Inter-sectoral water use in South Africa: efficiency versus equity

James Sharka Juana¹, Johann F. Kirsten² and Kenneth M. Strzepek³

Contributed paper prepared for presentation at the 26th International Association of Agricultural Economist Conference, Gold Coast, Australia, August 12-18, 2006.

Copyright 2006 by J.S. Juana, J.F. Kirsten and K.M. Strzepek: All rights reserved. Readers make verbatim copies of this document for non-commercial purposes by any means, provided that this copyright appears on all such copies

¹ Department of Economics and Economic History, Rhodes University, Grahamstown 6140, South Africa, or Department of Agricultural Economics, University of Pretoria, Pretoria 0002, South Africa
Email: j.juana@ru.ac.za
² Professor and Head, Department of Agricultural Economics, Extension and Rural Development, University of Pretoria, Pretoria 0002, South Africa
³ Professor, Department of Civil, Environmental and Architectural Engineering, University of Colorado, Boulder CO 80309-0428, USA
Inter-sectoral water use in South Africa: efficiency versus equity

Abstract
While water supply sources are dwindling in South Africa, the demand for the scarce water resource is increasing. This situation requires a switch from supply to demand management of water in the country. This article updates the 1999 social accounting matrix for South Africa using the Trade and Industrial Policy Strategies (TIPS) time series data, SATSA’s 2001 census report and 2000’s water accounts, the 2002 national income accounts, published by the South African Reserve Bank (SARB) and the Water Resource Management Strategy (WRMS) registration data. Using the updated SAM, the contribution of water to economic development in South Africa is estimated through the traditional SAM multiplier analysis. On the basis of sector specific marginal values of water, the article also investigates the impact of reallocating water among the production sectors on output growth, factors remuneration and households’ income generation.

The computational and simulation results show that though agriculture is among the sectors that have least marginal value of water, water reallocation from this sector to the others, based on the sectoral marginal values of the resource, will reduce the incomes of the poorest households, hence increases the disparity between the rich and poor households. Scenario analyses suggest that this effect will be minimal if marginal productivity consideration for inter-sectoral reallocation is reduced to 30%, while intra-sectoral water reallocation on the basis of efficiency is currently viewed as the most viable option.

JEL Classification: C67, D57, L60, Q25 and R20

Acknowledgements
The authors are grateful to the International Food Research Institute (IFPRI), Statistics South Africa (STASA) and the Department of Water Affairs and Forestry (DWAF) for allowing them to use their different data sources, and the African Economic Research Consortium (AERC), the United States Agency for International Development (USAID) and the University of Colorado, Boulder for jointly funding the study. All grammatical and computational errors are the responsibility of the authors.
1 Introduction

Water scarcity is increasingly becoming a pressing problem in developing countries. The demand for the world’s scarce water supply is rapidly increasing, challenging its availability for food production and putting global food security at risk. Agriculture, upon which the majority of the world’s population depends, is competing with industrial, domestic and environmental uses for the scarce water supply (Rosegrant et al, 2002). With increasing population growth and the need to increase agricultural production, the demand for the world’s 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 has sharply increased over the last decade. At the global level, while per capita water availability is declining, withdrawals are projected to increase more rapidly, especially in developing countries (Rosegrant et al, 2002). The concept of water has received considerable attention in the last decade (Seckler et al, 1998).

Global water scarcity raises two questions that are critical to development; i) to what extent can water resources be efficiently, equitably and sustainably allocated and used and ii) what are the possible ways and means by which water scarcity can be alleviated or mitigated in support of further development? The answers to these questions provide essential tools to water managers, to enable them design appropriate water development policies and allocation regimes and strategies.
In South Africa, as the economy grows, the competition for water among agriculture, mining, manufacturing industries, domestic and environmental uses increases, while the supply of water becomes inelastic. The demand for delivered water increases rapidly and externality problems become increasingly important. These factors increase the value of water, hence, the benefits from efficient water allocation among different sectors. Therefore, the benefits from and the necessity of demand-side management has significantly increased.

