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# PROGRESS REPORT

# Valuing water for South African industries: A production function approach

## Preliminary Report

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## 1. Introduction

This study aims to estimate the marginal value of industrial water use, and the price elasticity of demand associated with industrial water use, in South Africa. The need for this project has arisen in the context of the National Water Act (Act 36 of 1998) (Department of Water Affairs and Forestry, 1998) and its emphasis on demand-side management; specifically, the economic principle of encouraging more efficient water use by means of water pricing. Designing and implementing water pricing strategies for a particular user group requires information on the ***marginal value*** of water use to that user group, i.e. the increase in economic value generated per unit increase in water use (Gibbons, 1986) (in order to assess whether there is *scope* for water pricing strategies); as well as the ***price elasticity of demand,*** i.e. the responsiveness of this user group to changes in water prices (in order to assess the potential *effectiveness* of such strategies). For many groups of water users in South Africa, including industry, this type of information is not available. This project aimed to fill this gap by estimating the marginal value of industrial water use in South Africa, and the associated price elasticity of demand for water, using a production function approach; specifically, the marginal productivity approach.

## 2. Method

This study estimates the value of water for industry using the marginal productivity approach, which requires the estimation of a production function. The production function associated with a particular firm's product can be defined as the mathematical expression of the technical relationship between the quantity or value of the firm's output, and the quantity of one or more inputs (Miller and Meiners, 1986). Production functions take the following general form:

$$Q = A\ (K, L, W, E, M, \text{etc}) \tag{1}$$

Where $Q$ represents the quantity (or value) of output; $K$, $L$, $W$, $E$ and $M$ are the quantities of inputs (respectively capital, labour, water, energy and raw materials) used in producing the output; and $A$ represents technology, which determines the technical relationship between output and inputs.

The production function can be estimated econometrically using ordinary (or generalised) least squares regression techniques, and once estimated can be used to calculate the marginal value of water use, and the price elasticity of demand for water use. In turn, this information can be used to make important policy recommendations regarding the scope for and potential effectiveness of water pricing strategies.

This approach of using the marginal productivity to estimate the value of water use by industry was first proposed by Wang and Lall (1999, 2002), who develop a marginal productivity model for valuing industrial water use, where water is included along with capital, labour, energy and raw materials as inputs in a production function. Wang and Lall posit a translog[1] production function (which is quadratic and therefore twice differentiable), where the quantity (or value) of output is determined by five inputs; namely capital ($K$),

[1] The transcendental logarithmic (translog) production function was first proposed in 1973 by Christensen et al. and provides a greater variety of substitution-of-transformation patterns than those restricted by the constant elasticity of substitution implicit in the traditional Cobb-Douglas function.

labour (*L)*, water (*W*), energy (*E*), and raw materials (*M*); and assume the existence of constant returns to scale. The marginal productivity (or marginal value) of industry with respect to water is determined using this production function. Associated with this marginal productivity approach, a model on price elasticity of water demand is developed by assuming price is equal to the marginal cost of water use. These models were estimated using data on 2000 firms in the Chinese manufacturing sector.

This study adopted a similar approach to that developed by Wang and Lall, using data from a number of South African firms in the industrial (secondary) sector, obtained via a structured questionnaire (see Appendix); although in the current study we focus on only four inputs, namely capital (*K)*, labour (*L)*, water (*W*), and energy (*E*); i.e. raw materials (*M*) is dropped from the model[2]. In the case of a four-input model, the steps involved in calculating marginal values and price elasticities associated with water use are as follows:

1. Estimation of the translog function, which, in the case of a four-input model, takes the following form:

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

Where

> *lnY* = natural logarithm of the total value of output (sales revenue or turnover as per the firm's income statement, in Rands)
> *lnK* = natural logarithm of original value of fixed assets at the end of the year (value of 'property, plant and equipment' as per the firm's balance sheet or statement of financial position, in Rands)
> *lnL* = natural logarithm of the number of employees (full-time and part-time)

[2] *M* is dropped from the model for the following reasons. Firstly, for the variables *Y*, *K*, *L*, *W* and *E*; respondents should be able to obtain the required information relatively easily, e.g. from their financial statements or water/energy bills (for example, 'revenues,' which can be used as a proxy for the total value of output (*Y*), appears as a standard line item in a company's income statement). On the other hand, *M*, the value of raw materials used in production, does not tend to appear as a standard line item in companies' financial statements; or does so in an inconsistent way. In many cases, the value of raw materials appears under 'inventories,' where it refers to the company's current stock of raw materials, rather than the quantity of raw materials used in production for the previous year. In addition, the specific 'raw materials' used by different companies will differ significantly; and will tend to consist of a range of different items, and be reported in a variety of different units. The value of these raw materials is therefore likely to be difficult for respondents to estimate. Because of these various complications, it was decided to drop the *M* variable from the model. This is not expected to significantly influence the results. Indeed, Wang and Lall (1999, 2002) find that information on different types of raw materials is only available for a few dozen of the 2,000 firms in their dataset. They consequently drop this variable from their model, and still obtain an $R^2$ varying between 0.72 and 0.79, indicating an adequate fit. Importantly, though, dropping 'M' from the model implies that the quadratic and interaction terms based on this input are also dropped from the model. Thus, as explained in the following footnote, the numbering of coefficients differs slightly in this report as compared to in Wang and Lall (1999, 2002) and in previous progress reports, which affects the way in which formulae based on these coefficients are specified.

