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.

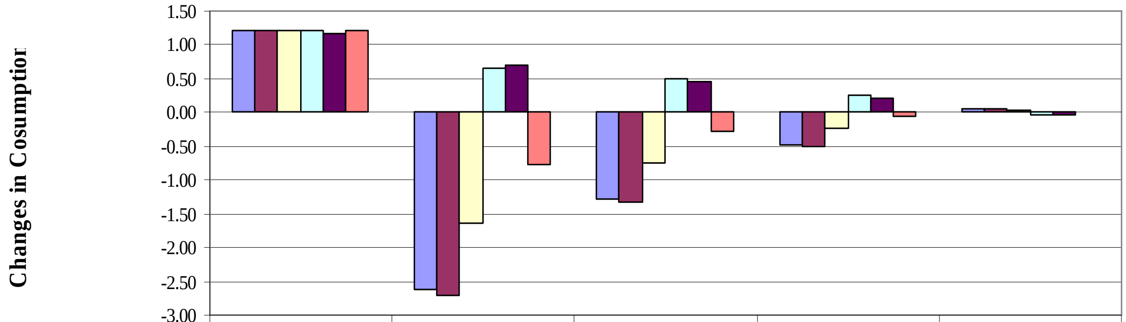
6.3.5 Households' welfare analysis under the different global change scenarios

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

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change on domestic supply of agricultural commodities, and exportation and importation of agricultural commodities

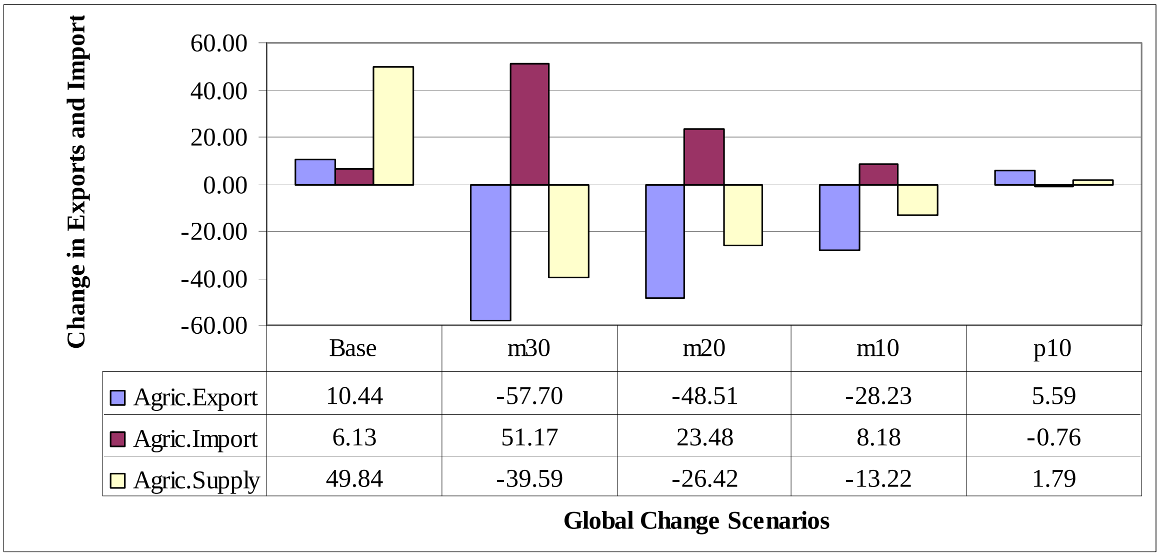


Figure 6: Agricultural exports and imports under the global change scenarios

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..