Irrigation water requirement in South Africa accounts for about 62 percent of the total water requirements, while agriculture accounts for only about four percent of the GDP, and employs about 11 percent of the total number of employees, while mining and manufacturing industries which respectively contribute about eight percent and 23 percent to the GDP and employ about seven percent and 19 percent of the total number of employees account for only 15 percent of the total water requirements (DWAF, 2004: 16-18). Thus, there has been an increased pressure on the Department of Water Affairs and Forestry to reallocate water from agriculture to mining and manufacturing industries, to promote sustainable economic growth and employment. 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 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 is therefore, not only how much does a particular sector contribute to the GDP, but how can a given water resource be allocated such that the standard of living of the critical mass of people is improved. This addresses the issue of equity of access to and benefits from efficient water
allocation, hence, justifies the inclusion of socio-economic values of water into the economic valuation framework. Against this background, this article critically analyzes inter-sectoral water demand in South Africa. Using the social accounting matrix framework the article:

i) analyzes the economy-wide contribution of water,

ii) estimates, using marginal values of water, the impact of reallocating water from low to high value uses, on output growth, value added and income generation and distribution, and,

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

The next section briefly describes the features of the generic social accounting matrix (SAM) for South Africa, and the aggregation method for the purpose of this article. Sections three explains the theoretical framework and the modeling procedure, while section four presents and discusses the model results, and section five discusses the conclusions drawn from the study and makes some policy recommendations.

2 The features of the South African micro 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 are consistent with the 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 figures 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 2001 census. Information on government’s income and expenditure accounts, investment and international trade was provided by the South African Reserve Bank’s publications for the period (SARB, 2002). Details of the structure of the generic SAM for South Africa is found in Thurlow and van Seventer (2002: 2-14). The water supply information from the municipalities’ billing records was grossly understated, since most sectors use self-supplied water. These entries were therefore replaced by the water resource management strategy (WRMS) registration information and Statistics South Africa’s 2000 water accounts for the nineteen water management areas. Using the municipal water pricing schedule the monetary values of the physical quantities of water used by the various sectors were computed.

For the purpose of this study the updated SAM was aggregated to 14 activities/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 mining, gold mining and uranium and other mining were aggregated to mining activities/commodities. The manufacturing sector, consisting of 41 activities and 41 commodities were aggregated to 12 activities/commodities accounts consisting of agro-industries (food, beverage and tobacco manufacturing), textile and wearing (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), 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 equipments (machinery and equipment, electrical machinery and apparatus, TV, 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 by the sectors and sub-sectors.

The capital, three labour and enterprises accounts in generic SAM were retained, while aggregating the 14 household accounts to five accounts, with the first two deciles reflecting the households that earn below 20% of the total income, the third and fourth deciles reflecting those that earn between 20 and 40% of total income, while the middle income households lie within 40 and 80% of the income structure, while the rich households lie above 80% of the total income structure. In South Africa, the majority of the population is in the first two categories, and less than three percent is in the tenth decile. Most of the poor households earn their income from the wages of unskilled and labour and transfers from semi-skilled labour (Thurlow and van Seventer, 2002: 13). These households are the historically disadvantaged individuals, 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 subsistence activities for their economic survival.
Government accounts, which were broken down into expenditure and income accounts (four accounts) in the disaggregated micro SAM were aggregated to net government account. Savings and investment and the rest of the world accounts were retained.

3.0 The theoretical framework and the modeling procedure

Social accounting matrix models have been extensively used in the early literature to analyze growth linkages between various economic sectors, (Juana and Mabugu, 2005, Bautista et al, 2002; Delgado, et al, 1998). The analysis of this type of interaction among sectors and institutions require economy-wide frameworks (Sadoulet and de Janvry, 1995: 273-301). The SAM framework is used to analyze the impact of reallocating water among sectors (based on economic efficiency), on output growth, factor remuneration and income generation and redistribution.

