that the welfare of the least and low-income households decline. To make these categories of households as well-off as were before these changes a welfare program is required such that the equivalent amount of the welfare loss is given to them. One such program which can target these categories of households is the distribution of food stamps among them to maintain their food consumption levels. Therefore, this sub-section investigates the impact of such a program on their welfare as well as the welfare of the other household categories.

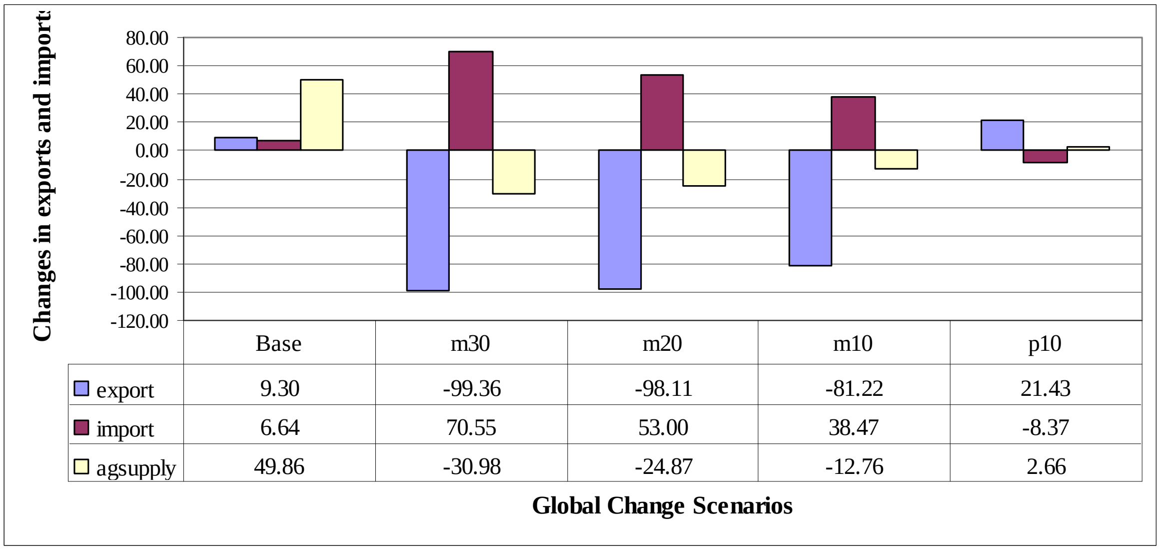


	Least-income	Low-income	Middle income	High-income	Highest-income	Total
Base Index	1.225	1.227	1.199	1.220	1.192	1.205
m30	23.44	20.43	-19.56	10.63	6.92	8.72
m20	11.70	13.79	-12.14	10.76	7.73	10.21
m10	6.81	8.04	-9.93	9.62	8.63	5.07

Global Change Scenarios

Figure 9: Welfare programmes and changes in households' consumption

The study investigated the impact of distributing food stamp among the least and low-income households which is equivalent to their welfare loss in the global change scenarios. The results are shown in Figure 9. The results show a significant improvement in the welfare of the least, low, high and highest-income households. However, the same results indicate a significant decline in the welfare of the middle-income households. The possible economic interpretation of these results is that the distribution of food stamps among the vulnerable households leads to an increase in demand for agricultural commodities, hence the need to import more agricultural commodities and a significant decline in the exportation of the same agricultural commodities, because domestic supplies can not meet the increased food demand. Figure 10 presents a detailed illustration of the welfare impacts of food stamp on agricultural supply, exports and imports. The same result should be expected if welfare programs are implemented to maintain the consumption level of least and low-income households under the water reallocation scenarios



	Base	m30	m20	m10	p10
export	9.30	-99.36	-98.11	-81.22	21.43
import	6.64	70.55	53.00	38.47	-8.37
agsupply	49.86	-30.98	-24.87	-12.76	2.66

Figure 10: Implications of welfare policy to maintain consumption levels

As shown in Figure 10, agricultural exports substantially decline under all the global change scenarios. This is followed by correspondingly substantial increase in the importation of agricultural imports because domestic production can not meet increased demand. This leads to an increase in the domestic prices of food commodities. Since the middle-income households are not included in the welfare program because of their income status, they adjust their expenditures on food consumption increases which leads a general decline in the consumption of non-food items.

6.4: DISCUSSION OF MAIN RESEARCH FINDINGS

The simulation results show that market allocation of water among the production sectors generally leads to an improvement in households' welfare, since it increases their income and consequently their consumption expenditures. The highest increase in households' consumption expenditure is recorded with the complete market allocation of water for all the production sectors than when only the non-agriculture sectors are subjected to the market allocation mechanism, while maintaining the level of water use in the agriculture sector. The results also show that total households' consumption expenditures increase when water is reallocated from the agriculture to the non-agriculture sectors. This increase is recorded for only the middle, high and highest-income household categories, while a decline in least and low-income households is shown by the simulation results. The percentage increase is total households' consumption from the base figures is highest when only five percent water is transferred from the agriculture to the non-agriculture sectors. The possible interpretation of this result is that transferring water from the agriculture sector to the non-agriculture sectors increases output in the non-agriculture sector while the output of the agriculture sector declines. Firstly, the decline in agriculture output leads to an increase in the price of agricultural commodities. Because the demand for agricultural commodities exceeds the supply of these commodities, the price of agricultural commodities increases to return to equilibrium in the product market. This leads to a decline in the consumption of these commodities by the least and low-income households. Secondly, because of the decline in agricultural output, the demand for unskilled labour decreases and the excess unskilled labour can not be absorbed by the non-agriculture sectors because of differences in skill requirements. Therefore, to clear the unskilled labour market, wages adjust downwards, which results in the decrease of the total wage payment to this category of labourers.

Reallocation of water from the agriculture to the non-agriculture sectors increases water availability for these non-agriculture sectors at cheaper prices than before. Therefore, water is substituted for capital by those sectors. This leads to a decline in the interest paid on capital. It also leads to an increase in output of sectors that are highly dependent of agriculture for their intermediate input requirements. It also leads to an increase in the output of the most of the sectors that receive the reallocated water. Output prices and wages in these sectors adjust until the market is cleared equilibrium is restored. While wages of the medium and high-skilled workers adjust upwards interest payments on capital declines.

Changes in factor remuneration have consequences for households' income and consumption expenditures. As noted Figure 6.3 the wages of unskilled labourers decline. This is directly transmitted to the least and low-income households, who receive a higher percentage of their income from unskilled labour. Hence, a decline in their payment will have adverse consequences on the least and low-income households welfare.

The other set of experiments show that global change global change leads to a decline in the output of the production sectors that can not easily substitute capital for water. These include agriculture, mining, agro-industries, electricity and services. The other sectors that can substitute capital for water experience growth in output. This leads to changes in factor remuneration. Specifically interest payment on capital increases, because more capital than water will be used by the production sectors that can easily substitute capital for water. Also, the revenue received from water use declines. Furthermore, the total wage paid to unskilled labourers declines. This results from a decline in agricultural output. Since agriculture employs most of the unskilled labourers, the demand for unskilled labourers decreases. To clear the unskilled labour market wages adjust downwards leading to a decline total wages paid to this category of labourers. Changes in factor remuneration have consequences for income generation and distribution among the various household categories.

Most of the interest paid on capital is transmitted to the high and highest-income households. As a result the increase in the remuneration on capital leads to an increase in the income/ consumption of these categories on households as shown in Figure 6.1. Conversely, most of the least and low-income households receive a higher percentage of their income from wages paid to unskilled labourers. Therefore, a decrease in the total wage bill to this category of labourers leads to deterioration in the welfare of the least and low-income households as shown in Figure 6.1. As payment to medium-skilled labourers increases so does the welfare of the middle-income households who earn a higher percentage of their income medium-skilled wages.

To make the least and low-income households as better off as they would have been after the reallocation of water from agriculture to the non-agriculture sectors or after the reduction in water availability for sectoral production activities the study investigated the impact of the granting of a food stamp to these households which is equivalent to the percentage reduction in their consumption. This leads to an overall improvement in households' welfare. However, the middle-income households experience a deterioration in welfare, while the least, low, high and highest-income households enjoy a welfare improvement. The reason is that the granting of food stamp to the poor households increases the demand for food. This increased food demand can not be met by domestic food production. Therefore, more food items will be imported, leading to an increase in domestic prices. Since the middle-income households are excluded from such a welfare program, their expenditure on food increases and leads to a decrease in the consumption of non-food items, hence a general decline in welfare.

6.5 SUMMARY AND CONCLUSIONS

This chapter was designed to investigate households' welfare changes that result from different water policies, including global change and water reallocation from agriculture to the non-agriculture sectors. Global change refers to climate change, changes in population, changes in policies and urbanization.

Using the 1998 social accounting matrix documented in Chapter 5 and the market allocation mechanism to reallocate water from the agriculture to the non-agriculture sectors, the study found out that this policy leads to households' welfare improvements.. The study also identifies the level of water reallocation that leads to a maximum households' welfare.

Next, the study investigated the impact of global change (leading to sectoral water-use reductions due to either population growth or urbanization which increases in domestic water use, climate change, increased environmental water use or increased externality problems) on households' welfare. These results indicate that global change generally leads to deterioration in households' welfare, especially the welfare of the least and low-income households. The institution of a welfare program that assists the poor households to attain the lost welfare generally leads to a deterioration in the welfare of the middle-income households.

These results have consequences for agricultural output, exportation and importation of agricultural commodities. While agricultural output declines, exportation of agricultural products consequently declines. Therefore, to maintain food consumption levels, importation of agricultural commodities increases. Hence policies that favour the importation of food commodities at affordable prices by households should be implemented to improve households' welfare.

Generally, any alteration in the allocation of water resources beyond the market allocation will lead to deterioration in the welfare of poor households. In some instances, water reallocation from agriculture to the non-agriculture sectors can lead to output growth, but the gains from the output growth are mainly distributed among the rich households. Therefore, reallocation of water beyond the market allocated point is not equitable. Also, reduction in water availability due to global change has adverse consequences for the poor households. To minimize these adverse consequences, there is a need for a welfare program that maintains their food consumption levels.

CHAPTER SEVEN

GENERAL SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

7.1 INTRODUCTION

This study was designed to investigate the structure of sectoral water use in South Africa, with the view to recommending policies that can promote water use efficiency and social equity in the country. In the general introduction the study makes an overview of the problem of global water scarcity, the threats and challenges posed by these problems and the responses to the challenges. Specifically, the introduction focuses on the growing problem of global water scarcity and water scarcity in South Africa, the policies and strategies designed and recommendations for improvement in water use efficiency. Review of available literature suggests that there are research gaps on the information about the structure of sectoral water use in South Africa. Previous studies especially in South Africa have focused on either individual or few water use sectors or catchments and have used their results to recommend national water policies. To address these research gaps, this study estimated the sectoral demand functions for water by thirteen different sectors and sub-sectors.

In Chapter two the study made a survey of economic methods used to value water. These range from the traditional econometric methods to the recent mathematical programming, economy-wide and the Computable General Equilibrium modeling methods. It then highlights the methods that are adopted for the current study. These include the marginal productivity analysis and economy-wide modeling techniques to investigate efficiency and equity issues in sectoral (non-residential) water use in South Africa.

In chapter three the study uses the marginal productivity econometric modeling approach to estimate and analyze the global sectoral water demand functions for thirteen sectors and sub-sectors. Data used for the analysis were extracted from the GTAP and UNIDO data bases. In the analysis the study estimated the output and price elasticities and marginal values of water for each of the thirteen sectors. This approach was extended to the estimation and analysis of sectoral water demand in South Africa for the same sectors and sub-sectors. This was done to validate the model used for the global sectoral water demand analysis. The country specific study used information from STATSA's census of manufacturing, agricultural, services and construction activities, water supply and use tables (STATSA 2004) and the Trade and Industrial Policy Strategy (TIPS) time series data. The output and price elasticities and marginal values of water for each of the sectors and sub-sectors were estimated at the mean values of the variables used. To account for variations in the marginal values over time, the study computed the marginal values of water for each of the sectors from 1970 to 2004. Also, to account for the spatial variation in sectoral marginal values of water, the study used the 1996 census of manufacturing activities, construction and services for each of the nine provinces to compute the marginal value of water in each of the thirteen sectors or sub-sectors and province.

However, with the computation of marginal values and sectoral elasticities, there was the need to investigate the economy-wide policy reliability of the estimated elasticities and marginal values of water. In South Africa for example, the new water act is aimed at improving efficiency of water use, instituting social equity and maintaining environmental sustainability. To investigate the policy relevance of the computed sectoral marginal values, the study updated the 1999 South African social accounting matrix, developed by Thurlow and van Seventer (2002) and used the updated SAM to investigate the economy-wide impact of sectoral water reallocation on sectoral output, value added and households' income generation. The SAM analysis was complemented by the use of the Computable General Equilibrium model to investigate the possible impact of global change and sectoral water reallocation on households' welfare.

7.2 GENERAL RESEARCH FINDINGS

The use of the marginal productivity analysis approach to estimate the sectoral water demand functions was found to be appropriate for the both the global and South African sectoral water demand analysis.

Generally, sectoral water demand was found to be price elastic for both the global and country specific analysis. However, the price elasticity of sectoral water demand varies from one sector to the other, with a few sectors like agriculture, and beverage and tobacco manufacturing sectors having price elasticities less than unity. The computed global sectoral elasticities and marginal values are consistent with South Africa sectoral water output and price elasticities. These results have some policy implications which will be discussed in the next section.

As with the output elasticities, the estimated sectoral marginal values are positive, but differ for the different sectors. These indicate that water contributes positively to sectoral output. At the global level, the petrol-coal extraction has the highest marginal value, while the agriculture sector has the least marginal value of water. Also, the South Africa sectoral water demand analysis show that the agriculture sector still has the least marginal value of water. These findings generally suggest that the marginal contribution of water to sectoral output is least in the agriculture sector as compared to all the other sectors and sub-sectors. Therefore, from the economic point of view, water reallocation from the agriculture to the non-agriculture sectors can lead to sectoral water use efficiency. However, although agriculture's contribution to the South Africa's gross domestic product might be minimal, its forward and backward linkages to other sectoral and household activities may be high compared to the other production sectors, hence the marginal productivity consideration alone in reallocating water from this sector to others may affect more poor households whose survival is highly dependent on the agriculture sector.

Another important research finding is that the sectoral marginal values of water vary with both time and space. The estimated results for South Africa generally show that the sectoral marginal values of water had a decreasing trend between 1970 and the late 1980s or early 1990s. Thereafter, sectoral marginal values increased and are still increasing, although few sectors show varying results to the general finding. These decreasing and increasing trends could be the result of variations in economic activities due to the policy changes and the then political struggle in the country within the given time frames. The estimated marginal values also show regional variations. This suggests that the marginal values of water in the different sectors vary from time to time and from one region to the other. Therefore, policy recommendations should also reflect these variations.

To investigate the economy-wide impact of water reallocation from the agriculture to the non-agriculture sectors, the study used the SAM analysis. The general results show that water reallocation from the agriculture to the non-agriculture sectors have leads to a decline in output in the agriculture sector and adverse consequences for the poor households who highly depend on the agriculture sector for their economic survival. However, the policy relevance of SAM analysis is limited due to the assumptions of linearity, non-factor substitutability, fixed prices and its being demand driven. Therefore, the study analyzed the households' welfare impacts of sectoral water reallocation and global change scenarios using the Computable General Equilibrium model. The results indicated that global change leads to welfare deterioration of the most vulnerable households if food consumption levels measures are not maintained. The results also indicate that water reallocation from the agriculture to the non-agriculture sectors leads to improvement in households' welfare only when food consumption levels are maintained. This households' welfare improvement in maximized at the five percent level of water reallocation from the agriculture to the non-agriculture sectors. Overall, the results show that the market allocation of water resources enhances improvements in the welfare of all the household categories. Furthermore, the CGE results indicate that alterations in the current water allocation in South Africa in favour of the non-agriculture sectors lead to a decline in agricultural commodities, hence the aggregate supply of these commodities. Consequently, the exportation of agricultural commodities declines, while the importation of these commodities increases in order meet the domestic demand for food. These findings, together with those from the chapters four and five have policy implications.

7.3 POLICY RECOMMENDATIONS

The analytical results of Chapters Four show that sectoral water demand is price elastic. This implies that water pricing could be used to institute sectoral water use efficiency.

