CHAPTER THREE

MARGINAL PRODCUTIVITY ANALYSIS OF GLOBAL SECTORAL WATER DEMAND

3.1 INTRODUCTION

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

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

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

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

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

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

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

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

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

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

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

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

3.2 THE EMPIRICAL MODEL AND THE MODEL ESTIMATION PROCEDURE

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

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

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

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

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

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

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

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

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

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

The marginal value of water is then computed as:

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

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

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

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

$$\begin{aligned} \ln Y = {} & \beta_0 + \beta_1 \ln L + \beta_2 \ln K + \beta_3 \ln W + \beta_4 \ln I + \beta_5 \ln L \ln K + \beta_6 \ln L \ln W + \\ & \beta_7 \ln L \ln I + \beta_8 \ln K \ln W + \beta_9 \ln K \ln I + \beta_{10} \ln W \ln I + \beta_{11} \frac{\ln^2 L}{2} + \beta_{12} \frac{\ln^2 K}{2} + \\ & \beta_{13} \frac{\ln^2 W}{2} + \beta_{14} \frac{\ln^2 I}{2} + \beta_3^1 S_1 \ln W_1 + \beta_3^2 S_2 \ln W_2 + \dots\dots\dots + \beta_3^{13} S_{13} \ln W_{13} \end{aligned} \tag{3.8}$$

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

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

3.3 DATA SOURCES AND DESCRIPTION OF EXTRACTED DATA

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

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

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

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

Where;

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

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

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

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

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

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

3.4 PRESENTATION AND DISCUSSION OF ESTIMATED RESULTS

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

3.4.1 Regression Results

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

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

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

Table 3.1: The estimated coefficients of the global model

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

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

3.4.2 The computed output and price elasticities of water

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

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

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

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

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

3.4.3 Estimated sectoral marginal values of water

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

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

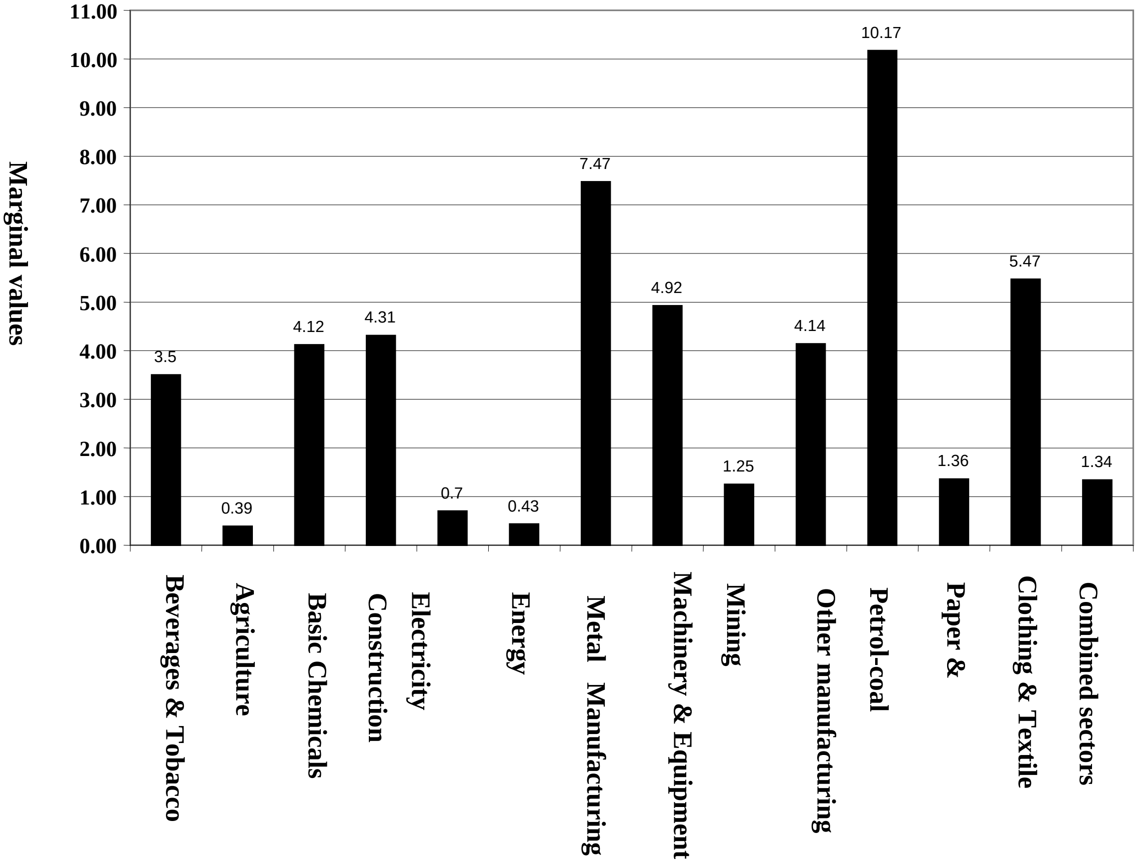

Figure 1: Global sectoral marginal values of water

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

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

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

3.8 SUMMARY AND CONCLUSIONS

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

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

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