Following Juana and Mabugu (2005: 349-351), and Sadoulet and de Janvry, (1995: 273-301), the basic materials balance equation could be specified as;

\[ X' = AX' + D \]  

(1)

Where \( X' \) 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 \( D \) is an nx1 column vector of final demand. The dimension of the ‘A’ matrix coincides with the number of productive sectors. Solving for \( X' \) yields:

\[ X' = (I - A)^{-1} D \]  

(2)
Where ‘I’ is the identity matrix and \((I-A)^{-1}\) is the Leontief inverse. This model solves for sectoral output levels \(X\) that satisfy final demand for those outputs \(D\) given the inter-industry structure of production \(A\). This is used to determine the production plan that is consistent with a desired final demand vector, given the inter-sectoral transactions matrix \(A\). The above equation can be used to derive various types of multipliers, the most common of which are the production and income multipliers.

This model is extended to the SAM multiplier matrix by including primary factors and consumption accounts to the production sectors. The inclusion of these accounts aim at incorporating the feedback from rents to consumption to new production that originates 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 matrix. Hence \(M^s\) can be computed as;

\[
M^s = (I - A_m)^{-1}
\]

Equation 3 solves for the equilibrium level of all endogenous accounts which result from a shock or exogenous injections, given by 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 \((1-A)^{-1}\) when the dimension \(m\) of the \(A_m\) matrix corresponds to \(A\) (Boughanmi et al, 2002: 3). The difference between \((1-A_m)^{-1}\) and \((1-A)^{-1}\) is due to the induced effect which is taken into account by \(M^s\), but not by \((1-A)^{-1}\) (Juana and Mabugu, 2005:350).
Economic multipliers estimate the economy-wide impact of a change in an exogenous account on intermediate and final demand, hence output, value added and income generation in a specified economy, such as a state or a province, suggesting a strict cause-effect relationship (Tanjuakio, 1996). In literature, four types of multipliers exist: i) the direct or production multiplier, which captures the immediate impact of the initial change in the output of the industry being analyzed. ii) The indirect/income multiplier, which captures the increased purchases of inputs required by industry to produce the change in the output. 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, an aggregate of the direct, indirect and induced effects (Boughanmi et al, 2002:3). This article computes the SAM multipliers and then shocks the entries by reallocating water among the sectors based on the marginal values of water (reported in column 2 of Table 1). It then analyzes the impact of the shock on output, value added and income generation and redistribution. The model then experiments which inter-sectoral water reallocation path simultaneously promotes efficiency and equity.

The transfer of water from one sector to the other changes the intermediate input use of water for the different sectors, hence the water input coefficients. This affects the sectoral outputs and value added via the multipliers, which is transmitted to the institutions, through its impact on income generation and distribution. The study assumes linearity, the absence of substitution effects, fixed prices and that the model is demand driven. These assumptions are consistent with traditional SAM modeling procedure, which are relaxed in a more dynamic general equilibrium modeling framework.
4.0 Presentation and discussion of 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 one sector to the other on output growth, factor remuneration and households’ income generation under different scenarios.

The marginal values, reported in column 2 of Table 1, which are used in the simulation were econometrically computed using the seemingly unrelated regression analysis and the TIPS time series data. The computed marginal values show that manufacture of machinery and equipments (MAC) has the highest marginal returns to water use, followed by petroleum (PET), heavy manufacturing (HEV), services (SER), and mining (MIN) respectively, while marginal returns to water in the chemicals (CHM), clothing and textile (TEX), and agriculture (AGR) sectors are among the least. To do the simulation water transfer is based on the proportion of marginal value in each sector or sub-sector.