In Chapter Five, the simulation results indicate that while minimum transfer of water from agriculture to the non-agriculture sectors increases economy-wide output, it leads to a decrease in output in the agriculture sector. The decrease in output in this sector has consequences for sectors that have strong linkages with the agriculture sector. It also has consequences for factor remuneration especially wages; hence, it leads to job losses and a decline in poor households' income. To minimize the impact on households' income generation the study recommends minimal transfer of water from the agriculture sector to the other sectors on the basis their respective of marginal values of water, while emphasizing intra-sectoral water reallocation. The CGE simulation results show a general improvement in households' welfare when water is allocated by the market mechanism. It also shows that water reallocation from the agriculture to the non-agriculture sectors only leads to improvement in households' welfare when food consumption levels are maintained. The results further indicate that global change has severe consequences for the poor and middle-income households if food consumption levels are not maintained. These results have the following policy implications:

i) Allow the market mechanism to allocate water among the production sectors after meeting the domestic and ecological requirements. The policy recommendation is not new on the South African water policy agenda, but the research findings only validates the country's intention to institute a market mechanism in allocating the scarce water resources of South Africa.

ii) Alterations in the current water allocation have consequences for agricultural output although it generally leads to households' welfare improvements. The research findings suggest that to maintain the welfare of the vulnerable population against the possible consequences of global change policies that insure the availability and affordability of food should be implemented. Since domestic agricultural output declines with the above situations, policies that favour the importation of agricultural commodities to complement domestic supplies should be implemented.

7.4 RESEARCH FINDINGS AND POLICY INSIGHTS

The findings of this study have some policy insights in water resource management in South Africa. Two such insights are discussed below.

Firstly, other studies have shown that agriculture's contribution to GDP is least among the other production sectors. The empirical findings of this research confirm this. The marginal productivity analysis of sectoral water uses in South Africa show that agriculture has the least marginal value of water. The social accounting matrix multiplier analysis also shows that the water use in the agriculture sector contributes least to the economy of South Africa. Additional empirical evidence is provided by the CGE analysis, which shows that water reallocation from agriculture to the non-agriculture sectors could be beneficial at minimal levels. However, policy implementers should be careful about this policy. As shown in the research the number of people who may loss from such a policy, if implemented, far outweighs the winners, although it leads to a general welfare gain.

Secondly, the concern for environmental sustainability as emphasized by the 1996 Water Act requires that at least ten percent of water should be reserved for ecological services. In the event that the adverse climate change projections become feasible the concern for human welfare should supersede environmental consideration. Deterioration in human welfare can lead to catastrophic environmental consequences. Conversely, improvement in human welfare can lead to concerns for environmental improvement. Hettige *et al.*(1997) show an Environmental Kuznets Curve (EKC) that environmental degradation is high with low per capita income. This degradation increases with increase PCI until a certain level of income is achieved. Further increase in income will lead to less environmental degradation.

7.5 FUTURE RESEARCH ISSUES

In global analysis of sectoral water demand does not classify data according to climatic stratifications or level of industrialization. According to Hettige *et al.*(1997). Industrial water use intensity drops with the level of industrialization. Future research should therefore pool the data according to climatic regions as well as the level of industrialization and through an appropriate modeling technique compute the sectoral elasticities and marginal values of water.

The social accounting matrix used in this study has a highly disaggregated manufacturing and services sectors, but an aggregated agriculture sector. The estimated sectoral marginal values and the simulation results suggest water reallocation from agriculture to the other sectors. This has the potential impact of an economy-wide increase in output, while output decreases in the agriculture sector. Consequently, as seen from the simulation results, the action leads to job losses and a decrease in the consumption levels of the vulnerable households if measures are not taken to insure food security in the country. To minimize this possible impact there is a need to design and implement agricultural water use policies that maintain agricultural productivity, hence the basic livelihoods of poor households. One such policy is a switch from irrigated to rainfed crops. To understand this synergy there is the need to construct and analyze a social accounting matrix with a highly disaggregated agriculture sector that incorporates both rainfed and irrigated accounts for the different crops grown in the country. This will then investigate the impact of a switch from irrigated to rainfed agriculture and to recommend the importation of those agricultural commodities that have high water requirements. Furthermore, the emergence of both formal and informal smallholder farmers requires the inclusion of smallholder irrigators/rainfed farmers into the analytical framework by developing separate SAM accounts for them. This will investigate other critical agricultural and sectoral water use policies.

South Africa is a country with nineteen water management areas (WMA). Each water management area has hydrologic, climatic, agronomic and socio-economic characteristics that are distinct from the others. Therefore national water use policies should reflect these distinctive WMA agronomic, hydrologic and socio-economic characteristics. Thus, to recommend plausible water allocation and pricing policies, and policies that can mitigate the adverse consequences of global change for each WMA, there is the need to construct social accounting matrices for each and every water management area in the country.

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APPENDIX 1: DATA FOR THE GLOBAL SECTORAL WATER DEMAND ANALYSIS AND DETAILED ESTIMATION RESULTS

Table A1. Extracted GTAP and water data

Sector (1)	Country (2)	Output (US$10 Billion) (3)	Labour (US$ 10 Billion) (4)	Capital (US$10 Billion) (5)	Water (mm^3) (6)	Intermediate (US$10 Billion) (7)
ELE	COL	0.0016640	0.0000124	0.0001436	0.0004155	0.0004034
ELE	AUS	1.2229395	0.0077950	0.1452815	0.2482354	0.2169195
ELE	NZL	0.0011612	0.0000110	0.0002128	0.0002881	0.0001245
ELE	CHN	11.7487888	0.0189458	0.1533147	2918.1707995	5.2844855
ELE	JPN	513.7278332	2.3398912	42.8801811	10.0910241	88.7330583
ELE	KOR	3.6780192	0.0153140	0.4295517	0.6103352	0.7213619
ELE	MYS	0.0897308	0.0000865	0.0021487	0.0183117	0.0511096
ELE	PHL	0.0388263	0.0000860	0.0039041	0.0024138	0.0149616
ELE	THA	0.3398922	0.0007436	0.0414032	0.0418479	0.0807242
ELE	VNM	0.0010880	0.0000304	0.0000020	0.0004155	0.0005144
ELE	BGD	0.0018374	0.0000013	0.0000940	0.1356749	0.0007481
ELE	IND	8.0815391	0.0634276	0.2160418	373.8424061	2.3614343
ELE	LKA	0.0000944	0.0000004	0.0000149	0.0000248	0.0000181
ELE	XSA	0.0030369	0.0000001	0.0000004	2.2131311	0.0023045
ELE	CAN	0.9862629	0.0107422	0.1791466	81.3083077	0.0986844
ELE	USA	1136.3866118	7.6692085	107.7909097	43503.8396654	261.8623645
ELE	MEX	0.1529450	0.0000325	0.0002994	1.8361220	0.1789823
ELE	XCM	0.0591762	0.0003476	0.0013674	0.0176010	0.0219108
ELE	PER	0.0002196	0.0000109	0.0000064	0.0000248	0.0000375
ELE	VEN	0.0079301	0.0000742	0.0007335	0.0017194	0.0014755
ELE	XAP	0.0002675	0.0000081	0.0000034	0.0560063	0.0000737
ELE	ARG	0.0613541	0.0013895	0.0008342	3.3658332	0.0162404
ELE	BRA	0.0100221	0.0003706	0.0000603	0.5527437	0.0038736
ELE	CHL	0.0102576	0.0001165	0.0023148	0.0015367	0.0011596
ELE	URY	0.0000038	0.0000000	0.0000007	0.0000539	0.0000004
ELE	XSM	0.0002207	0.0000043	0.0000622	0.0000006	0.0000074
ELE	AUT	0.0110177	0.0007947	0.0008077	0.5593518	0.0009779
ELE	DNK	0.0306866	0.0002904	0.0013036	0.0033347	0.0098797
ELE	FIN	0.0476058	0.0004165	0.0029513	1.8753223	0.0092783
ELE	DEU	25.7452795	0.5259703	1.1781160	501.4407473	6.5496191
ELE	GBR	11.6507963	0.2780514	0.3738628	1.0608836	2.3291549
ELE	GRC	0.0500234	0.0003342	0.0005529	0.0106345	0.0233192
ELE	IRL	0.0156671	0.0002956	0.0001742	0.3501819	0.0044378
ELE	ITA	3.3262248	0.0795806	0.1102381	0.3252667	0.7061899
ELE	NLD	0.3678187	0.0012699	0.0109035	7.3353088	0.1289214
ELE	PRT	0.0467794	0.0008204	0.0013484	0.0034269	0.0153751
ELE	ESP	2.1136886	0.0156224	0.2311090	45.5826261	0.3128692
ELE	SWE	0.0533920	0.0001443	0.0039436	0.0185522	0.0183314
ELE	BEL	0.3196398	0.0096769	0.0230799	6.7926491	0.0565634
ELE	CHE	0.0363111	0.0005059	0.0047677	1.6258144	0.0068700
ELE	XEF	0.0000001	0.0000000	0.0000000	0.0000001	0.0000000

ELE	HUN	0.0256049	0.0000760	0.0002367	3.1989595	0.0146788
ELE	POL	0.2791363	0.0004100	0.0005933	24.0314060	0.1974922
ELE	XCE	0.9632183	0.0028850	0.0181360	28.9799295	0.4283175
ELE	XSU	14.7265706	0.0022935	0.0160472	1225.6233678	21.0303745
ELE	TUR	0.2282658	0.0018374	0.0078152	9.3737774	0.0556236
ELE	XME	5.4323053	0.0079608	0.0887580	7.9909314	2.8292055
ELE	MAR	0.0088647	0.0001973	0.0009053	0.0005368	0.0011397
ELE	XNF	0.2769934	0.0012176	0.0065177	13.0457606	0.1125941
ELE	BWA	0.0000102	0.0000002	0.0000005	0.0000006	0.0000028
ELE	XSC	2.1695268	0.0104091	0.1013892	2.0506274	0.7843462
ELE	ZMB	0.0000000	0.0000000	0.0000000	0.0000006	0.0000000
ELE	ZWE	0.0001671	0.0000060	0.0000272	0.0001370	0.0000199
ELE	XSF	0.0000043	0.0000000	0.0000000	0.0000006	0.0000032
ELE	XSS	0.0139057	0.0000153	0.0002307	0.1463151	0.0075911
ELE	XRW	0.0793493	0.0009748	0.0017986	0.5461799	0.0292851
CON	COL	1.0707658	0.0338828	0.0498222	0.0000002	0.2295665
CON	AUS	38.3266610	1.4049553	1.3480015	0.0000068	8.3951586
CON	NZL	0.8754428	0.0133095	0.0018009	0.0000000	0.4636258
CON	CHN	1100.3252409	25.2026912	2.2264579	0.0976125	513.8256756
CON	JPN	20190.0518159	1763.6888395	72.5540253	0.0020015	4574.1125088
CON	KOR	148.1196631	6.0150600	1.0829409	0.0000157	42.7828399
CON	IDN	31.0669006	0.5670202	0.9673017	0.0000003	9.6789388
CON	MYS	7.5714698	0.1411379	0.0283302	0.0000113	3.7156032
CON	PHL	0.6036611	0.0182817	0.0097817	0.0000267	0.1682161
CON	THA	2.8583791	0.0032439	0.1819267	0.0000011	1.0048221
CON	VNM	0.2259850	0.0040831	0.0013442	0.0000000	0.0952105
CON	BGD	0.6483958	0.0011985	0.1339535	0.0000000	0.0932505
CON	IND	54.8195817	0.8210810	1.7665465	0.0020938	14.5620480
CON	LKA	0.0233905	0.0028109	0.0006609	0.0000010	0.0026574
CON	XSA	0.4714525	0.0046525	0.0227955	0.0000051	0.1225767
CON	CAN	138.5524289	12.8957875	0.3268165	0.0021790	36.4270562
CON	USA	40232.8174783	3849.0235664	204.7346316	0.1360081	9661.8366312
CON	MEX	20.1908068	0.8797982	0.2144631	0.0000290	6.3324234
CON	XCM	0.7053621	0.0134709	0.0222156	0.0000040	0.2043461
CON	PER	1.0479172	0.0039142	0.1320310	0.0000070	0.2261606
CON	VEN	0.3662107	0.0108804	0.0373819	0.0000001	0.0471072
CON	XAP	0.0716704	0.0002661	0.0063506	0.0000002	0.0198037
CON	ARG	21.8825183	3.4278361	0.2060774	0.0000013	2.9837051
CON	BRA	196.0987698	3.5430964	6.7535462	0.0000988	58.9241734
CON	CHL	1.1899904	0.0341539	0.0317994	0.0000223	0.2939317
CON	URY	0.0155156	0.0003590	0.0000621	0.0000000	0.0066524
CON	XSM	0.0033154	0.0000656	0.0000676	0.0000000	0.0011136
CON	AUT	14.3117832	1.4009343	0.1066789	0.0000012	2.8647295
CON	DNK	5.3685290	0.3123123	0.0251016	0.0000000	1.7204498
CON	FIN	0.6938381	0.0369719	0.0015861	0.0000001	0.2355957
CON	FRA	380.2825493	17.8465064	3.4157106	0.0003276	106.0219459
CON	DEU	1898.4121820	114.1936022	24.4026975	0.0007066	485.4054083
CON	GBR	855.1077080	16.2199224	19.0140385	0.0000276	293.3928652
CON	GRC	2.5876545	0.0424546	0.0212793	0.0000000	1.0494553
CON	IRL	0.8703476	0.0435766	0.0018905	0.0000000	0.3071783

CON	ITA	276.9621972	7.1594979	14.9500729	0.0003298	59.7906615
CON	NLD	42.4773269	1.3363164	0.1561469	0.0000067	17.9556460
CON	PRT	2.0572260	0.0305973	0.0152589	0.0000009	0.9140875
CON	ESP	115.0092400	7.1165397	2.6763667	0.0000059	16.1162402
CON	SWE	6.6401993	0.4536724	0.0256435	0.0000007	1.8683266
CON	BEL	6.8235909	0.4290710	0.1817070	0.0000120	1.3185377
CON	CHE	9.8667121	1.5654965	0.0084749	0.0000004	2.0326875
CON	XEF	5.2199483	0.7962818	0.0044934	0.0000093	1.1030925
CON	HUN	0.1098940	0.0014639	0.0029029	0.0000034	0.0391367
CON	POL	3.9165348	0.0584921	0.1377251	0.0000673	1.1815333
CON	XCE	5.4965208	0.2502106	0.0330521	0.0003061	1.8884948
CON	XSU	125.6425266	7.5130405	0.8233967	0.0150475	36.2894129
CON	TUR	14.1067934	0.5070716	0.2420204	0.0000230	3.9069272
CON	XME	84.2392757	2.3542920	0.5416168	0.0000074	32.8539940
CON	MAR	0.1967506	0.0121232	0.0004734	0.0000000	0.0674006
CON	XNF	7.3089368	0.3965662	0.0180107	0.0001394	2.6460273
CON	BWA	0.0042113	0.0000866	0.0000573	0.0000000	0.0016194
CON	XSC	1.6916518	0.0800748	0.0042991	0.0000000	0.6395809
CON	ZMB	0.0009100	0.0000021	0.0000029	0.0000000	0.0006016
CON	ZWE	0.0071105	0.0001870	0.0000120	0.0000000	0.0029419
CON	XSF	0.0164140	0.0002178	0.0001835	0.0000000	0.0066379
CON	XSS	3.3490201	0.0273226	0.2970527	0.0000008	0.7451190
CON	XRW	19.9161235	0.4191566	0.6856206	0.0000038	5.6832176
CHM	COL	0.5570175	0.0036997	0.0083681	0.0067801	0.2933897
CHM	AUS	4.3922710	0.0684290	0.0619336	0.1282306	1.8771030
CHM	NZL	0.1173859	0.0027347	0.0014753	0.0006298	0.0505443
CHM	CHN	601.7472284	2.2026066	2.7505327	3283.7472700	279.3360063
CHM	JPN	2496.8861110	32.9210984	24.9558975	14.3809157	902.3725768
CHM	KOR	69.9339481	0.4513723	0.9207808	0.4548201	31.7051219
CHM	IDN	3.1637360	0.0985031	0.1535815	0.0195806	0.9331359
CHM	MYS	1.5854375	0.0015277	0.0398501	0.0470898	0.9142566
CHM	PHL	0.2254703	0.0007244	0.0024823	0.4078962	0.0959971
CHM	THA	0.9090790	0.0029166	0.3765454	0.3961019	0.1442803
CHM	VNM	0.0040758	0.0000076	0.0000027	0.0000008	0.0034160
CHM	BGD	0.0230743	0.0000201	0.0001359	0.0000573	0.0106428
CHM	IND	29.2666172	0.0603211	0.1187671	59.2092559	11.7087182
CHM	LKA	0.0019674	0.0000328	0.0001120	0.0043009	0.0006060
CHM	XSA	0.4740576	0.0005945	0.0014964	0.2517726	0.1860655
CHM	CAN	26.9965910	0.6552630	0.4861973	42.6183073	10.7292961
CHM	USA	10622.6746304	288.3447484	228.8675840	3921.9369687	3611.6050853
CHM	MEX	18.9459963	0.0670600	0.9961120	0.8497611	6.0890346
CHM	XCM	0.6418573	0.0032392	0.0074921	0.3708088	0.3175617
CHM	PER	0.1190789	0.0003761	0.0113000	0.2580830	0.0229172
CHM	VEN	0.5932797	0.0102310	0.0163333	0.0229188	0.1921338
CHM	XAP	0.0150641	0.0000234	0.0004980	0.0054419	0.0049032
CHM	ARG	32.0302318	0.9122749	0.9633889	0.1310220	8.0714893
CHM	BRA	197.9794582	2.1174103	3.3811937	22.7216927	79.5958514
CHM	CHL	0.3097059	0.0041691	0.0074932	1.0475295	0.0944498
CHM	URY	0.0152578	0.0001992	0.0002814	0.0000142	0.0046146
CHM	XSM	0.0024804	0.0000149	0.0000229	0.0001069	0.0011155