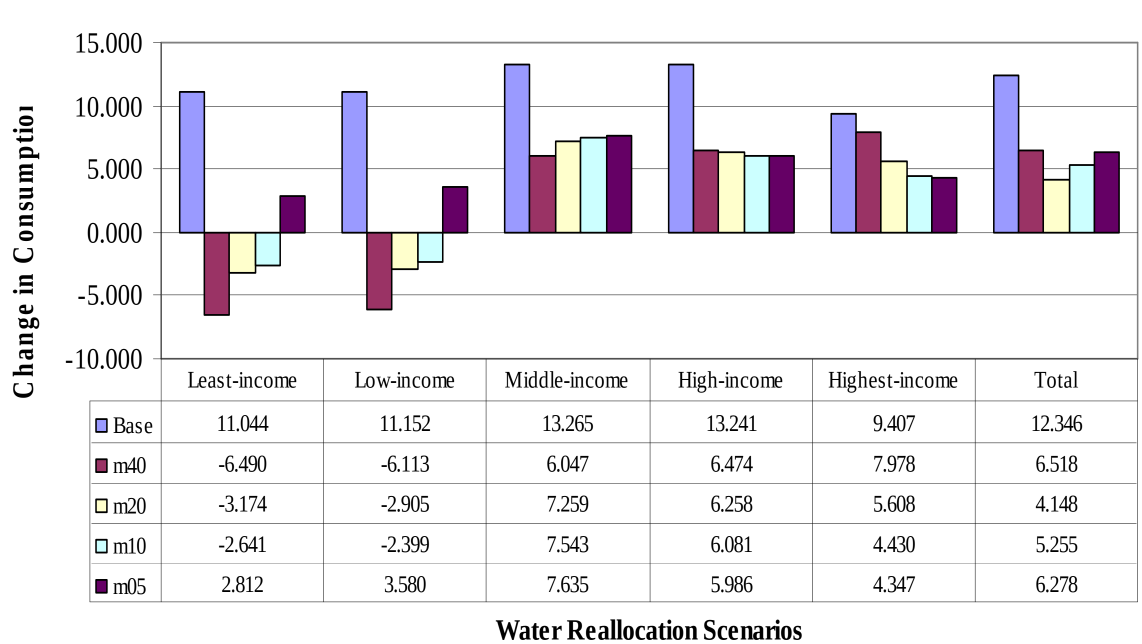
Table 6.6: Changes in factor payments under the different water reallocation scenarios

Primary factors (1)	Base remuneration (2)	Global change scenarios M40 (3)	M20 (4)	M10 (5)	M05 (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

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.

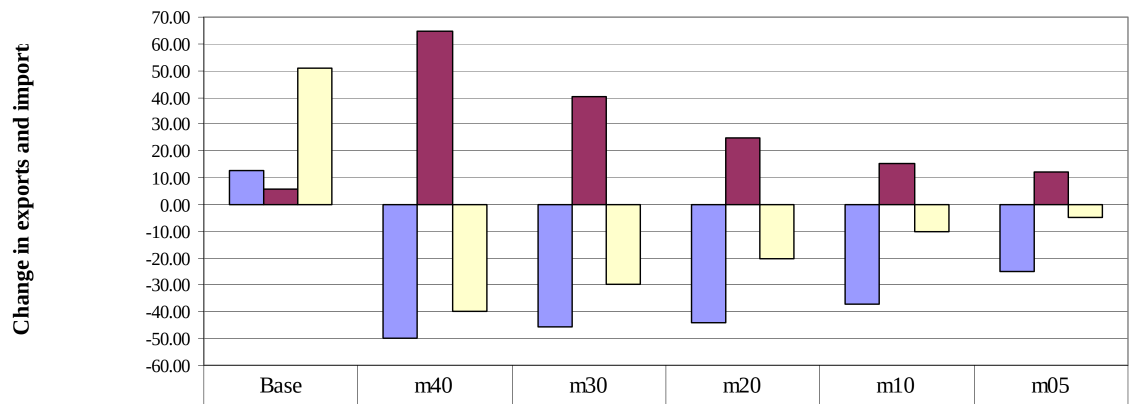
All the water reallocation scenarios show a general potential increase in households' welfare. However, while there is general welfare improvement for the middle, high and highest-income households, the welfare of the least and low-income households decline when more than five percent of water in the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