4.1 Contribution of water to economic activities in South Africa

Column 3 of Table 1 presents the SAM multipliers of water, which show the contribution of water to the economy generally, and specifically to output growth, factor remuneration and households’ income generation. The figures show that for every Rand increase in investment in the water sector, output grows by about ZAR6.67, while value added at factor cost increases by ZAR1.49, and households income increases ZAR1.01. In terms of output growth, water’s contributes more to the services sector than the others, followed by agro-industries. The
agriculture sector is again among the sectors that get the least direct impact from water, though it is the highest 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 labour as it does to output growth or factor remuneration. Since water’s contribution to agriculture and agriculture’s marginal return to water is minimal, there is enough justification to reallocate water from agriculture to the other sectors.

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

The Department of Water Affairs and Forestry in South Africa has been under increased pressure to reallocate water from the agriculture sector to mining and manufacturing sectors. Therefore, the first experiment examines the impact of reallocating water among the production sectors based on their marginal returns to water use, on output growth, factor remuneration and households’ income generation. The simulation results are shown in column 4 of Table1.

The experimental results show that output increases by about R51 million, while payments to the primary factors of production and households’ income generation generally increase by about R3.7 million and R1.6 million respectively. However, while output increases in the other sectors, it declines by about R6.9 million in the agriculture sector. This has an impact on payment to unskilled labour, which declines by about R0.56 million. This decline in agricultural output is transmitted to the two poorest household categories, via payment to labour, thus, leading to a total decline of about R2.6 million in the income of these households. At the same time, the incomes of middle and high income earners increase. This suggests that though, households’
income generally increases, this reallocation strategy increases the income gap between rich and the poorest households; hence it leads to an inequitable distribution of the benefits of water use. The experiment therefore tried different percentages to find out which one increases remuneration to factors generally and unskilled labour specifically and at the same time increases the income levels of the poor households categories, without much negative distortion in the incomes of middle and high income households. The simulation results are presented in columns 5, 6, and 7 of Table1. These results indicate that the best strategy is 30% transfer of water from agriculture to the other sectors on the basis of marginal value on water. This implies that out of the quantity of water to be transferred from agriculture, only 30% should be transferred if the equity criterion of water use in the country is considered. This strategy increases output by about R49.73 million, factor remuneration by about R2.83 million and household incomes by about R1.96. Specifically, the process increases payments to unskilled labour and the incomes of the two poorest household categories, though output in the agriculture sector generally decreases by about R3.23 million. The results suggest that decline in agricultural output due to water transfer from the sector is not transferred to the general economy as it would have been with the other scenarios.

5.0 Conclusion

Using the traditional SAM multiplier analysis, this study was designed to analyze the contribution of water to the various inter-sectoral activities and estimate the impact of reallocating water among different sectors on the basis of the marginal returns to water use. The study found out that though agriculture’s marginal returns to water use in South Africa is not as high as manufacturing industries and mining, it plays a major role in sustaining the livelihoods of
the poorest households in the country. That is, it has forward and backward linkages in the economy, which are not captured in the direct impact analysis (Delgado et al, 1998). 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. However, the simulation results show the minimum transfer from agriculture to other sectors on the basis of marginal value, which will at least promote income generation for the most vulnerable households and at the same time not significantly alter output growth.

Also, as South Africa is in the process of implementing land and water reforms, emerging and historically disadvantaged farmers, with little technological background will predominantly rely on the use of water to improve the living standards. Therefore, policy makers should very cautious in designing and implementing current water reforms.