CHM	AUT	0.8644686	0.0243058	0.0032593	0.0083429	0.3930113
CHM	DNK	0.6387339	0.0300270	0.0093362	0.0015402	0.2162296
CHM	FIN	0.3330087	0.0055652	0.0057952	0.0070366	0.1305379
CHM	FRA	268.8156743	6.9466047	2.2848068	49.0774902	116.1649288
CHM	DEU	915.3753043	31.3701654	1.1931565	74.7219759	393.6455297
CHM	GBR	198.0141496	5.8161264	2.8272216	3.8038682	63.2793472
CHM	GRC	0.0993476	0.0401024	0.0051480	0.0008639	0.0072900
CHM	IRL	2.2308814	0.0235869	0.1310406	0.0060566	0.5911781
CHM	ITA	243.4743088	2.6953208	2.2330333	47.7866529	109.0427233
CHM	NLD	31.4799670	0.2339521	0.3687668	0.4508225	12.4906302
CHM	PRT	0.3941687	0.0085440	0.0010937	0.0979305	0.1990620
CHM	ESP	15.8696659	0.4658341	0.1749053	0.1481886	5.2833357
CHM	SWE	4.1395452	0.2948583	0.0172075	0.1739789	1.5908181
CHM	BEL	14.2653162	0.4196096	0.0658941	4.5241832	6.1839309
CHM	CHE	12.8723888	0.2078570	0.7527029	0.0220813	3.5640819
CHM	XEF	0.3594919	0.0042774	0.0161476	0.0192404	0.0948069
CHM	HUN	0.1208279	0.0012700	0.0031336	1.1265437	0.0453005
CHM	POL	1.4093137	0.0158297	0.0132880	7.0133023	0.6425657
CHM	XCE	4.3586345	0.0425961	0.0410649	20.0597651	1.9956544
CHM	XSU	26.7271262	0.3257944	0.1522343	251.1684753	12.5841751
CHM	TUR	1.7597346	0.0090010	0.0561062	0.1573972	0.6976479
CHM	XME	16.6533786	0.1896378	0.1688211	0.2301079	7.3621471
CHM	MAR	0.0931329	0.0008395	0.0003342	0.0008515	0.0568105
CHM	XNF	2.0430030	0.0153270	0.0071006	2.0733800	1.2968115
CHM	BWA	0.0000082	0.0000004	0.0000001	0.0000063	0.0000078
CHM	XSC	1.8876657	0.0359938	0.0337645	0.0020118	0.7176150
CHM	ZMB	0.0000037	0.0000000	0.0000000	0.0000038	0.0000003
CHM	ZWE	0.0002103	0.0000001	0.0000002	0.0000019	0.0000655
CHM	XSF	0.0001477	0.0000003	0.0000026	0.0000009	0.0000628
CHM	XSS	0.2732183	0.0008691	0.0034748	0.0092506	0.1378754
CHM	XRW	6.9474542	0.1459301	0.1493751	0.5100981	2.2957505
AGI	COL	9.2171801	0.1352390	0.1045126	0.0016052	3.6169551
AGI	AUS	29.9101874	0.4974336	0.2866308	0.0060375	13.6673842
AGI	NZL	3.4140546	0.0611951	0.0153742	0.0000913	1.6669161
AGI	CHN	1230.7590958	15.0126847	4.7318475	144.9639219	466.8516313
AGI	JPN	3749.0623168	34.6107571	19.8330207	0.0979247	1383.1261420
AGI	KOR	53.4886780	0.1606012	0.1103841	0.0010481	29.6646054
AGI	IDN	48.2068731	0.5292354	1.1460244	0.0006814	16.6068771
AGI	MYS	4.0813219	0.0025562	0.0116124	0.0005103	3.1600069
AGI	PHL	8.8641979	0.0662098	0.1364125	0.2414743	3.7618491
AGI	THA	7.0205880	0.0108230	0.2924708	0.0095203	2.5742504
AGI	VNM	0.1024957	0.0009821	0.0001781	0.0000007	0.0647661
AGI	BGD	1.7262908	0.0023753	0.0135724	0.0000439	1.0405774
AGI	IND	76.9328450	1.1274051	0.5088077	7.1675180	19.8905912
AGI	LKA	0.0209824	0.0002016	0.0026594	0.0001715	0.0043582
AGI	XSA	1.9739995	0.0192567	0.0133606	0.0528188	0.7120115
AGI	CAN	57.3397150	0.8776077	0.8100017	0.3697003	27.6047951
AGI	USA	14738.9826343	124.5809612	234.4889639	10.9751137	7084.8449497
AGI	MEX	120.9479697	0.5329938	4.1115020	0.0437446	43.2376213
AGI	XCM	5.9172144	0.0501575	0.1405571	0.0371893	2.8940619

AGI	PER	2.2165465	0.0053368	0.2323087	0.0237213	0.4755319
AGI	VEN	3.8769903	0.0430479	0.0551587	0.0006246	1.4590191
AGI	XAP	0.4164847	0.0009006	0.0374962	0.0013583	0.1114571
AGI	ARG	180.1093973	3.3468703	6.0628037	0.0031133	46.1656501
AGI	BRA	566.0690915	2.8070803	7.7106842	0.1951009	277.6080952
AGI	CHL	4.3840679	0.0298986	0.0458634	0.0486563	2.1289170
AGI	URY	0.3012599	0.0059647	0.0052977	0.0000028	0.0969117
AGI	XSM	0.0368071	0.0003867	0.0004554	0.0000180	0.0182054
AGI	AUT	3.9762225	0.1262060	0.0316032	0.0002806	1.5719044
AGI	DNK	9.8702047	0.1506840	0.0909614	0.0000501	4.9835010
AGI	FIN	2.8553948	0.0511820	0.0134322	0.0004191	1.5710639
AGI	FRA	595.5131486	10.0595538	9.7277394	0.4603173	295.6897895
AGI	DEU	740.6667992	10.8331142	31.0261157	0.1671297	290.7843229
AGI	GBR	502.9349603	10.6973546	10.6611227	0.0453145	249.9312293
AGI	GRC	4.3682491	0.0371131	0.0344065	0.0000052	3.2709030
AGI	IRL	3.1606899	0.0467634	0.0410918	0.0000778	1.9272792
AGI	ITA	333.8815434	3.5363568	3.3449370	0.4060888	169.4294370
AGI	NLD	56.2898613	0.4039033	0.2295679	0.0050411	33.9969375
AGI	PRT	4.2104075	0.0168680	0.0286410	0.0012522	2.9416234
AGI	ESP	117.1978214	1.1502655	1.5298574	0.0023700	58.5787534
AGI	SWE	4.0163229	0.0373758	0.0176349	0.0001428	2.5211464
AGI	BEL	13.7339635	0.2513883	0.0682989	0.0175553	8.8980756
AGI	CHE	8.9001233	0.1562269	0.1274013	0.0001075	3.9602658
AGI	XEF	3.5319294	0.0730580	0.0388675	0.0021285	1.5790263
AGI	HUN	0.7478040	0.0042266	0.0021295	0.0242831	0.4646592
AGI	POL	19.9804435	0.2134057	0.0636001	0.6123841	10.7367209
AGI	XCE	19.7574176	0.2639844	0.1520557	0.8051993	9.7529594
AGI	XSU	69.4688003	1.0768086	0.4860689	5.3768618	41.5523116
AGI	TUR	15.3704100	0.0461121	0.7731575	0.0052227	5.7174315
AGI	XME	64.3911348	0.8989711	0.6982764	0.0070651	28.8459322
AGI	MAR	0.9115294	0.0263716	0.0056890	0.0001732	0.3711462
AGI	XNF	24.2468034	0.7722835	0.1772099	0.6766551	10.2088934
AGI	BWA	0.0004090	0.0000256	0.0000192	0.0000029	0.0002810
AGI	XSC	7.3355223	0.0569404	0.0792317	0.0000206	3.7655224
AGI	ZMB	0.0070098	0.0001249	0.0000388	0.0006050	0.0031392
AGI	ZWE	0.0344526	0.0003712	0.0013094	0.0000494	0.0110934
AGI	XSF	0.0169591	0.0002502	0.0008010	0.0000051	0.0100254
AGI	XSS	23.6558219	0.2318070	0.3381050	0.0159800	12.0681388
AGI	XRW	98.9997852	1.2918836	0.7395946	0.0292483	45.5189636
AGR	COL	0.9943274	0.0809240	0.0182508	39.1836833	0.0602698
AGR	AUS	2.8611889	0.1292049	0.0313298	777.9060680	0.5445506
AGR	NZL	0.1015925	0.0014556	0.0032885	9.7871403	0.0245639
AGR	CHN	806.4241039	73.6825508	1.7731406	1138748.9196494	82.1029652
AGR	JPN	214.6048490	9.0942878	3.9577334	10269.7672433	19.4119972
AGR	KOR	14.1182846	0.5443430	0.0644866	154.1158889	0.4064294
AGR	IDN	26.8447288	1.7501283	0.4475593	21156.4626487	0.4600279
AGR	PHL	4.3741068	0.3353073	0.0373181	628.6938338	0.1704310
AGR	THA	2.8457983	0.1132158	0.1517594	26053.1516473	0.0575725
AGR	VNM	0.1095840	0.0038507	0.0003912	7656.9451549	0.0119587
AGR	BGD	2.2934011	0.0277120	0.0291672	21640.9160338	0.4615010

AGR	IND	292.2784145	13.2050098	4.6392741	2113778.2937179	20.5005306
AGR	LKA	0.1051889	0.0072623	0.0023301	305.1920812	0.0013987
AGR	XSA	6.6730444	0.2594269	0.1011336	142070.9086700	0.5732277
AGR	CAN	10.9417604	0.3356799	0.1660853	48.8223534	2.8326134
AGR	USA	511.3282139	13.0237527	13.3230663	193646.0593052	103.9343308
AGR	MEX	14.8573475	1.1881413	0.5790438	275.9736902	0.3602832
AGR	XCM	2.4884777	0.1329980	0.0463394	499.1164286	0.2473184
AGR	PER	0.4882045	0.0276398	0.0113761	0.7567661	0.0330446
AGR	VEN	0.1616403	0.0108642	0.0046154	23.9619124	0.0066732
AGR	XAP	0.1764171	0.0092614	0.0031881	519.7804471	0.0161958
AGR	ARG	12.7748974	1.3963952	0.3727219	1172.1487677	0.2458546
AGR	BRA	131.0866701	1.5698841	13.1220864	3988.2803003	15.0861019
AGR	CHL	0.8078401	0.0305126	0.0163702	118.9001725	0.0872018
AGR	URY	0.0155743	0.0006410	0.0001939	12.8789922	0.0020977
AGR	XSM	0.0106374	0.0004949	0.0001429	4.6540321	0.0013520
AGR	AUT	0.0562161	0.0022453	0.0031249	0.0001370	0.0159551
AGR	DNK	0.2301112	0.0051383	0.0136983	0.2378915	0.0692645
AGR	FIN	0.2260958	0.0092681	0.0434799	0.0019138	0.0119758
AGR	FRA	19.5073102	2.3188540	0.7423409	23.1777207	3.1256880
AGR	DEU	2.5812116	0.5113915	0.1328420	170.3349985	1.7636230
AGR	GBR	4.7285651	0.3673144	0.0810150	0.0537773	1.2204339
AGR	GRC	8.3782326	0.7991602	0.1321123	67.9111772	0.5911721
AGR	ITA	16.2753073	3.2168367	0.4687543	991.9322090	0.6204612
AGR	NLD	1.3239524	0.1261616	0.0129833	52.7727093	0.2156461
AGR	PRT	0.1793604	0.0044737	0.0029485	150.0864089	0.0626834
AGR	ESP	8.8900007	1.0280149	0.2127621	1541.5687795	1.1410301
AGR	SWE	0.2562486	0.0070335	0.0253079	0.0465794	0.0615708
AGR	CHE	0.0738231	0.0048108	0.0036395	0.0010099	0.0136251
AGR	XEF	0.0739763	0.0016221	0.0016270	0.0335712	0.0095449
AGR	HUN	0.0727751	0.0029043	0.0001806	7.8868579	0.0152101
AGR	POL	1.0055186	0.0567194	0.0058517	1119.8974332	0.1167398
AGR	XCE	2.1460247	0.0893535	0.0069892	529.1702406	0.3921524
AGR	XSU	9.1863048	0.4432421	0.0339464	180299.3852292	1.9756259
AGR	TUR	15.0798439	1.6790182	0.6785142	2123.6565491	0.7152094
AGR	XME	5.9681438	0.1850541	0.0863632	106700.7253564	1.0171284
AGR	XNF	6.8748385	0.9993790	0.2950370	14568.6614960	0.4348235
AGR	BWA	0.0000024	0.0000003	0.0000003	0.0015367	0.0000014
AGR	XSC	0.3463762	0.0064237	0.0203135	309.1312547	0.0457527
AGR	ZMB	0.0087106	0.0009790	0.0001744	1.8950983	0.0006466
AGR	ZWE	0.0191933	0.0008673	0.0001255	6.4241290	0.0043819
AGR	XSF	0.0095367	0.0009210	0.0001279	0.2852810	0.0011677
AGR	XSS	36.8482705	3.8440964	0.3751864	14985.7589743	4.4748311
AGR	XRW	21.5360234	1.3039899	0.1817793	17397.7013634	1.2213185
TXT	COL	0.0678047	0.0009109	0.0008206	0.0000014	0.0306122
TXT	AUS	0.3633957	0.0094008	0.0029601	0.0000146	0.1929384
TXT	NZL	0.0136070	0.0001485	0.0000174	0.0000000	0.0115775
TXT	CHN	562.2742997	2.6507321	2.3689820	3.2696278	277.3382642
TXT	JPN	20.8805415	0.9744188	0.0698934	0.0003522	11.0384082
TXT	KOR	11.6956532	0.1971087	0.0553719	0.0001643	5.5150335
TXT	IDN	0.8875363	0.0124547	0.0196537	0.0000020	0.2945218