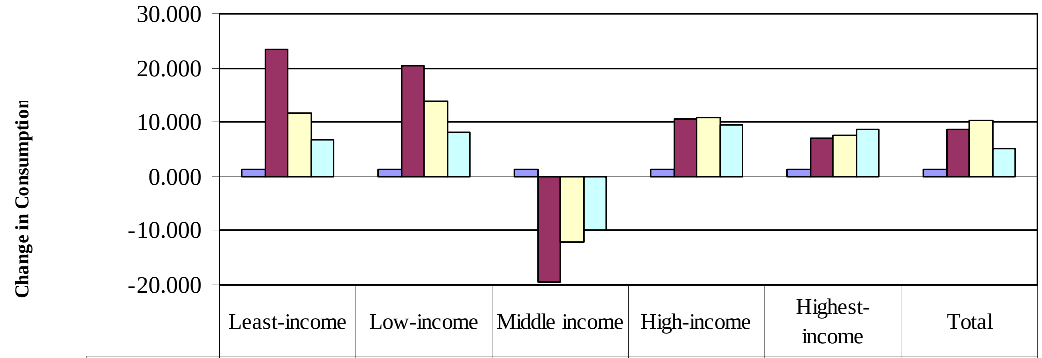
	Base	m40	m30	m20	m10	m05
Agric. Exports	12.74	-49.83	-45.75	-43.88	-37.42	-25.07
Agric. Imports	5.54	64.66	40.35	24.98	15.49	12.23
Agric. Supply	50.99	-40.00	-30.00	-20.00	-10.00	-5.00

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.

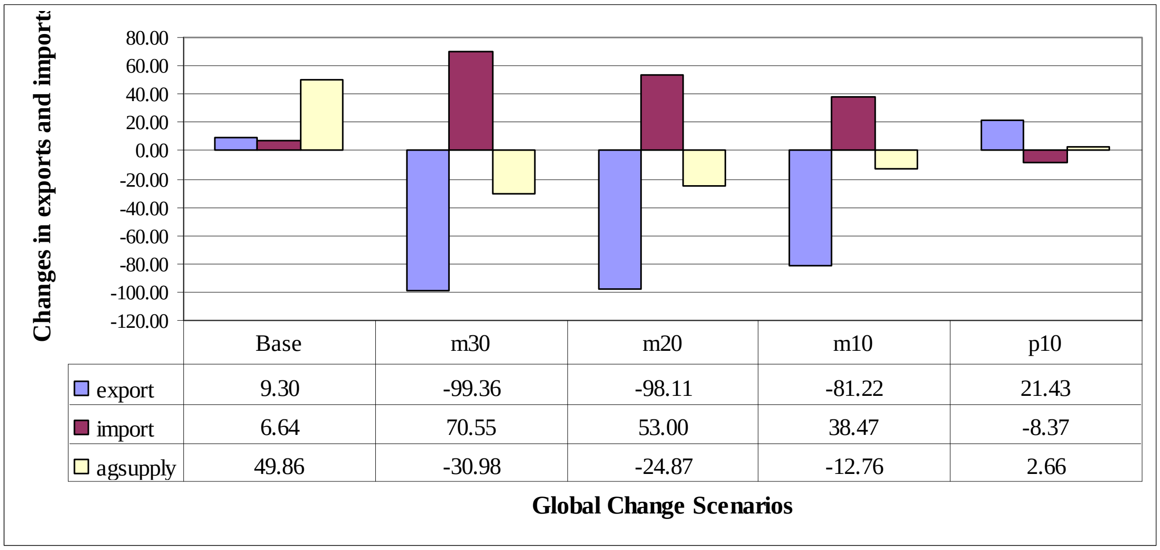


	Least-income	Low-income	Middle income	High-income	Highest-income	Total
Base Index	1.225	1.227	1.199	1.220	1.192	1.205
m30	23.44	20.43	-19.56	10.63	6.92	8.72
m20	11.70	13.79	-12.14	10.76	7.73	10.21
m10	6.81	8.04	-9.93	9.62	8.63	5.07

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.