This paper recommends minimum transfer of water from agriculture to the other sectors and the implementation of intra-sectoral transfer based on efficiency. Alternatively, the institution of user rights and intra-sectoral transfer of rights could be a workable policy, if poor livelihoods are to be protected. However, since South Africa has 19 water management areas (WMA), and each WMA has unique economic and hydrologic characteristics, it is recommended that analysis of inter-sectoral water use be done at these levels, because the above findings may overstate or understate the situation in individual WMAs. There is also the need to investigate water quality and pricing issues using dynamic modeling techniques.
References


### Table 1: Marginal values of water, contribution of water to the economy and different water reallocation scenarios

<table>
<thead>
<tr>
<th>Sectors</th>
<th>Marginal value (Rand)$^1$</th>
<th>Contribution of water to economic activities $^2$</th>
<th>Water reallocation scenarios</th>
<th>100%</th>
<th>50%</th>
<th>30%</th>
<th>10%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td></td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
</tr>
<tr>
<td>Agriculture</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mining</td>
<td>3.21</td>
<td>0.1302</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agro-industry</td>
<td>1.70</td>
<td>0.4351</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clothing and textiles</td>
<td>0.84</td>
<td>0.1046</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paper, pulp &amp; printing</td>
<td>1.38</td>
<td>0.1183</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Petroleum</td>
<td>6.22</td>
<td>0.1123</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemicals</td>
<td>0.87</td>
<td>0.2327</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavy manufacturing</td>
<td>5.39</td>
<td>0.1443</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machinery&amp; equipments</td>
<td>6.38</td>
<td>0.2811</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other manufacturing</td>
<td>1.23</td>
<td>0.1517</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electricity</td>
<td>0.35</td>
<td>0.2430</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>--</td>
<td>3.5608</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td>1.21</td>
<td>0.0368</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Services</td>
<td>4.68</td>
<td>2.0345</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.7689</td>
<td></td>
<td>51.339</td>
<td>50.734</td>
<td>49.734</td>
<td>41.574</td>
</tr>
<tr>
<td>Capital</td>
<td>-</td>
<td>0.8729</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unskilled labour</td>
<td>-</td>
<td>0.2280</td>
<td></td>
<td>(0.569)</td>
<td>(0.028)</td>
<td>0.005</td>
<td>0.002</td>
</tr>
<tr>
<td>Medium skilled labour</td>
<td>-</td>
<td>0.2257</td>
<td></td>
<td>1.173</td>
<td>1.453</td>
<td>1.270</td>
<td>0.579</td>
</tr>
<tr>
<td>High skilled labour</td>
<td>-</td>
<td>0.1635</td>
<td></td>
<td>0.427</td>
<td>0.083</td>
<td>0.072</td>
<td>0.033</td>
</tr>
<tr>
<td>Firms</td>
<td>-</td>
<td>0.8086</td>
<td></td>
<td>1.603</td>
<td>1.211</td>
<td>1.002</td>
<td>0.001</td>
</tr>
<tr>
<td>Least income households</td>
<td>-</td>
<td>0.0176</td>
<td></td>
<td>(1.879)</td>
<td>(0.035)</td>
<td>0.038</td>
<td>0.017</td>
</tr>
<tr>
<td>Low income households</td>
<td>-</td>
<td>0.0394</td>
<td></td>
<td>(0.723)</td>
<td>(0.002)</td>
<td>0.003</td>
<td>0.001</td>
</tr>
<tr>
<td>Mid income households</td>
<td>-</td>
<td>0.4564</td>
<td></td>
<td>2.936</td>
<td>0.332</td>
<td>0.366</td>
<td>0.158</td>
</tr>
<tr>
<td>High income households</td>
<td>-</td>
<td>0.2560</td>
<td></td>
<td>1.388</td>
<td>0.660</td>
<td>0.727</td>
<td>0.315</td>
</tr>
<tr>
<td>Highest income households</td>
<td>-</td>
<td>0.2374</td>
<td></td>
<td>0.992</td>
<td>0.748</td>
<td>0.823</td>
<td>0.357</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.0069</td>
<td></td>
<td>2.714</td>
<td>1.703</td>
<td>1.957</td>
<td>0.848</td>
</tr>
</tbody>
</table>

---

$^1$ Source: Juana (2005)

$^2$ Source: Extracted from the computed multipliers and simulation results

$^6$ Numbers in parenthesis are negative