TXT	MYS	0.0995304	0.0007238	0.0004436	0.0000185	0.0658039
TXT	PHL	0.0505285	0.0003852	0.0005219	0.0001795	0.0212162
TXT	THA	1.3330216	0.0018935	0.1903704	0.0002128	0.4297408
TXT	VNM	0.0324410	0.0002536	0.0000293	0.0000000	0.0169021
TXT	BGD	0.2549852	0.0056644	0.0014080	0.0000134	0.1538035
TXT	IND	21.6050964	0.1256077	0.2329788	0.1020084	9.7288244
TXT	LKA	0.0087313	0.0001258	0.0007607	0.0000137	0.0013430
TXT	XSA	1.5056778	0.0095636	0.0156781	0.0033509	0.7244433
TXT	CAN	0.6171245	0.0379703	0.0040363	0.0020433	0.3247628
TXT	USA	231.1988635	11.6734527	1.7650083	0.1313674	125.5941337
TXT	MEX	3.6751480	0.0341626	0.2121299	0.0003582	1.0979043
TXT	XCM	0.5967884	0.0041897	0.0158421	0.0003968	0.3127976
TXT	PER	0.1143858	0.0003449	0.0169776	0.0001958	0.0245878
TXT	VEN	0.0759443	0.0006029	0.0003033	0.0000011	0.0414634
TXT	XAP	0.0086563	0.0000389	0.0014166	0.0000075	0.0032366
TXT	ARG	15.0261918	0.2818513	0.5178735	0.0000335	4.3032459
TXT	BRA	44.6213223	0.4200574	0.7475347	0.0037294	19.1874750
TXT	CHL	0.0588647	0.0007545	0.0012585	0.0001568	0.0262374
TXT	URY	0.0061417	0.0000297	0.0001509	0.0000000	0.0027089
TXT	XSM	0.0002996	0.0000011	0.0000037	0.0000000	0.0001775
TXT	AUT	0.0181815	0.0004324	0.0000187	0.0000001	0.0384399
TXT	DNK	0.0173223	0.0007378	0.0000440	0.0000000	0.0180070
TXT	FIN	0.0030086	0.0002471	0.0000645	0.0000003	0.0024639
TXT	FRA	3.7888588	0.1909842	0.0212349	0.0011164	3.3908815
TXT	DEU	3.6334901	0.7329741	0.0119581	0.0014445	7.1109742
TXT	GBR	4.8965504	0.4672529	0.0354276	0.0002528	2.7152375
TXT	GRC	0.1045897	0.0095551	0.0013893	0.0000002	0.0648425
TXT	IRL	0.0005414	0.0002031	0.0000015	0.0000000	0.0034357
TXT	ITA	45.0274564	0.4865320	0.4078186	0.0071369	21.8891804
TXT	NLD	0.1841513	0.0039874	0.0001935	0.0000064	0.2433761
TXT	PRT	0.4530185	0.0118422	0.0023720	0.0001123	0.3551098
TXT	ESP	1.5343547	0.1110156	0.0143209	0.0000292	0.7242353
TXT	SWE	0.0000002	0.0000795	0.0000037	0.0000000	0.0074453
TXT	BEL	0.0553862	0.0306491	0.0015845	0.0002734	0.2756436
TXT	CHE	0.0067868	0.0026655	0.0007324	0.0000002	0.0197983
TXT	HUN	0.0047547	0.0003298	0.0000485	0.0002420	0.0048582
TXT	POL	0.1166266	0.0030210	0.0008792	0.0011074	0.0637189
TXT	XCE	2.1279716	0.0503542	0.0164148	0.0196197	1.2604305
TXT	XSU	1.9521892	0.0742922	0.0144625	0.0473876	1.2319006
TXT	TUR	1.2609636	0.0027020	0.0299361	0.0000391	0.5264101
TXT	XME	0.8586408	0.0098492	0.0159839	0.0000099	0.6159960
TXT	MAR	0.2352330	0.0150931	0.0022826	0.0000127	0.0489465
TXT	XNF	4.2276566	0.2773236	0.0500476	0.0310390	0.9499812
TXT	BWA	0.0000010	0.0000000	0.0000000	0.0000000	0.0000017
TXT	XSC	0.2200125	0.0127429	0.0011538	0.0000006	0.0851377
TXT	ZMB	0.0000660	0.0000002	0.0000007	0.0000001	0.0000408
TXT	ZWE	0.0012397	0.0000288	0.0000311	0.0000005	0.0004234
TXT	XSF	0.0034920	0.0000591	0.0001205	0.0000002	0.0014471
TXT	XSS	0.5196668	0.0135541	0.0069188	0.0001194	0.2898417
TXT	XRW	1.4248454	0.0374693	0.0260040	0.0001084	0.6097239

PPP	COL	0.0727091	0.0007434	0.0008790	0.0029534	0.0353252
PPP	AUS	2.5309833	0.1001154	0.0629536	0.4067033	0.6732557
PPP	NZL	0.1269820	0.0047937	0.0018303	0.0023932	0.0383916
PPP	CHN	25.9335429	0.3405008	0.1600598	1100.4652676	10.2631473
PPP	JPN	582.5512829	21.2847902	6.7687615	20.1561242	148.2400976
PPP	KOR	5.2590493	0.1293811	0.0544617	0.2826187	1.8743562
PPP	IDN	0.2189023	0.0039499	0.0075285	0.0017021	0.0640808
PPP	MYS	0.0645532	0.0017705	0.0022503	0.1183064	0.0160916
PPP	PHL	0.0230787	0.0001786	0.0004060	0.2180758	0.0085361
PPP	THA	0.0638366	0.0000538	0.0244810	0.0158340	0.0092299
PPP	VNM	0.0009936	0.0000016	0.0000022	0.0000004	0.0005741
PPP	BGD	0.0017453	0.0000178	0.0000153	0.0001100	0.0006888
PPP	IND	0.5916848	0.0028725	0.0069718	6.1122908	0.2525162
PPP	LKA	0.0002511	0.0000027	0.0000083	0.0007814	0.0000521
PPP	XSA	0.0121367	0.0000500	0.0001387	0.0458604	0.0046614
PPP	CAN	27.8635398	1.5617496	0.3726859	220.2000548	8.7787592
PPP	USA	2645.1924904	132.2697661	61.9276507	3900.0895426	649.0808386
PPP	MEX	1.2855915	0.0038678	0.0790225	0.1062473	0.3609427
PPP	XCM	0.0459134	0.0003687	0.0010867	0.0914945	0.0198806
PPP	PER	0.0162779	0.0000437	0.0053101	0.0650409	0.0010644
PPP	VEN	0.0392422	0.0007179	0.0005441	0.0034864	0.0149744
PPP	XAP	0.0015569	0.0000038	0.0003298	0.0019209	0.0003372
PPP	ARG	2.0585986	0.0454513	0.0728550	0.0141511	0.5404894
PPP	BRA	14.7735031	0.2779644	0.2781892	6.4662161	5.5396855
PPP	CHL	0.0693229	0.0006065	0.0025781	0.3303409	0.0220443
PPP	URY	0.0015949	0.0000325	0.0000119	0.0000050	0.0005826
PPP	XSM	0.0001546	0.0000013	0.0000007	0.0000195	0.0000868
PPP	AUT	0.5768505	0.0226949	0.0039017	0.0168874	0.2559796
PPP	DNK	0.6256664	0.0549968	0.0026289	0.0061154	0.1697650
PPP	FIN	4.4379726	0.0468237	0.0918867	0.1283430	1.8097165
PPP	FRA	58.9100685	2.3003760	0.5217296	35.2317337	18.6574785
PPP	DEU	66.6210101	3.4682191	0.2545810	17.9086767	23.3502507
PPP	GBR	58.1706368	3.9159627	0.5021161	5.5520786	17.1627247
PPP	GRC	0.0494878	0.0017435	0.0004109	0.0000814	0.0192750
PPP	IRL	0.0117754	0.0012532	0.0000540	0.0006976	0.0047007
PPP	ITA	26.4655216	0.5188038	0.4154985	19.9399791	10.2665286
PPP	NLD	3.8442519	0.1122141	0.0527464	0.4687609	1.4142268
PPP	PRT	0.1249283	0.0032785	0.0007691	0.0814623	0.0478063
PPP	ESP	2.0013854	0.1112858	0.0223283	0.0767448	0.8244252
PPP	SWE	6.0688115	0.2359777	0.0208013	0.3018420	2.5589250
PPP	BEL	0.4560153	0.0283368	0.0012166	0.6623257	0.2006845
PPP	CHE	0.9260334	0.0858947	0.0054814	0.0197812	0.2799922
PPP	XEF	0.3850596	0.0297877	0.0019795	0.2904687	0.1117063
PPP	HUN	0.0108898	0.0000836	0.0001133	0.1607962	0.0052408
PPP	POL	0.2634800	0.0023144	0.0065334	2.2228725	0.1002196
PPP	XCE	0.3899034	0.0086594	0.0037473	8.8403707	0.1472536
PPP	XSU	6.1455565	0.2508158	0.0517373	419.1812805	1.9690261
PPP	TUR	0.1079502	0.0005462	0.0020763	0.0207061	0.0457646
PPP	XME	2.5780100	0.0737810	0.0276004	0.1940782	0.9061878
PPP	MAR	0.0094185	0.0000778	0.0000328	0.0001711	0.0051606

PPP	XNF	0.2762846	0.0021537	0.0010561	0.6315720	0.1543778
PPP	XSC	0.4964678	0.0105699	0.0141857	0.0012807	0.1549883
PPP	ZMB	0.0000115	0.0000004	0.0000014	0.0006180	0.0000010
PPP	ZWE	0.0000035	0.0000033	0.0000003	0.0001488	0.0000020
PPP	XSF	0.0000452	0.0000022	0.0000020	0.0000149	0.0000106
PPP	XSS	0.0239101	0.0004538	0.0005761	0.0104709	0.0088076
PPP	XRW	1.1279548	0.0181695	0.0353918	0.1376816	0.3487365
PEC	COL	0.0320780	0.0000165	0.0000030	0.0000173	0.0280328
PEC	AUS	0.3372370	0.0000024	0.0004715	0.0000026	0.2966563
PEC	NZL	0.0034092	0.0000000	0.0000038	0.0000000	0.0030338
PEC	CHN	20.7700060	0.0101189	0.0415047	8.5918772	12.5378665
PEC	JPN	62.4731702	0.1397037	0.7323310	0.0347571	34.9647632
PEC	KOR	6.4297870	0.0024042	0.0373521	0.0013797	4.3944823
PEC	IDN	0.2982442	0.0001788	0.0002657	0.0000202	0.3536039
PEC	MYS	0.0848701	0.0000002	0.0000085	0.0000031	0.0816941
PEC	THA	0.4742484	0.0000006	0.0056927	0.0000450	0.2252671
PEC	BGD	0.0001604	0.0000000	0.0000002	0.0000000	0.0002013
PEC	IND	1.1798066	0.0005277	0.0009940	0.2950288	1.3318770
PEC	LKA	0.0009318	0.0000000	0.0000000	0.0000000	0.0007822
PEC	XSA	0.0199209	0.0000004	0.0000011	0.0000900	0.0073595
PEC	CAN	3.0446276	0.0007675	0.0000055	0.0284317	2.8578491
PEC	USA	604.7173386	0.4261672	0.3550043	3.3013543	510.5301850
PEC	MEX	1.3414967	0.0006756	0.0015752	0.0048761	1.0957559
PEC	XCM	0.1652667	0.0000063	0.0000845	0.0004113	0.1391290
PEC	PER	0.0128866	0.0000085	0.0000002	0.0033145	0.0075146
PEC	VEN	0.4151530	0.0000016	0.0014135	0.0000020	0.3348225
PEC	XAP	0.0182661	0.0000113	0.0000002	0.0014969	0.0109206
PEC	ARG	0.1947644	0.0000117	0.0050470	0.0000010	0.1099940
PEC	BRA	2.2583144	0.0012692	0.0020153	0.0077572	1.8957862
PEC	CHL	0.0188458	0.0000009	0.0000856	0.0001287	0.0135885
PEC	URY	0.0002041	0.0000006	0.0000013	0.0000000	0.0001801
PEC	AUT	0.0119145	0.0000028	0.0000010	0.0000005	0.0129753
PEC	DNK	0.0106205	0.0000007	0.0000000	0.0000000	0.0121246
PEC	FIN	0.0142610	0.0000032	0.0000027	0.0000023	0.0138860
PEC	FRA	1.5472619	0.0006945	0.0000073	0.0027946	1.8891871
PEC	DEU	1.9995129	0.0000000	0.0078341	0.0000000	2.4139833
PEC	GBR	5.0713926	0.0030167	0.0607417	0.0011237	3.1904982
PEC	GRC	0.0497582	0.0000001	0.0000190	0.0000000	0.0507770
PEC	IRL	0.0001139	0.0000001	0.0000004	0.0000000	0.0006426
PEC	ITA	2.2737884	0.0001413	0.0021141	0.0014269	1.9994324
PEC	NLD	0.9596091	0.0000579	0.0003643	0.0000635	0.8589719
PEC	PRT	0.0215979	0.0000000	0.0000082	0.0000001	0.0227533
PEC	ESP	0.7814452	0.0000194	0.0006907	0.0000035	0.6502691
PEC	BEL	0.1703636	0.0000143	0.0000558	0.0000877	0.2006537
PEC	XEF	0.0370026	0.0000002	0.0000100	0.0000006	0.0426514
PEC	HUN	0.0067956	0.0000002	0.0000048	0.0000998	0.0060673
PEC	POL	0.0351801	0.0000026	0.0000206	0.0006686	0.0318956
PEC	XCE	0.1928145	0.0000161	0.0000775	0.0043175	0.1646530
PEC	XSU	17.8864935	0.0021760	0.0037290	0.9554541	14.6011855
PEC	TUR	0.1734522	0.0000061	0.0020706	0.0000609	0.1229924

PEC	XME	26.6251126	0.0012748	0.0167241	0.0008810	23.3373126
PEC	MAR	0.0069203	0.0000002	0.0005330	0.0000001	0.0028294
PEC	XNF	1.0689665	0.0000008	0.0043549	0.0000622	0.8529418
PEC	XSC	0.2607458	0.0005269	0.0022557	0.0000168	0.1606832
PEC	ZMB	0.0001421	0.0000000	0.0000000	0.0000000	0.0000281
PEC	XSF	0.0007464	0.0000000	0.0000011	0.0000001	0.0002915
PEC	XSS	0.1928959	0.0000131	0.0001778	0.0000797	0.1845184
PEC	XRW	0.0254967	0.0000034	0.0000177	0.0000068	0.0235365
MNF	COL	0.4152399	0.0063734	0.0032532	0.0014122	0.2219559
MNF	AUS	6.2652956	0.2179839	0.0999667	0.0493893	3.0052082
MNF	NZL	0.1862909	0.0067315	0.0016487	0.0001874	0.0957708
MNF	CHN	2626.2074456	24.6516306	25.2411569	4443.6120239	1087.8024372
MNF	JPN	14983.2461831	372.3191386	132.7999887	19.6646077	5592.3095291
MNF	KOR	167.9600198	1.5820385	0.9156880	0.1927434	88.4808673
MNF	IDN	14.8187047	0.3448550	0.5505139	0.0082884	4.1413943
MNF	MYS	54.5022262	0.1492380	0.4408489	0.5561956	39.2445392
MNF	PHL	5.2925590	0.0076134	0.0059110	0.5183386	4.2459546
MNF	THA	32.7533805	0.0290290	6.3579797	0.4766759	5.4734448
MNF	VNM	0.1820053	0.0005009	0.0004295	0.0000065	0.1283576
MNF	BGD	0.2062220	0.0011949	0.0009207	0.0004121	0.1111383
MNF	IND	42.1102873	0.3768088	0.8622787	44.7196891	13.7945856
MNF	LKA	0.0473354	0.0004619	0.0026869	0.0073345	0.0128377
MNF	XSA	0.5571163	0.0034830	0.0092708	0.1783425	0.2035844
MNF	CAN	47.2824662	3.3857468	0.2152798	26.6251925	31.7033837
MNF	USA	13704.6937460	816.1297162	152.8220047	1342.1636062	5622.3076246
MNF	MEX	41.0821656	0.2376998	3.0457828	0.3641833	14.9299709
MNF	XCM	1.6011017	0.0136392	0.0993529	0.1887812	0.9128196
MNF	PER	0.9288343	0.0004120	0.3284230	0.0341851	0.0679683
MNF	VEN	0.2873322	0.0043478	0.0019506	0.0011776	0.1304392
MNF	XAP	0.1061268	0.0000493	0.0336914	0.0013892	0.0110326
MNF	ARG	16.7658823	0.7060878	0.2650847	0.0122613	4.5748488
MNF	BRA	215.4469870	3.5241699	5.5132145	4.5724631	79.4894978
MNF	CHL	0.2828291	0.0037538	0.0134167	0.1140382	0.1213211
MNF	URY	0.0083080	0.0002760	0.0002933	0.0000024	0.0025723
MNF	XSM	0.0018041	0.0000373	0.0000290	0.0000323	0.0012066
MNF	AUT	4.8893463	0.3413197	0.0612975	0.0141654	2.5943923
MNF	DNK	2.0969787	0.1452269	0.0182225	0.0009007	0.9902660
MNF	FIN	2.9225743	0.0531841	0.0330686	0.0081306	1.4305512
MNF	FRA	442.0648416	27.3344573	6.7863362	23.3495179	188.6979285
MNF	DEU	1616.1474917	126.6211793	6.0199920	36.4666272	684.2230764
MNF	GBR	212.1828551	15.5530855	1.9787637	1.2298889	123.8589255
MNF	GRC	1.7807106	0.1230016	0.0210457	0.0003204	0.6283425
MNF	IRL	2.6869571	0.0506669	0.0464978	0.0015730	1.2568204
MNF	ITA	699.0032660	11.2723890	13.4051436	24.1640551	285.6321389
MNF	NLD	34.7081756	1.4117348	0.2058420	0.3289194	20.7416304
MNF	PRT	3.1743272	0.0911410	0.0130334	0.1263073	1.6568783
MNF	ESP	61.6357578	2.1605279	2.1061457	0.0831000	15.9199078
MNF	SWE	11.5513880	0.7472774	0.0866965	0.0533117	4.8985030
MNF	BEL	10.4772718	0.4367069	0.0640533	0.5693018	7.4154487
MNF	CHE	2.0886799	0.2404591	0.0227380	0.0030886	2.3906500

