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

**By**

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Submitted in partial fulfilment of the requirements for the degree of

Doctor of Philosophy: Environmental Economics

in the Department of

Agricultural Economics, Extension and Rural Development, Faculty of

Natural and Agricultural Sciences

University of Pretoria

Pretoria

February, 2008



## 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

## ACKNOWLEDGEMENTS

I am grateful to my supervisors; Prof. Johann Kirsten, Head, Department of Agricultural Economics, Extension and Rural Development, University of Pretoria, and Prof. Kenneth Strzepek, Associate Chair and professor in Water Resource Engineering and Economics, Department of Civil, Environmental and Architectural Engineering, University of Colorado in Boulder, for their invaluable guidance and interest in this rigorous academic exercise.

My special gratitude to Professor Strzepek and his family and Mr. Brent Butzin and the Butzin family of Colorado Springs for providing me with the necessary support and guidance whenever I visited the United States of America for my PhD research.

I acknowledge, with gratitude, the generous financial support from the United States Agency for International Development (USAID), International Food Policy Research Institute (IFPRI) through the University of Colorado, Boulder, and the African Economic Research Consortium (AERC). Similar gratitude is extended to the International Water Management Institute (IWMI) and the Center for Environmental Economics and Policy in Africa (CEEPA) for offering me part-time research assistantship which financially helped me during the coursework.

I am greatly indebted to Professor Patrick J. Squire, Dr. Abdul B. Kamara and Dr. Abdul P. Lamin, and their respective families for their moral, academic and financial assistance and brotherly advice that kept me going in difficult times. In the same way, I would like to

thank my colleagues for helping me in diverse ways. These include Dr Teddie Nakhumwa, Dr. Patrick Birungi, Dr. Moses Sichei, Dr. Charles Abuka, Jethro Zuwarimwe, and Dr. Chilot. Tizale. I would also like to thank my colleagues in the Department of Economics and Economic History, Rhodes University, and Dr. Albert Domson Lindsay for their inspirational support in the mist of domestic crisis.

I would also like to acknowledge the patience and love from my children Thomas, Nyakeh, Khormahun and Ndemogbe, who remembered me in their prayers although they dearly missed me.

Finally, I would like to thank my dear wife Zainab for her support and love, and Messrs Moses Bangura, Alusain Kallon, L.A.M Jah, Mohamed Koroma and Milton Ndaloma for their moral support. There are numerous individuals whose contributions to the success of this academic exercise are highly appreciated.



## DEDICATION

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**

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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

<b>Acronym</b>	<b>Meaning</b>
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