MNF	XEF	0.2727906	0.0173188	0.0021339	0.0094192	0.2345576
MNF	HUN	0.4178897	0.0040381	0.0036661	0.4330880	0.2342783
MNF	POL	4.2820284	0.0720946	0.0562729	3.8619744	1.7232387
MNF	XCE	8.2576544	0.2767001	0.0744835	15.7551830	4.0550148
MNF	XSU	39.1527818	1.8012466	0.3635609	167.9006689	16.7440856
MNF	TUR	7.1972535	0.0303745	0.3091072	0.0642206	2.8502345
MNF	XME	29.9870497	0.7246859	0.3887213	0.1063198	15.2068409
MNF	MAR	0.4885237	0.0081274	0.0044957	0.0009967	0.2198870
MNF	XNF	9.8438851	0.1655737	0.1191068	2.7081379	4.0935597
MNF	BWA	0.0001018	0.0000042	0.0000024	0.0000089	0.0000550
MNF	XSC	0.7435185	0.0487461	0.0096817	0.0003294	0.2224948
MNF	ZMB	0.0010079	0.0000042	0.0000263	0.0003809	0.0003646
MNF	ZWE	0.0142825	0.0003050	0.0004507	0.0007581	0.0037427
MNF	XSF	0.0322181	0.0003106	0.0008585	0.0001173	0.0103877
MNF	XSS	1.9935256	0.0313957	0.0399892	0.0404025	0.7401618
MNF	XRW	15.6035453	0.3920380	0.3533962	0.1656893	5.4447063
MIN	COL	0.0016890	0.0002254	0.0000376	0.0000000	0.0000980
MIN	AUS	1.8706693	0.0138164	0.0695780	0.0000011	0.4717905
MIN	NZL	0.0004599	0.0000065	0.0000153	0.0000000	0.0000995
MIN	CHN	14.9137262	0.2568058	0.0829400	0.0159088	4.4356419
MIN	JPN	1.8549031	0.0226811	0.0315653	0.0000004	0.2881922
MIN	KOR	0.0929195	0.0020279	0.0114972	0.0000001	0.0036404
MIN	IDN	0.2409746	0.0133764	0.0241641	0.0000001	0.0112096
MIN	MYS	0.0065045	0.0000082	0.0019568	0.0000000	0.0002026
MIN	PHL	0.0090520	0.0000971	0.0003179	0.0000023	0.0015423
MIN	THA	0.0025757	0.0000196	0.0011952	0.0000001	0.0001314
MIN	VNM	0.0022708	0.0000014	0.0000011	0.0000000	0.0015665
MIN	BGD	0.0005336	0.0000002	0.0000606	0.0000000	0.0001069
MIN	IND	0.0441398	0.0005016	0.0011750	0.0000205	0.0097130
MIN	LKA	0.0000491	0.0000023	0.0000081	0.0000000	0.0000009
MIN	XSA	0.0001585	0.0000042	0.0000202	0.0000001	0.0000049
MIN	CAN	0.7771204	0.0068707	0.0130560	0.0000186	0.2257917
MIN	USA	9.8628847	0.4994527	0.1894572	0.0002823	1.6796919
MIN	MEX	0.2172278	0.0026908	0.0167036	0.0000014	0.0305165
MIN	XCM	0.0039596	0.0000402	0.0001294	0.0000002	0.0009645
MIN	PER	0.0180448	0.0003283	0.0005153	0.0000094	0.0046452
MIN	VEN	0.0026506	0.0000373	0.0004622	0.0000000	0.0001386
MIN	XAP	0.0001605	0.0000005	0.0000006	0.0000000	0.0000823
MIN	ARG	0.0645400	0.0097156	0.0051023	0.0000001	0.0006776
MIN	BRA	1.5196269	0.0195527	0.0256319	0.0000087	0.4730648
MIN	CHL	0.2268734	0.0027721	0.0159596	0.0000289	0.0386117
MIN	URY	0.0000189	0.0000007	0.0000009	0.0000000	0.0000019
MIN	XSM	0.0000592	0.0000017	0.0000051	0.0000000	0.0000047
MIN	AUT	0.0030986	0.0003605	0.0000561	0.0000000	0.0002425
MIN	FIN	0.0024617	0.0000245	0.0000276	0.0000000	0.0005874
MIN	FRA	0.0602894	0.0071304	0.0000685	0.0000021	0.0034811
MIN	DEU	0.0474384	0.0001483	0.0002465	0.0000000	0.0131888
MIN	GBR	0.0134654	0.0000265	0.0000099	0.0000000	0.0035707
MIN	GRC	0.0000475	0.0000002	0.0000005	0.0000000	0.0000066
MIN	IRL	0.0000957	0.0000000	0.0000000	0.0000000	0.0000460

MIN	ITA	0.0939104	0.0034635	0.0032442	0.0000026	0.0115147
MIN	NLD	0.0077684	0.0000049	0.0003627	0.0000000	0.0014548
MIN	PRT	0.0002213	0.0000031	0.0000074	0.0000000	0.0000396
MIN	ESP	0.0225082	0.0003516	0.0003067	0.0000000	0.0053910
MIN	SWE	0.0144189	0.0003159	0.0004203	0.0000000	0.0032217
MIN	BEL	0.0001263	0.0000109	0.0000452	0.0000000	0.0002802
MIN	CHE	0.0063118	0.0003520	0.0001694	0.0000000	0.0006360
MIN	XEF	0.0046440	0.0003706	0.0001845	0.0000001	0.0002819
MIN	HUN	0.0000310	0.0000010	0.0000001	0.0000000	0.0000070
MIN	POL	0.0238777	0.0004713	0.0007773	0.0000087	0.0037060
MIN	XCE	0.1944180	0.0021730	0.0004085	0.0000425	0.0872081
MIN	XSU	2.2756705	0.0358618	0.0047537	0.0011488	0.9464717
MIN	TUR	0.0112272	0.0000871	0.0017253	0.0000001	0.0004325
MIN	XME	0.3206999	0.0051013	0.0043079	0.0000003	0.0911869
MIN	MAR	0.0126487	0.0004676	0.0009431	0.0000000	0.0010974
MIN	XNF	0.1100554	0.0037212	0.0087523	0.0000209	0.0090599
MIN	BWA	0.0286204	0.0000648	0.0153826	0.0000000	0.0001120
MIN	XSC	0.2159016	0.0029911	0.0017192	0.0000000	0.0678273
MIN	ZMB	0.0000234	0.0000000	0.0000029	0.0000000	0.0000034
MIN	ZWE	0.0011047	0.0000070	0.0000420	0.0000000	0.0002361
MIN	XSF	0.0004743	0.0000038	0.0000473	0.0000000	0.0000555
MIN	XSS	0.0460726	0.0003021	0.0040804	0.0000001	0.0067816
MIN	XRW	0.1258769	0.0036680	0.0064330	0.0000005	0.0153965
MAC	COL	0.2138079	0.0017609	0.0005962	0.0000003	0.1549953
MAC	AUS	28.4164141	0.7729511	0.3250333	0.0001531	9.7914358
MAC	NZL	0.3868378	0.0114850	0.0040594	0.0000003	0.1506098
MAC	CHN	2813.8335254	17.7474615	15.1983175	2.7966150	1262.2567363
MAC	JPN	24036.2435466	615.0225646	143.4213623	0.0283966	9387.2125260
MAC	KOR	540.8239385	7.2710914	5.5967413	0.0007744	197.3766055
MAC	IDN	2.0468042	0.0152786	0.0220747	0.0000003	0.6404791
MAC	MYS	4.2374561	0.0255822	0.1696379	0.0000833	1.5994802
MAC	PHL	0.3202566	0.0005819	0.0008359	0.0000346	0.1361584
MAC	THA	12.9285423	0.0069216	2.5991858	0.0000994	1.2447257
MAC	VNM	0.0023742	0.0000207	0.0000017	0.0000000	0.0032480
MAC	BGD	0.0179544	0.0000775	0.0002045	0.0000000	0.0073466
MAC	IND	51.0547804	0.4292613	0.6751684	0.0445354	15.6625549
MAC	LKA	0.0006095	0.0000029	0.0000227	0.0000000	0.0000849
MAC	XSA	0.4826838	0.0022935	0.0043960	0.0001027	0.1114300
MAC	CAN	259.5636094	11.1342268	1.6380664	0.0765428	151.7005486
MAC	USA	74900.5513950	4975.4133989	536.8438643	7.1528877	25844.6053445
MAC	MEX	99.3307490	0.5881385	4.2369479	0.0007877	31.4233705
MAC	XCM	0.9328948	0.0082770	0.0137626	0.0001001	0.4429789
MAC	PER	0.6364343	0.0012485	0.1700610	0.0000906	0.0400465
MAC	VEN	0.6351356	0.0077488	0.0046240	0.0000018	0.2662836
MAC	XAP	0.0607805	0.0000519	0.0073627	0.0000013	0.0088734
MAC	ARG	70.2436813	2.2997373	0.6515188	0.0000349	21.6778866
MAC	BRA	463.4516048	10.9378858	3.3948062	0.0124060	178.4119050
MAC	CHL	0.1762754	0.0020835	0.0024546	0.0000553	0.0678616
MAC	URY	0.0030270	0.0001488	0.0000708	0.0000000	0.0008453
MAC	XSM	0.0010794	0.0000082	0.0000051	0.0000000	0.0007225

MAC	AUT	12.9961191	0.5474577	0.0982196	0.0000199	6.0884486
MAC	DNK	6.3349673	0.4844941	0.0195500	0.0000026	2.3252397
MAC	FIN	3.7717179	0.1399638	0.0275947	0.0000187	1.6698766
MAC	FRA	1552.5660262	64.6582716	7.7656967	0.0482834	847.8019155
MAC	DEU	7887.7741540	550.3142557	9.7313968	0.1385498	3222.4706754
MAC	GBR	875.5166461	76.7780617	4.4367601	0.0053075	427.1241460
MAC	GRC	0.4561074	0.1319582	0.0048942	0.0000003	0.0879083
MAC	IRL	2.5134168	0.0912372	0.0117641	0.0000025	1.0769527
MAC	ITA	882.8914282	15.8696602	8.7034962	0.0297391	456.5977978
MAC	NLD	38.3829086	1.1497876	0.2200956	0.0002342	21.0301258
MAC	PRT	2.2662970	0.1298947	0.0050168	0.0001574	1.2731641
MAC	ESP	101.3740989	5.1614669	0.3362266	0.0001735	47.8975227
MAC	SWE	40.0185347	1.3798445	0.1127686	0.0000861	18.7086999
MAC	BEL	37.3996811	1.5679887	0.0415744	0.0017869	20.7647883
MAC	CHE	53.0348748	3.3556653	0.7114085	0.0000377	16.9648522
MAC	XEF	4.5917509	0.2910787	0.0657372	0.0001384	1.6061250
MAC	HUN	0.7665224	0.0056041	0.0078661	0.0005254	0.3631941
MAC	POL	7.3496506	0.1079609	0.0566748	0.0050557	3.1405650
MAC	XCE	17.5254798	0.6049802	0.1419298	0.0301135	7.8065474
MAC	XSU	140.5015655	8.7674833	0.9923878	0.7144308	43.3128226
MAC	TUR	3.3636380	0.0251926	0.1357956	0.0000466	1.4420811
MAC	XME	41.2988201	1.3222463	0.3048352	0.0001696	15.5615541
MAC	MAR	0.0914277	0.0010903	0.0005661	0.0000001	0.0476632
MAC	XNF	4.0296321	0.0338510	0.0200634	0.0004840	1.8703523
MAC	BWA	0.0006393	0.0000009	0.0000004	0.0000000	0.0006207
MAC	XSC	5.6720982	0.1947643	0.0519867	0.0000012	2.1417807
MAC	ZMB	0.0001133	0.0000014	0.0000015	0.0000001	0.0000201
MAC	ZWE	0.0010616	0.0000478	0.0000382	0.0000001	0.0001704
MAC	XSF	0.0042273	0.0000279	0.0000422	0.0000000	0.0002653
MAC	XSS	0.3039044	0.0044994	0.0050142	0.0000051	0.0909855
MAC	XRW	17.6356219	0.4184803	0.2184991	0.0001546	6.5120373
HEV	COL	0.0136448	0.0000932	0.0000708	0.0000926	0.0054709
HEV	AUS	6.2343428	0.0464651	0.0530042	0.0471775	2.7530079
HEV	NZL	0.0294957	0.0002587	0.0003237	0.0000323	0.0134998
HEV	CHN	216.2306026	0.9628692	0.3261149	777.7792023	119.7056996
HEV	KOR	43.8833451	0.0974803	0.3741413	0.0532204	24.2435688
HEV	IDN	0.2422669	0.0031023	0.0047685	0.0003341	0.0686832
HEV	PHL	0.0363784	0.0000116	0.0005124	0.0035380	0.0159186
HEV	THA	0.0987553	0.0000513	0.0167608	0.0037772	0.0041419
HEV	VNM	0.0009492	0.0000103	0.0000042	0.0000006	0.0003672
HEV	IND	16.9953929	0.0363293	0.0683362	19.3211660	7.2940288
HEV	LKA	0.0000316	0.0000001	0.0000003	0.0000084	0.0000091
HEV	XSA	0.1185318	0.0001725	0.0003871	0.0395884	0.0479689
HEV	CAN	13.0126909	0.3968002	0.0607520	13.9832675	4.9659020
HEV	USA	1021.6233565	35.1600429	2.4841354	259.1159844	426.2154594
HEV	MEX	5.6379540	0.0171940	0.2067299	0.1180500	2.2170157
HEV	XCM	0.1386640	0.0006840	0.0021972	0.0424249	0.0567979
HEV	PER	0.0662536	0.0004639	0.0034863	0.1724740	0.0174265
HEV	VEN	0.1463124	0.0009897	0.0035352	0.0012013	0.0534344
HEV	XAP	0.0015850	0.0000054	0.0000208	0.0006866	0.0004093

HEV	ARG	7.1676214	0.2675101	0.4398796	0.0208168	1.1318836
HEV	BRA	46.3822304	0.1300382	0.1096482	0.7560714	31.8801775
HEV	CHL	0.5260041	0.0033989	0.0206963	0.4627156	0.1640965
HEV	URY	0.0001338	0.0000023	0.0000040	0.0000001	0.0000272
HEV	XSM	0.0021578	0.0000068	0.0000528	0.0000266	0.0009581
HEV	AUT	0.4905579	0.0142229	0.0036196	0.0026452	0.1908945
HEV	DNK	0.0091717	0.0000425	0.0000090	0.0000012	0.0053794
HEV	FIN	0.4873012	0.0023042	0.0049130	0.0015785	0.2458354
HEV	FRA	32.1043229	0.4863921	0.1522961	1.8618836	14.1002773
HEV	DEU	155.9968230	1.1548599	0.0517942	1.4904489	102.7378191
HEV	GBR	28.6799206	0.8410172	0.0785945	0.2980250	11.5457798
HEV	GRC	0.0278865	0.0004514	0.0000078	0.0000053	0.0141869
HEV	IRL	0.0029696	0.0000159	0.0000066	0.0000022	0.0013531
HEV	ITA	41.2903161	0.2689864	0.3026810	2.5839422	22.4810872
HEV	NLD	1.3071623	0.0121485	0.0068736	0.0126841	0.6354563
HEV	PRT	0.0196987	0.0003853	0.0000028	0.0023931	0.0109428
HEV	ESP	2.8647106	0.0457622	0.0028765	0.0078876	1.6243771
HEV	SWE	0.4274175	0.0033372	0.0021618	0.0010669	0.2083213
HEV	BEL	3.7700448	0.1073645	0.0001628	0.6272084	2.0462687
HEV	CHE	4.1325951	0.3130295	0.0365398	0.0180178	1.0156566
HEV	XEF	0.8138766	0.0373625	0.0054489	0.0910603	0.2570567
HEV	HUN	0.0232581	0.0000965	0.0000043	0.0463620	0.0167792
HEV	POL	0.4306206	0.0078288	0.0001881	1.8793281	0.2080304
HEV	XCE	2.0629202	0.0194730	0.0122649	4.9687417	0.9933230
HEV	XSU	26.3632424	0.4450409	0.1583474	185.8993011	11.0247683
HEV	TUR	1.5950870	0.0083016	0.0111492	0.0786554	0.7307860
HEV	XME	2.0299680	0.0176921	0.0163945	0.0116316	0.8136653
HEV	MAR	0.0054593	0.0000428	0.0000047	0.0000235	0.0029299
HEV	XNF	0.3554760	0.0027064	0.0003626	0.1983651	0.1807093
HEV	XSC	3.0689319	0.0354540	0.0553563	0.0010737	1.2282734
HEV	ZMB	0.0017161	0.0000000	0.0000043	0.0000186	0.0012079
HEV	ZWE	0.0008912	0.0000033	0.0000124	0.0000367	0.0003422
HEV	XSF	0.0000301	0.0000000	0.0000004	0.0000001	0.0000068
HEV	XSS	0.0660049	0.0000625	0.0001108	0.0003606	0.0280595
HEV	XRW	1.2042402	0.0231789	0.0036725	0.0438994	0.5298795
ENG	COL	0.3053602	0.0012010	0.0222389	0.0002615	0.0274531
ENG	AUS	2.5137536	0.0136379	0.2991973	0.0030370	0.0884228
ENG	NZL	0.0066236	0.0000280	0.0008181	0.0000008	0.0003007
ENG	CHN	14.5676639	0.1374570	0.6635652	24.3522178	1.0400364
ENG	JPN	0.1917581	0.0000198	0.0001322	0.0000010	0.0027804
ENG	KOR	0.0392645	0.0000006	0.0000000	0.0000001	0.0000047
ENG	IDN	4.1194285	0.2099901	0.2785348	0.0049604	0.0702810
ENG	MYS	0.7095238	0.0006666	0.1181460	0.0024417	0.0247793
ENG	THA	0.0538652	0.0000589	0.0095336	0.0009502	0.0006101
ENG	VNM	0.0195845	0.0000969	0.0012479	0.0000012	0.0014274
ENG	BGD	0.0014906	0.0000326	0.0000578	0.0000111	0.0000219
ENG	IND	1.0745823	0.0235355	0.0402922	2.7452482	0.0205235
ENG	XSA	0.0217403	0.0004164	0.0008580	0.0209536	0.0006184
ENG	CAN	16.0424130	0.0503904	0.3907784	0.3894637	2.4281285
ENG	USA	391.5957443	7.4131250	11.2629020	11.9819811	54.9892118

ENG	MEX	6.9160880	0.0143304	1.5643745	0.0215789	0.0968773
ENG	XCM	0.0245553	0.0001271	0.0008980	0.0017290	0.0017518
ENG	PER	0.0041384	0.0001030	0.0001667	0.0083997	0.0001272
ENG	VEN	4.2664441	0.0140408	0.5383965	0.0037377	0.1774475
ENG	XAP	0.0637619	0.0017428	0.0027578	0.0482274	0.0025160
ENG	ARG	0.6654779	0.0553825	0.0715111	0.0009452	0.0097289
ENG	BRA	0.6443547	0.0006605	0.0266499	0.0008422	0.0856964
ENG	CHL	0.0007872	0.0000004	0.0000023	0.0000120	0.0000144
ENG	XSM	0.0000001	0.0000000	0.0000000	0.0000000	0.0000000
ENG	AUT	0.0008288	0.0000029	0.0000070	0.0000001	0.0000880
ENG	DNK	0.0366846	0.0000459	0.0049588	0.0000003	0.0026077
ENG	FIN	0.0003814	0.0000001	0.0000013	0.0000000	0.0000275
ENG	FRA	0.0037329	0.0001297	0.0000156	0.0001089	0.0002361
ENG	DEU	0.4150089	0.0136592	0.0056208	0.0038663	0.0669102
ENG	GBR	10.8177803	0.1282142	0.8828212	0.0099648	0.7211814
ENG	GRC	0.0027753	0.0000589	0.0000016	0.0000002	0.0002691
ENG	IRL	0.0004508	0.0000164	0.0000102	0.0000005	0.0000151
ENG	ITA	0.0711545	0.0003808	0.0097341	0.0008023	0.0003316
ENG	NLD	0.6918838	0.0027149	0.0703413	0.0006217	0.0367356
ENG	ESP	0.0098530	0.0001895	0.0000120	0.0000072	0.0003408
ENG	XEF	7.6823650	0.0518782	0.1640550	0.0277307	0.6907295
ENG	HUN	0.0007898	0.0000247	0.0000317	0.0026009	0.0002729
ENG	POL	0.1998134	0.0144225	0.0001046	0.7593274	0.0254384
ENG	XCE	0.0907266	0.0011996	0.0019762	0.0671297	0.0114396
ENG	XSU	223.9742651	1.4676272	19.4872701	134.4547143	9.6081628
ENG	TUR	0.0090174	0.0003219	0.0005066	0.0006689	0.0001622
ENG	XME	432.7552933	1.4069054	48.4334690	0.2028665	19.5197825
ENG	MAR	0.0000390	0.0000001	0.0000001	0.0000000	0.0000007
ENG	XNF	12.1805500	0.3654890	0.1165390	5.8753643	1.6585937
ENG	BWA	0.0000016	0.0000000	0.0000002	0.0000000	0.0000000
ENG	XSC	0.7390297	0.0047730	0.0066823	0.0000317	0.1809117
ENG	ZMB	0.0000004	0.0000000	0.0000000	0.0000000	0.0000000
ENG	ZWE	0.0000079	0.0000001	0.0000001	0.0000002	0.0000024
ENG	XSF	0.1670896	0.0002209	0.0183202	0.0000820	0.0080690
ENG	XSS	5.2618410	0.1215598	0.2249523	0.1537478	0.3901627
ENG	XRW	0.1626681	0.0070973	0.0098017	0.0029481	0.0033483

Table A2: Summary statistics of the estimated variables of the model

Variable	Observation	Mean	Standard Deviation	Minimum	Maximum
lnY	727	-0.7974	4.508621	-18.4378	11.22392
lnL	727	-5.48099	5.390958	-27.1992	8.512264
lnK	727	-5.28625	4.775795	-25.8766	6.285707
lnW	727	-6.58969	7.608014	-31.3733	14.56399
lnI	727	-2.02884	4.70282	-20.5835	10.15986
lnLlnK	727	52.25963	76.86333	-6.54698	636.7753
lnLlnW	727	60.32033	92.65262	-49.7206	675.9008
lnLlnI	727	33.53781	59.15936	-20.995	548.4359
lnKlnW	727	56.2089	84.16849	-70.1726	563.7658
lnKlnI	727	30.37538	53.63009	-14.9917	472.0616
lnWlnI	727	33.32025	64.42302	-59.6428	481.9828
ln2L	727	29.53187	44.26175	1.93E-07	369.8993
ln2K	727	25.36065	36.61965	7.59E-06	334.7997
ln2W	727	50.61312	64.11324	0.001038	492.142
ln2I	727	13.10115	22.76317	1.16E-05	211.8403
S1lnwater	727	-0.43984	1.906938	-14.1997	4.976485
S2lnwater	727	0.355925	1.930055	-8.89542	14.56399
S3lnwater	727	-0.2044	1.630146	-14.0189	8.274341
S4lnwater	727	-1.03529	3.759212	-23.4353	0
S5lnwater	727	-0.1864	1.805704	-15.903	10.6806
S6lnwater	727	-0.57178	2.730725	-26.0792	4.901227
S7lnwater	727	-0.35596	1.936327	-16.4677	6.656443
S8lnwater	727	-0.79711	3.116477	-22.1757	1.967516
S9lnwater	727	-1.33223	4.796245	-31.3733	0
S10lnwater	727	-0.22879	1.538591	-12.9484	8.399222
S11lnwater	727	-0.74005	3.094756	-21.1343	2.150817
S12lnwater	727	-0.22011	1.538511	-14.7805	8.268755
S13lnwater	727	-0.83365	3.168045	-21.2663	1.184676

Table A3: Estimated coefficients of the Cobb-Douglas model

Variable	Coefficient	Standard Error	t-stat	p-value
Constant	2.242	0.0564603	39.71	0.000
lnL	0.083	0.0140837	5.91	0.000
lnK	0.227	0.0153231	14.80	0.000
lnW	0.215	0.0470366	4.57	0.001
lnI	0.633	0.0140804	44.96	0.000

Table A4: Estimated coefficients of the Translog model for the global water analysis

Variable	Coefficient	Standard Error	t-stat	p-value
Constant	2.757	0.0888567	31.02749	0.000
lnL	0.262	0.029433	8.901573	0.000
lnK	0.380	0.0265836	14.29453	0.000
lnW	0.150	0.0083469	17.97074	0.000
lnI	0.446	0.495809	0.9773	0.674
LnL*lnK	-0.005	.0065111	-0.76792	0.589
LnLlnW	0.0014	.0023482	0.596201	0.548
LnLlnI	-0.229	.0054597	-41.9437	0.000
LnKlnW	-0.002	.0025426	-0.7866	0.007
LnKlnI	-0.024	.0053395	-4.4948	0.000
LnWlnI	0.011	.0023282	4.72468	0.054
$0.5\ln^2 L$	0.030	.0065893	4.552836	0.000
$0.5\ln^2 K$	0.046	.0076358	6.024254	0.000
$0.5\ln^2 W$	0.001	.0011489	0.870398	0.162
$0.5\ln^2 I$	0.051	.0082763	6.162174	0.000

APPENDIX 2: DETAILED ESTIMATION RESULTS AND DATA FOR SOUTH AFRICA MODEL

Table B1. Data extracted from STATSA census of manufacturing activities

SECTOR	PROVINCE	OUTPUT (R million)	CAPITAL (R million)	EMPLOYMENT (R million)	INTERMEDIATE (R million)	WATER USE (mm^3)
AGI	EC	1046.10	50.78	119.63	789.14	1.23
AGI	FS	57.49	2.08	6.94	42.71	2.18
AGI	GP	6683.68	293.35	645.99	5102.10	6.83
AGI	KZN	2535.67	97.10	302.28	1866.31	6.19
AGI	MP	576.83	18.41	63.25	446.43	0.48
AGI	NW	855.54	30.54	101.93	644.40	3.86
AGI	LP	1311.48	40.85	159.39	977.00	0.50
AGI	NC	388.79	9.12	40.89	306.23	1.69
AGI	WC	1966.27	85.92	212.83	1477.74	3.87
AGR	EC	626.29	63.16	109.42	291.50	1776.00
AGR	FS	42.40	6.62	9.93	11.99	864.00
AGR	GP	3702.64	288.78	541.02	1827.16	336.00
AGR	KZN	1418.85	140.38	240.61	623.12	1394.00
AGR	MP	316.68	56.53	53.84	138.44	1349.00
AGR	NW	520.66	81.16	79.72	195.91	1999.00
AGR	LP	657.38	96.17	119.50	266.73	1797.00
AGR	NC	218.90	39.74	39.36	92.86	972.00
AGR	WC	1125.80	116.53	191.52	509.79	2140.00
CHM	EC	696.85	26.82	84.23	518.39	7.75
CHM	FS	21.86	1.56	2.53	16.83	7.03
CHM	GP	5575.52	186.22	597.92	4256.51	56.37
CHM	KZN	1312.66	55.96	197.52	924.11	36.08
CHM	MP	262.06	19.75	34.30	203.42	2.13
CHM	NW	454.92	32.04	63.09	336.61	18.67
CHM	LP	694.00	37.78	103.45	496.05	2.90
CHM	NC	174.16	10.39	20.43	137.09	9.34
CHM	WC	1116.46	43.55	147.53	808.99	23.92
CON	EC	905.40	15.01	165.38	621.98	0.06
CON	FS	73.76	0.91	16.06	55.22	0.17
CON	GP	5031.69	88.87	708.38	3585.02	0.25
CON	KZN	1951.70	38.60	418.54	1280.23	0.29
CON	MP	492.84	13.70	108.94	347.05	0.03
CON	NW	762.35	20.74	158.06	541.43	0.22
CON	LP	1103.45	26.63	238.19	765.33	0.03
CON	NC	353.46	9.24	78.00	251.75	0.09
CON	WC	1582.03	28.40	299.32	1063.98	0.18

Table B1 cont

SECTOR	PROVINCE	OUTPUT (R million)	CAPITAL (R million)	EMPLOYMENT (R million)	INTERMEDIATE (R million)	WATER USE (mm^3)
ELE	EC	329.42	86.52	85.39	189.14	0.00
ELE	FS	9.50	2.90	3.08	4.21	39.00
ELE	GP	1926.11	391.10	479.00	1276.64	68.00
ELE	KZN	852.74	298.21	192.66	369.46	3.00
ELE	MP	164.38	75.65	38.38	77.45	4.00
ELE	NW	298.42	125.00	67.33	127.28	221.00
ELE	LP	447.72	180.64	98.94	186.26	0.00
ELE	NC	89.74	40.32	22.51	42.48	0.00
ELE	WC	614.88	181.32	147.90	314.63	0.00
HEV	EC	1035.44	70.91	273.90	728.57	19.31
HEV	FS	55.63	3.07	20.18	37.06	43.55
HEV	GP	7422.81	404.35	1464.35	5513.71	105.81
HEV	KZN	2269.00	119.88	639.37	1511.86	89.51
HEV	MP	557.97	34.82	139.17	404.12	7.79
HEV	NW	880.68	46.92	224.34	628.85	58.06
HEV	LP	1229.79	57.07	335.24	852.73	7.22
HEV	NC	419.27	23.34	97.53	300.08	25.44
HEV	WC	1903.59	119.77	485.01	1304.05	60.28
MAC	EC	1267.28	35.67	203.58	961.97	0.35
MAC	FS	72.33	1.92	14.82	51.45	0.78
MAC	GP	9229.61	253.09	1144.64	7230.30	2.02
MAC	KZN	2629.34	67.90	467.86	1887.67	1.60
MAC	MP	557.57	19.57	117.87	396.95	0.18
MAC	NW	940.90	28.88	186.82	662.81	1.20
MAC	LP	1362.31	33.39	270.80	941.90	0.14
MAC	NC	469.80	9.38	91.97	344.90	0.52
MAC	WC	2074.58	58.74	352.14	1527.63	1.07
MIN	EC	1138.61	123.15	298.84	498.65	155.00
MIN	FS	55.93	4.72	13.43	21.93	61.00
MIN	GP	7412.32	759.92	1711.25	3318.72	49.00
MIN	KZN	2416.16	311.67	707.64	1035.33	50.00
MIN	MP	831.10	60.26	186.38	328.50	103.00
MIN	NW	1141.45	110.54	293.30	498.63	39.00
MIN	LP	1348.54	175.65	408.11	574.87	13.00
MIN	NC	503.09	35.73	119.68	180.79	137.00
MIN	WC	2019.83	218.54	541.76	858.14	5.00

Table B1 cont

SECTOR	PROVINCE	OUTPUT (R million)	CAPITAL (R million)	EMPLOYMENT (R million)	INTERMEDIATE (R million)	WATER USE (mm^3)
OHM	EC	598.19	15.75	315.21	367.50	11.58
OHM	FS	35.56	0.85	23.81	24.17	26.75
OHM	GP	3991.16	106.21	1737.62	2539.13	65.45
OHM	KZN	1408.71	27.25	745.57	798.56	54.41
OHM	MP	267.15	6.79	190.83	156.98	6.24
OHM	NW	470.57	11.97	293.33	272.46	41.49
OHM	LP	757.37	15.08	428.50	433.93	4.81
OHM	NC	194.30	3.26	149.88	117.10	17.34
OHM	WC	1058.34	24.77	546.20	631.87	35.39
PET	EC	371.52	37.53	21.44	266.79	1.54
PET	FS	4.36	0.80	0.71	1.93	1.54
PET	GP	3109.52	284.46	88.14	2283.91	6.51
PET	KZN	635.86	73.27	55.41	411.13	7.93
PET	MP	143.23	23.92	11.94	75.01	0.53
PET	NW	192.48	36.40	20.35	105.61	5.07
PET	LP	282.66	43.49	30.61	162.25	0.67
PET	NC	83.90	12.64	6.55	53.59	2.36
PET	WC	558.80	59.15	41.60	389.63	5.28
PPP	EC	405.35	30.58	103.07	359.52	13.27
PPP	FS	16.91	1.02	5.98	14.56	23.62
PPP	GP	2625.62	186.34	651.38	2427.68	85.95
PPP	KZN	953.10	46.29	225.91	803.91	57.75
PPP	MP	168.71	16.55	42.34	157.44	4.01
PPP	NW	313.65	25.15	66.33	288.91	32.22
PPP	LP	489.18	23.27	112.64	432.30	4.43
PPP	NC	102.61	4.94	27.54	98.59	13.73
PPP	WC	698.84	46.97	175.06	614.26	39.74
SER	EC	8860.42	619.77	2992.51	3431.35	61.42
SER	FS	338.46	21.05	135.73	115.48	75.13
SER	GP	61873.35	3914.94	17702.50	27661.17	308.60
SER	KZN	18427.38	1389.21	6631.42	6563.60	146.30
SER	MP	2911.01	281.46	1150.22	1034.90	23.04
SER	NW	4989.69	475.77	1836.51	1830.15	71.76
SER	LP	8264.19	735.78	3086.49	2903.83	23.28
SER	NC	1823.64	176.27	712.80	650.13	56.25
SER	WC	14596.19	1065.62	5202.56	5285.11	189.90

Table B1 cont

SECTOR	PROVINCE	OUTPUT (R million)	CAPITAL (R million)	EMPLOYMENT (R million)	INTERMEDIATE (R million)	WATER USE (mm^3)
TEX	EC	347.80	12.82	80.25	246.85	0.34
TEX	FS	28.80	1.28	7.72	18.44	0.99
TEX	GP	1998.04	62.55	325.41	1501.26	1.41
TEX	KZN	843.36	23.64	201.24	562.22	1.69
TEX	MP	196.18	7.48	51.03	129.64	0.18
TEX	NW	331.22	11.59	81.53	218.15	1.27
TEX	LP	467.04	15.00	112.29	308.24	0.14
TEX	NC	145.56	4.16	37.74	95.37	0.55
TEX	WC	636.07	20.61	145.95	441.01	1.09

Key

Sector		Province	
AGI	Food, Beverage and Tobacco	EC	Eastern Cape
AGR	Agriculture, Fishing & Forestry	FS	Free State
CHM	Basic Chemicals	GP	Gauteng
CON	Construction	KZN	KwaZulu-Natal
ELE	Electricity	MP	Mpumalanga
HEV	Metal Manufacturing	NW	North West
MAC	Machinery and Equipment	LP	Limpopo
MIN	Mining and Quarrying	NC	Northern Cape
OHM	Other Manufacturing	WC	Western Cape
PET	Petroleum		
PPP	Paper, Pulp and Printing		
SER	Services		
TEX	Leather and Wearing Apparel		

Table B2: The coefficients of the Cobb-Douglas' model for South Africa

Variable	Coefficient	Standard Error	t-Stat	p-Value
lnK	0.195938	0.01789	10.95	0.000
lnI	0.608792	0.026624	22.87	0.000
lnL	0.216531	0.021296	10.17	0.000
lnW	0.066518	0.026992	2.46	0.014
Cons	1.082778	0.066393	16.31	0.000
Observations	112			
F(4,107)	3682.24			0.000
R-squared	0.65324			
Adjusted R-squared	0.64528			

Table B3: The coefficients of the translog model for South Africa

Variable	Coefficient	Standard Error	t-Stat	p-Value
lnk	0.3853116	0.1139645	3.380	0.001
lnL	0.7720868	0.1271347	6.070	0.000
lnW	0.1654442	0.0665219	2.490	0.015
ln2K	-0.0463149	0.0262756	-1.760	0.081
ln2L	-0.0513564	0.0289235	-1.780	0.079
ln2W	-0.0065339	0.0069380	-0.940	0.345
lnKlnL	0.0774132	0.0475606	1.630	0.107
lnKlnW	-0.0051680	0.0256288	-0.200	0.841
lnLlnW	0.0129294	0.0228915	0.560	0.573
Cons	2.0555990	0.1852263	11.100	0.000
Observations	112			
F(10, 102)	280.41			0.000
R-squared	0.6134			
Adjusted R-squared	0.6059			

Table B4: The coefficients of the translog model with sectoral dummies for South Africa

Variable	Coefficient	Standard Error	t-Stat	p-Value
lnK	0.2463	0.0897	2.75	0.007
lnL	0.8125	0.0991	8.2	0
lnW	0.4731	0.0689	6.86	0
ln2K	-0.0309	0.0250	-1.24	0.218
ln2L	-0.0426	0.0293	-1.45	0.15
ln2W	-0.0545	0.0095	5.73	0
lnKlnL	0.0712	0.0511	1.39	0.167
lnKlnW	-0.0182	0.0262	-0.7	0.488
lnLlnW	0.0197	0.0260	0.76	0.45
s1lnW	0.1758	0.0686	6.94	0
s2lnW	0.0035	0.0490	0.07	0.943
s3lnW	0.3019	0.0398	7.58	0
s4lnW	0.4421	0.0924	4.78	0
s5lnW	-0.0134	0.0571	-0.24	0.815
s6lnW	0.0990	0.0292	3.39	0.001
s7lnW	0.5371	0.0962	5.58	0
s8lnW	0.0569	0.0320	1.78	0.079
s9lnW	0.0635	0.0613	1.04	0.303
s10lnW	0.5434	0.5434	6.22	0.000
s11lnW	0.1037	0.0339	3.06	0.003
s12lnW	0.5371	0.0962	5.58	0.000
s13lnW	0.6339	0.0961	6.6	0.000
Cons	2.0905	0.1211	17.26	0.000
Observations	112			
F(23, 89)	321.11			0.000
R-squared	0.5817			
Adjusted R-squared	0.5743			

Table B5: Table Summary statistics of the estimated variables in South Africa

Variable	Observation	Mean	Standard Deviation	Minimum	Maximum
Output (Y)	117	2133.423	6206.991	4.357515	61873.35
Capital (K)	117	143.1419	406.0066	0.802957	3914.936
Labour (L)	117	555.8714	1830.534	0.712638	17702.5
Water (W)	117	1147.82	2815.18	1.931405	27661.17
lnW	117	134.394	402.1936	0	2140
lnY	117	6.47854	1.569691	1.471902	11.03284
lnK	117	3.665874	1.639767	-0.21945	8.272554
lnL	117	4.91519	1.649053	-0.33878	9.781462
lnW	111	2.293423	2.493998	-2.30259	7.668561
lnKlnL	117	20.17628	13.93106	-0.52812	80.91767
lnKlnW	117	9.974499	12.0142	-8.07837	47.41866
lnllnw	111	12.31915	14.41168	-12.8977	56.06779
lnksq	117	3.665874	1.639767	0.21945	8.272554
lnlsq	117	4.91519	1.649053	0.33878	9.781461
lnwsq	117	2.293423	2.493998	2.30259	7.668561
s1lnw	111	0.059266	0.333243	0.69315	1.916923
s2lnw	111	0.577928	1.960708	0	7.668561
s3lnw	111	0.195901	0.726901	0	4.032469
s4lnw	111	-0.10668	0.426514	-2.30259	0
s5lnw	111	0.142037	0.746236	0	5.398163
s6lnw	111	0.282121	0.990833	0	4.661551
s7lnw	111	-0.03877	0.299072	-2.30259	0.693147
s8lnw	111	0.309467	1.088924	0	5.043425
s9lnw	111	0.247334	0.873912	0	4.18205
s10lnw	111	0.070921	0.361259	-0.69315	2.066863
s11lnw	111	0.242307	0.868769	0	4.453184
s12lnw	111	0.351252	1.211332	0	5.732046
s13lnw	111	-0.03966	0.300012	-2.30259	0.530628

APPENDIX 3: **UPDATED SOCIAL ACCOUNTING MATRIX AND MULTIPLIERS FOR SOUTH AFRICA**

Table C1: Updated Social Accounting Matrix for South Africa

SECTORS	Agriculture	Mining	Beverages& Tobacco	Clothing & Textile	Paper, Pulp & Publishing	Petroleum	Other Manufacturing	Metal Manufacturing
Agriculture	51179.44	39	31236.81	614.55	1257.44	1.34	441.12	83.39
Mining	174.49	84078.39	117.13	23.89	216.72	11935.15	2368.04	9466.06
Beverages & Tobacco	4917.889	60.46	99823.11	1178.62	134.75	0	1103.543	16.90133
Clothing & Textile	536.25	450.43	109.4447	33442.74	38.12039	0	240.5841	44.69
Paper, Pulp & Publishing	322.98	153.46	2824.19	353.0498	41966.02	1.58	1332.618	281.6255
Petroleum	2907.73	1256.07	523.55	110.1	270.22	23328.16	5421.384	1399.62
Basic Chemicals	4544.83	3254.82	967.39	2557.774	2313.88	362.9285	68996.97	2654.39
Metal Manufacturing	585.69	2808.21	2070.35	295.7044	139.56	81.68237	1526.521	94345.85
Machinery & Equipment	2005.96	5118.48	517.84	528.7002	779.6	288.96	831.0025	3708.045
Other Manufacturing	430.75	2304.21	2465.59	819.4579	1292.191	30.15	3426.252	766.0711
Electricity	452.27	3733.23	624.92	279.17	512.28	257.92	1125.73	4665.73
Water	225.71	426.54	217.04	59.88	87.27	21.6	66.96	117.37
Construction	206.05	841.63	0	0	0	0	0	0
Services	9847.098	22060.78	45002.11	22173.53	11432.47	15179.26	26264.49	22238.34
Capital	16839.68	23460.27	14246.86	1415.704	5228.822	8134.283	8438.903	12188.8
Unskilled Labour	7101.787	16898.2	4972.932	5265.065	1895.607	542.8917	2170.905	7221.988
Medium-skilled Labour	1040.271	4365.496	3456.139	922.7977	2733.825	501.1002	2003.79	3996.142
High-skilled Labour	238.2006	2348.441	2859.657	822.2685	2327.55	855.98	3422.877	2990.921
Firms	0	0	0	0	0	0	0	0
Least-income Households	0	0	0	0	0	0	0	0
Low-income Households	0	0	0	0	0	0	0	0
Middle-income Households	0	0	0	0	0	0	0	0
High-income Households	0	0	0	0	0	0	0	0
Highest-income Households	0	0	0	0	0	0	0	0
Government	572.413	854.7123	15482.47	2803.183	1174.737	16660.98	2428.248	1102.039
Investment	0	0	0	0	0	0	0	0
Rest of the World	3419.824	11962.82	10878.17	6646.451	5705.463	4011.269	17012.52	8669.843
Total	**107549.3**	**186475.6**	**238395.7**	**80312.64**	**79506.52**	**82195.24**	**148622.5**	**175957.8**

Table C1 cont

SECTORS	Machinery & Equipment	Other Manufacturing	Electricity	Water	Construction	Services	Capital	Unskilled Labour
Agriculture	206.14	2292.17	9.71	0	713.2413	973.9	0	0
Mining	156.37	1669.464	3952.16	136.93	4173.316	721.4719	0	0
Beverages & Tobacco	8.93	41.36907	29.74	0	0	12610.38	0	0
Clothing & Textile	770.6393	1304.204	6.35	1.87	523.99	2933.951	0	0
Paper, Pulp & Publishing	383.1449	905.4129	28.89	55.98	490.88	21499.09	0	0
Petroleum	526.35	287.05	103.72	40.64	1987.12	19180.95	0	0
Basic Chemicals	2799.127	6677.15	64.87	199	853	13899.83	0	0
Metal Manufacturing	15303.41	1923.57	180.92	129.32	12595.27	7631.274	0	0
Machinery & Equipment	115517.9	733.3131	1163.26	282.77	6059.42	30934.03	0	0
Other Manufacturing	4075.272	39579.01	55.75	147.83	3261.68	10810.72	0	0
Electricity	647.06	474.72	28993.26	427.29	1067.536	6050.114	0	0
Water	23.56	30.45	121.37	13062.64	91.59	2077.53	0	0
Construction	0	0	1250.87	0	86746.12	8350.898	0	0
Services	48440.81	20095.73	1377.614	560.8218	6128.277	1115810	0	0
Capital	7562.646	3027.285	11465.5	2199.904	8281.711	238502	0	0
Unskilled Labour	6627.511	5307.775	3329.165	333.417	8740.542	71106.68	0	0
Medium-skilled Labour	4507.312	2379.858	1476.14	166.5247	2711.795	138810.7	0	0
High-skilled Labour	4937.438	1832.052	2314.796	302.12	2317.645	58968.61	0	0
Firms	0	0	0	0	0	0	343111.4	0
Least-income Households	0	0	0	0	0	0	0	6549.209
Low-income Households	0	0	0	0	0	0	0	13335.19
Middle-income Households	0	0	0	0	0	0	0	85838.35
High-income Households	0	0	0	0	0	0	0	25429.51
Highest-income Households	0	0	0	0	0	0	0	10362.2
Government	11935.55	2582.164	1111.735	100.1784	3099.811	29088.56	0	0
Investment	0	0	0	0	0	0	0	0
Rest of the World	70792.9	9071.414	276.1526	70.87598	591.8585	34922.44	27305	0
Total	**295222.1**	**100214.2**	**57311.97**	**18218.11**	**150434.8**	**1824883**	**370416.4**	**141514.5**

Table C1 cont

SECTORS	Medium-skilled Labour	High-skilled Labour	Firms	Least-income Households	Low-income Households	Middle-income Households	High-income Households	Highest-income Households
Agriculture	0	0	0	1161.373	1873.908	8861.837	2372.792	1606.611
Mining	0	0	0	14.68648	18.1452	105.3415	47.31159	20.97652
Beverages & Tobacco	0	0	0	10440.25	16852.28	79871.43	21517.39	14586.28
Clothing & Textile	0	0	0	1175.996	2700.606	19080.48	5965.266	3396.541
Paper, Pulp & Publishing	0	0	0	15.05778	85.67436	2087.359	1853.211	1768.568
Petroleum	0	0	0	159.8663	265.381	7150.867	6102.661	4701.724
Basic Chemicals	0	0	0	671.6051	1222.933	10502.69	5452.788	3588.556
Metal Manufacturing	0	0	0	11.5771	36.82683	498.1534	302.6131	233.0671
Machinery & Equipment	0	0	0	94.77138	341.6139	10846.41	10860.44	10720.69
Other Manufacturing	0	0	0	175.1699	600.6077	8687.129	4629.741	3366.27
Electricity	0	0	0	727.8532	899.2652	5220.66	2344.734	1039.584
Water	0	0	0	135.376	224.5612	1150.432	360.299	195.7601
Construction	0	0	0	0	0	0	0	0
Services	0	0	0	2687.07	6969.896	88084.79	57292.87	49661.34
Capital	0	0	0	0	0	0	0	0
Unskilled Labour	0	0	0	0	0	0	0	0
Medium-skilled Labour	0	0	0	0	0	0	0	0
High-skilled Labour	0	0	0	0	0	0	0	0
Firms	0	0	0	0	0	0	0	0
Least-income Households	2482.516	208.9023	1399.727	0	0	0	0	0
Low-income Households	6193.585	457.8611	3725.615	0	0	0	0	0
Middle-income Households	94717.09	31087.69	56383.88	0	0	0	0	0
High-income Households	49466.65	37397.79	33236.89	0	0	0	0	0
Highest-income Households	15211.24	16681.09	71667	0	0	0	0	0
Government	0	0	35767.22	195.0689	1440.441	39085.72	26950.41	18801.36
Investment	0	0	140842	9.104741	21.42932	739.6052	725.4737	555.3871
Rest of the World	1000.783	705.217	89	0.074399	0.380314	23.52336	57.78476	44.23717
Total	**169071.9**	**86538.55**	**343111.4**	**17674.9**	**33553.95**	**281996.4**	**146835.8**	**114287**

Table C1 cont

SECTORS	Government	Investment	Rest of the World	Total
Agriculture	0	-5771.77	8396.309	**107549.3**
Mining	0	1470.733	65608.87	**186475.6**
Beverages & Tobacco	0	-37041.8	12244.17	**238395.7**
Clothing & Textile	0	3057.809	4532.683	**80312.64**
Paper, Pulp & Publishing	0	-1406.75	4504.488	**79506.52**
Petroleum	0	2648.263	3823.803	**82195.24**
Basic Chemicals	0	4327.503	12710.43	**148622.5**
Metal Manufacturing	0	6926.326	28331.93	**175957.8**
Machinery & Equipment	0	73883.72	20005.14	**295222.1**
Other Manufacturing	0	1478.518	11811.79	**100214.2**
Electricity	0	-3274.91	1043.556	**57311.97**
Water	0	-519.754	41.92777	**18218.11**
Construction	0	52922.5	116.7313	**150434.8**
Services	192114	28750.64	32711.16	**1824883**
Capital	0	0	9424	**370416.4**
Unskilled Labour	0	0	0	**141514.5**
Medium-skilled Labour	0	0	0	**169071.9**
High-skilled Labour	0	0	0	**86538.55**
Firms	0	0	0	**343111.4**
Least-income Households	7014.094	0	20.44769	**17674.9**
Low-income Households	9796.266	0	45.43085	**33553.95**
Middle-income Households	13826.76	0	142.6527	**281996.4**
High-income Households	1287.388	0	17.55192	**146835.8**
Highest-income Households	360.4957	0	4.916807	**114287**
Government	210036.8	0	173	**421446.8**
Investment	-18840	3248.039	3398	**130699.1**
Rest of the World	5851	0	0	**219109**
Total	**421446.8**	**130699.1**	**219109**	**6021555**

Table C2: South African SAM Multipliers

Sectors (1)	Agriculture (2)	Mining & Quarrying (3)	Beverages & Tobacco (4)	Clothing & Textiles (5)	Paper, Pulp & Publishing (6)	Petroleum (7)	Basic Chemicals (8)
Agriculture	2.1180	0.1838	0.5980	0.2120	0.2369	0.1202	0.1662
Mining & Quarrying	0.0949	1.9056	0.0726	0.0719	0.0832	0.4180	0.1433
Beverages & Tobacco	0.5881	0.4645	2.1547	0.4896	0.4395	0.3062	0.3962
Clothing & Textile	0.1188	0.1166	0.0997	1.8182	0.1045	0.0737	0.0947
Paper, Pulp & Publishing	0.1163	0.1056	0.1477	0.1323	2.2235	0.0778	0.1319
Petroleum	0.1785	0.1218	0.1201	0.1158	0.1182	1.4742	0.1876
Basic Chemicals	0.3104	0.2245	0.2000	0.2701	0.2802	0.1356	2.0192
Metal Manufacturing	0.1125	0.1523	0.1168	0.1030	0.0945	0.0756	0.1204
Machinery & Equipments	0.2441	0.2750	0.1996	0.2169	0.2236	0.1627	0.1925
Other Manufacturing	0.1211	0.1446	0.1308	0.1389	0.1620	0.0822	0.1640
Electricity	0.0919	0.1518	0.0831	0.0890	0.1012	0.0755	0.0983
Water	0.0416	0.0429	0.0349	0.0340	0.0358	0.0240	0.0284
Construction	0.0397	0.0539	0.0346	0.0376	0.0338	0.0296	0.0329
Services	2.2543	2.3087	2.4851	2.8945	2.4627	1.9144	2.3650
Capital	0.7617	0.6923	0.6309	0.5582	0.6150	0.5314	0.5635
Unskilled Labour	0.2898	0.3315	0.2253	0.2950	0.2190	0.1628	0.1905
Medium Skilled Labour	0.2260	0.2538	0.2493	0.2730	0.2930	0.1842	0.2375
High Skilled Labour	0.1126	0.1328	0.1318	0.1433	0.1738	0.1020	0.1498
Firms	0.7055	0.6412	0.5844	0.5170	0.5696	0.4922	0.5220
Least-income Households	0.0199	0.0220	0.0168	0.0201	0.0172	0.0125	0.0148
Low-income Households	0.0438	0.0482	0.0374	0.0442	0.0385	0.0280	0.0331
Middle-income households	0.4587	0.4964	0.4197	0.4683	0.4531	0.3195	0.3883
High-income Households	0.2352	0.2534	0.2270	0.2449	0.2554	0.1749	0.2191
Highest-income Households	0.2106	0.2067	0.1864	0.1818	0.1949	0.1510	0.1732

Table C2 cont

Sectors (1)	Metal Manufacturing (9)	Machinery & Equipments (10)	Other Manufacturing (11)	Electricity (12)	Water (13)	Construction (14)	Services (15)
Agriculture	0.1807	0.1171	0.2457	0.1850	0.1729	0.2144	0.2044
Mining & Quarrying	0.2983	0.0658	0.1310	0.3251	0.1402	0.2507	0.0793
Beverages & Tobacco	0.4546	0.2886	0.4404	0.4708	0.4352	0.4822	0.5217
Clothing & Textile	0.1089	0.0760	0.1392	0.1122	0.1046	0.1297	0.1231
Paper, Pulp & Publishing	0.1136	0.0791	0.1416	0.0967	0.1183	0.1234	0.1593
Petroleum	0.1323	0.0772	0.1219	0.1081	0.1123	0.1572	0.1408
Basic Chemicals	0.2304	0.1446	0.3735	0.1710	0.2327	0.2225	0.2050
Metal Manufacturing	2.2554	0.2408	0.1575	0.1229	0.1443	0.5363	0.1118
Machinery & Equipments	0.2801	1.7790	0.2160	0.2701	0.2812	0.3742	0.2618
Other Manufacturing	0.1277	0.1089	1.7648	0.1150	0.1518	0.2029	0.1348
Electricity	0.1994	0.0665	0.0971	2.1086	0.2430	0.1421	0.0937
Water	0.0356	0.0198	0.0308	0.0436	3.5611	0.0365	0.0378
Construction	0.0412	0.0245	0.0356	0.1341	0.0368	2.3981	0.0548
Services	2.4871	1.8396	2.6027	1.9546	2.0347	2.3264	4.4546
Capital	0.6673	0.3893	0.5613	0.8356	0.8730	0.6543	0.7384
Unskilled Labour	0.2797	0.1621	0.2705	0.2888	0.2280	0.3427	0.2479
Medium Skilled Labour	0.2783	0.1904	0.2743	0.2393	0.2258	0.2715	0.3742
High Skilled Labour	0.1557	0.1105	0.1506	0.1790	0.1635	0.1587	0.1778
Firms	0.6181	0.3606	0.5200	0.7740	0.8087	0.6061	0.6840
Least-income Households	0.0199	0.0120	0.0190	0.0205	0.0176	0.0227	0.0202
Low-income Households	0.0441	0.0268	0.0420	0.0453	0.0394	0.0497	0.0454
Middle-income households	0.4831	0.3039	0.4573	0.5007	0.4564	0.5166	0.5363
High-income Households	0.2589	0.1675	0.2443	0.2742	0.2560	0.2683	0.2971
Highest-income Households	0.2046	0.1256	0.1821	0.2389	0.2374	0.2067	0.2290

Table C2 cont

Sectors (1)	Capital (16)	Unskilled Labour (17)	Medium Skilled Labour (18)	High Skilled Labour (19)	Firms (20)	Least-income Households (21)	Low-income Households (22)
Agriculture	0.1267	0.3412	0.3106	0.2779	0.1367	0.5574	0.4977
Mining & Quarrying	0.0380	0.0851	0.0843	0.0842	0.0411	0.0932	0.0868
Beverages & Tobacco	0.3265	0.8859	0.8038	0.7160	0.3525	1.4708	1.3079
Clothing & Textile	0.0769	0.1988	0.1886	0.1731	0.0830	0.2181	0.2401
Paper, Pulp & Publishing	0.0641	0.1393	0.1385	0.1394	0.0692	0.1424	0.1424
Petroleum	0.0702	0.1488	0.1508	0.1549	0.0758	0.1394	0.1345
Basic Chemicals	0.1072	0.2499	0.2442	0.2380	0.1157	0.2795	0.2722
Metal Manufacturing	0.0485	0.1077	0.1063	0.1058	0.0523	0.1162	0.1138
Machinery & Equipments	0.1355	0.2664	0.2746	0.2912	0.1463	0.2225	0.2262
Other Manufacturing	0.0712	0.1602	0.1594	0.1578	0.0769	0.1463	0.1557
Electricity	0.0466	0.1156	0.1103	0.1051	0.0503	0.1700	0.1388
Water	0.0175	0.0442	0.0416	0.0387	0.0188	0.0622	0.0576
Construction	0.0168	0.0379	0.0373	0.0369	0.0182	0.0418	0.0403
Services	1.2445	2.7319	2.7138	2.7178	1.3436	2.7304	2.7752
Capital	1.2467	0.5654	0.5516	0.5404	0.2664	0.6486	0.6274
Unskilled Labour	0.0885	1.2048	0.1992	0.1942	0.0956	0.2360	0.2296
Medium Skilled Labour	0.1130	0.2517	1.2485	0.2470	0.1220	0.2638	0.2636
High Skilled Labour	0.0576	0.1294	0.1273	1.1260	0.0622	0.1395	0.1376
Firms	1.1548	0.5237	0.5109	0.5006	1.2467	0.6008	0.5811
Least-income Households	0.0106	0.0619	0.0299	0.0174	0.0115	1.0176	0.0172
Low-income Households	0.0253	0.1291	0.0707	0.0387	0.0273	0.0392	1.0383
Middle-income households	0.3275	1.0043	0.9499	0.7429	0.3535	0.4398	0.4319
High-income Households	0.1857	0.3968	0.5056	0.6423	0.2005	0.2381	0.2341
Highest-income Households	0.2690	0.2452	0.2582	0.3581	0.2904	0.1934	0.1884

Table C2 cont

Sectors (1)	Middle-income Households (23)	High-income Households (24)	Highest-income Households (25)
Agriculture	0.3417	0.2446	0.2357
Mining & Quarrying	0.0842	0.0856	0.0844
Beverages & Tobacco	0.8868	0.6266	0.6025
Clothing & Textile	0.2096	0.1587	0.1422
Paper, Pulp & Publishing	0.1375	0.1397	0.1483
Petroleum	0.1461	0.1617	0.1631
Basic Chemicals	0.2511	0.2358	0.2274
Metal Manufacturing	0.1066	0.1053	0.1097
Machinery & Equipments	0.2554	0.3049	0.3421
Other Manufacturing	0.1633	0.1571	0.1559
Electricity	0.1140	0.1046	0.0921
Water	0.0443	0.0364	0.0342
Construction	0.0377	0.0368	0.0374
Services	2.7176	2.7150	2.8377
Capital	0.5628	0.5299	0.5414
Unskilled Labour	0.2046	0.1894	0.1922
Medium Skilled Labour	0.2505	0.2452	0.2544
High Skilled Labour	0.1287	0.1249	0.1285
Firms	0.5213	0.4908	0.5015
Least-income Households	0.0156	0.0147	0.0150
Low-income Households	0.0348	0.0328	0.0336
Middle-income households	1.3963	0.3778	0.3877
High-income Households	0.2162	1.2073	0.2131
Highest-income Households	0.1712	0.1625	1.1665

APPENDIX 4: ADJUSTED 2003 SOUTH AFRICAN SAM

	AGR	MIN	AGI	TEX	PPP	PET	CHM	HEV	MAC
AGR	51179.44	39	31236.81	614.55	1257.44	1.34	441.12	83.39	206.14
MIN	174.49	84078.39	117.13	23.89	216.72	11935.15	2368.04	9466.06	156.37
AGI	4917.889	60.46	99823.11	1178.62	134.75	0	1103.543	16.90133	8.93
TEX	536.25	450.43	109.4447	33442.74	38.12039	0	240.5841	44.69	770.6393
PPP	322.98	153.46	2824.19	353.0498	41966.02	1.58	1332.618	281.6255	383.1449
PET	2907.73	1256.07	523.55	110.1	270.22	23328.16	5421.384	1399.62	526.35
CHM	4544.83	3254.82	967.39	2557.774	2313.88	362.9285	68996.97	2654.39	2799.127
HEV	585.69	2808.21	2070.35	295.7044	139.56	81.68237	1526.521	94345.85	15303.41
MAC	2005.96	5118.48	517.84	528.7002	779.6	288.96	831.0025	3708.045	115517.9
OHM	430.75	2304.21	2465.59	819.4579	1292.191	30.15	3426.252	766.0711	4075.272
ELE	452.27	3733.23	624.92	279.17	512.28	257.92	1125.73	4665.73	647.06
CON	206.05	841.63	0	0	0	0	0	0	0
SER	9847.098	22060.78	45002.11	22173.53	11432.47	15179.26	26264.49	22238.34	48440.81
WAT	225.71	426.54	217.04	59.88	87.27	21.6	66.96	117.37	23.56
CAP	16839.68	23460.27	14246.86	1415.704	5228.822	8134.283	8438.903	12188.8	7562.646
LABLO	7101.787	16898.2	4972.932	5265.065	1895.607	542.8917	2170.905	7221.988	6627.511
LABMED	1040.271	4365.496	3456.139	922.7977	2733.825	501.1002	2003.79	3996.142	4507.312
LABHI	238.2006	2348.441	2859.657	822.2685	2327.55	855.98	3422.877	2990.921	4937.438
HHLeast	0	0	0	0	0	0	0	0	0
HHLow	0	0	0	0	0	0	0	0	0
HHMiddle	0	0	0	0	0	0	0	0	0
HHHigh	0	0	0	0	0	0	0	0	0
HHHighest	0	0	0	0	0	0	0	0	0
FIRMS	0	0	0	0	0	0	0	0	0
GOV	572.413	717.7823	15482.47	2801.313	1118.757	16620.34	2229.248	972.7189	11652.78
INV	0	0	0	0	0	0	0	0	0
ROW	3419.824	11962.82	10878.17	6646.451	5705.463	4011.269	17012.52	8669.843	70792.9
TOTAL	107549.3	186338.7	238395.7	80310.77	79450.54	82154.6	148423.5	175828.5	294939.3

	OHM	ELE	CON	SER	WAT	CAP	LABLO	LABMED	LABHI
AGR	2292.17	9.71	713.2413	973.9	0	0	0	0	0
MIN	1669.464	3952.16	4173.316	721.4719	0	0	0	0	0
AGI	41.36907	29.74	0	12610.38	0	0	0	0	0
TEX	1304.204	6.35	523.99	2933.951	0	0	0	0	0
PPP	905.4129	28.89	490.88	21499.09	0	0	0	0	0
PET	287.05	103.72	1987.12	19180.95	0	0	0	0	0
CHM	6677.15	64.87	853	13899.83	0	0	0	0	0
HEV	1923.57	180.92	12595.27	7631.274	0	0	0	0	0
MAC	733.3131	1163.26	6059.42	30934.03	0	0	0	0	0
OHM	39579.01	55.75	3261.68	10810.72	0	0	0	0	0
ELE	474.72	28993.26	1067.536	6050.114	0	0	0	0	0
CON	0	1250.87	86746.12	8350.898	0	0	0	0	0
SER	20095.73	1377.614	6128.277	1115810	0	0	0	0	0
WAT	30.45	121.37	91.59	2077.53	0	0	0	0	0
CAP	3027.285	11465.5	8281.711	238502	0	0	0	0	0
LABLO	5307.775	3329.165	8740.542	71106.68	0	0	0	0	0
LABMED	2379.858	1476.14	2711.795	138810.7	0	0	0	0	0
LABHI	1832.052	2314.796	2317.645	58968.61	0	0	0	0	0
HHLeast	0	0	0	0	0	0	6215.792	2482.516	208.9023
HHLow	0	0	0	0	0	0	13335.19	6193.585	457.8611
HHMiddle	0	0	0	0	0	0	85838.35	94550.57	31087.69
HHHigh	0	0	0	0	0	0	25429.51	49466.65	37095.67
HHHighest	0	0	0	0	0	0	10362.2	15211.24	16681.09
FIRMS	0	0	0	0	0	340911.5	0	0	0
GOV	2434.334	684.4455	3099.811	28527.74	18147.24	0	0	0	0
INV	0	0	0	0	0	0	0	0	0
ROW	9071.414	276.1526	591.8585	34922.44	70.87598	27305	0	1000.783	705.217
TOTAL	**100066.3**	**56884.68**	**150434.8**	**1824322**	**18218.11**	**368216.5**	**141181**	**168905.3**	**86236.43**

	HHLeast	HHLow	HHMiddle	HHHigh	HHHighest	FIRMS	GOV	INV	ROW	TOTAL
AGR	1161.373	1873.908	8861.837	2372.792	1606.611	0	0	-5771.77	8396.309	**107549.3**
MIN	14.68648	18.1452	105.3415	47.31159	20.97652	0	0	1470.733	65608.87	**186338.7**
AGI	10440.25	16852.28	79871.43	21517.39	14586.28	0	0	-37041.8	12244.17	**238395.7**
TEX	1175.996	2700.606	19080.48	5965.266	3396.541	0	0	3057.809	4532.683	**80310.77**
PPP	15.05778	85.67436	2087.359	1853.211	1768.568	0	0	-1406.75	4504.488	**79450.54**
PET	159.8663	265.381	7150.867	6102.661	4701.724	0	0	2648.263	3823.803	**82154.6**
CHM	671.6051	1222.933	10502.69	5452.788	3588.556	0	0	4327.503	12710.43	**148423.5**
HEV	11.5771	36.82683	498.1534	302.6131	233.0671	0	0	6926.326	28331.93	**175828.5**
MAC	94.77138	341.6139	10846.41	10860.44	10720.69	0	0	73883.72	20005.14	**294939.3**
OHM	175.1699	600.6077	8687.129	4629.741	3366.27	0	0	1478.518	11811.79	**100066.3**
ELE	727.8532	899.2652	5220.66	2344.734	1039.584	0	0	-3274.91	1043.556	**56884.68**
CON	0	0	0	0	0	0	0	52922.5	116.7313	**150434.8**
SER	2687.07	6969.896	88084.79	57292.87	49661.34	0	192114	28750.64	32711.16	**1824322**
WAT	0	0	0	0	0	0	15129.07	-519.754	41.92777	**18218.11**
CAP	0	0	0	0	0	0	0	0	9424	**368216.5**
LABLO	0	0	0	0	0	0	0	0	0	**141181**
LABMED	0	0	0	0	0	0	0	0	0	**168905.3**
LABHI	0	0	0	0	0	0	0	0	0	**86236.43**
HHLeast	0	0	0	0	0	1399.727	7212.135	0	20.44769	**17539.52**
HHLow	0	0	0	0	0	3725.615	9571.705	0	45.43085	**33329.39**
HHMiddle	0	0	0	0	0	56383.88	12842.85	0	142.6527	**280846**
HHHigh	0	0	0	0	0	33236.89	1229.209	0	17.55192	**146475.5**
HHHighest	0	0	0	0	0	71667	164.7356	0	4.916807	**114091.2**
FIRMS	0	0	0	0	0	0	2199.904	0	0	**343111.4**
GOV	195.0689	1440.441	39085.72	26950.41	18801.36	35767.22	211640.9	0	173	**439115.5**
INV	9.104741	21.42932	739.6052	725.4737	555.3871	140842	-18840	3248.039	3398	**130699.1**
ROW	0.074399	0.380314	23.52336	57.78476	44.23717	89	5851	0	0	**219109**
TOTAL	**17539.52**	**33329.39**	**280846**	**146475.5**	**114091.2**	**343111.4**	**439115.5**	**130699.1**	**219109**	**6032173**