$lnW$ = natural logarithm of the quantity of water use in kilolitres (KL)
$lnE$ = natural logarithm of the quantity of energy use in megajoules (MJ)
$\beta_0$ = the intercept term
$\beta_1$ - $\beta_4$ = the coefficients on the independent variables lnK, lnL, lnW and lnE respectively
$\beta_5$ - $\beta_{14}$ = the coefficients on the various quadratic and interaction terms constructed on the basis of lnK, lnL, lnW and lnE; and which must be included as further independent variables in estimation of the quadratic production function in order to enable calculation of marginal values and elasticities through differentiation.

Thus, in a four-input model, the quadratic production function consists of 14 independent variables (including quadratic and interaction terms)[3].

2. The elasticity ($\sigma$) of production with respect to each input is then calculated by taking the partial derivatives of output with respect to the input under consideration; e.g., the water elasticity of output is calculated as follows:

$$\sigma_w = \frac{\partial \ln Y}{\partial \ln W} = \beta_3 + \beta_7 \ln W + \beta_{10} \ln K + \beta_{12} \ln L + \beta_{14} \ln E \quad (3)$$

Where $\beta_3$, $\beta_7$, $\beta_{10}$, $\beta_{12}$, and $\beta_{14}$ are the statistically estimated coefficients associated with specific terms in the production function; and ln$W$, ln$K$, ln$L$, and ln$E$ are averages over all observations included in the model; or for all firms in a specific sector (depending on whether the aim is to calculate a single MV and elasticity for all firms in the sample, or to calculate sector-specific MV's and elasticities, or both).

3. The marginal productivity of water in industrial production ($\rho$) is then calculated by multiplying the water elasticity of output (equation 3) by the average value of output per unit of water ($\frac{Y}{W}$):

$$\rho = \sigma_w \cdot \frac{Y}{W} \quad (4)$$

Similarly, the marginal productivity of capital, labour, and other factors of production can be calculated. If $Y$ is the total value of industrial output, Equation (4) gives the marginal value of water for industrial use.

4. Then, to determine the price elasticity of demand for water, it is assumed that the water price, $P$, is equal to the marginal cost of water use. The marginal cost of water ($MC_w$) is calculated based on the following economic theory: that profit maximising firms produce where the marginal value of output (or marginal revenue) is equal to the marginal cost. This applies to each input in turn, hence the marginal value of

[3] Note that dropping 'M' from the model (as explained in previous footnote) implies that the quadratic and interaction terms based on this input are also dropped from the model. In Wang and Lall's 5-input model, there are a total of 20 independent variables (including quadratic and interaction terms); whereas in our 4-input model there are only 14 independent variables. Thus, the numbering of coefficients differs slightly in this study as compared to in Wang and Lall (1999, 2002). The specification of the equations for marginal values and elasticities also differs slightly in this report as compared to previous progress reports – in previous reports, equations are specified using the 5-input model coefficient numbering of Wang and Lall (1999, 2002); whereas in the current report, equations are specified using coefficient numbering associated with the 4-input model.

water ($\rho$) equals the marginal cost of water (i.e., $MC_w = \rho$). Since we assume $P = MC_w$ it follows that $P = \rho$. The price elasticity of water demand can now be calculated:

$$\gamma = \frac{\partial \ln W}{\partial \ln P} = \frac{\partial \ln W}{\partial \ln \rho} = -\frac{\sigma}{\sigma - \sigma^2 - \beta_7} \quad (5)$$

Where $\beta_7$ is one the estimated coefficients of the original production function.

On the basis of the results of the above calculations, it is possible to make important policy recommendations regarding the scope for and potential effectiveness of water demand management strategies based on water pricing. Firstly, the calculated marginal value of industrial water use (which reflects firms' willingness to pay for water) can be compared with prevailing water prices (what firms actually pay); in order to assess the scope for increasing water prices through some form of water pricing strategy. If the marginal value of water use is higher than actual water prices, there is scope for increasing water prices to better reflect firms' willingness to pay. Secondly, the calculated price elasticity of water demand is an indicator of the responsiveness of firms to changes in water prices, and therefore of the extent to which water pricing strategies are likely to be effective. A high negative price elasticity of demand (e.g. –1) implies that firms' water use is highly responsive to changes in price; i.e., that an increase in water prices will result in a significant reduction in water use; and therefore that a demand-side management strategy which results in higher water prices is likely to be highly effective in reducing water demand, thereby contributing to the water conservation objective. On the other hand, a price elasticity of demand close to zero (inelastic) implies that firms would be far less responsive to price changes; implying that higher water prices would not be effective in reducing demand (although they would be effective in raising revenue, if that was the objective).

The marginal productivity approach requires data on company-specific water consumption and prices (as well as data on the value of output and the use of other inputs), for a sufficiently large sample of companies (and/or over a sufficient time-span) to generate a large number of observations with sufficient variation to enable statistical estimation of a production function; from which marginal values and elasticities can be calculated.

Note that estimating *sector-specific* marginal values and elasticities based on Wang and Lall's method does *not* require that a separate production function be estimated for each sector individually. Instead; a single production function is estimated for all firms in the sample. This ensures that the production function is estimated based on a sufficiently large (statistically significant) number of observations. Thereafter, it is possible to estimate sector-specific marginal values and elasticities based on the results of the common production function; by substituting sector-specific average values into equations 3 and 4 above.

The parameters of the common production function can therefore be used to estimate sector-specific elasticities and values using "the sample average data of variables in the model for each sector" (Wang and Lall, 1999: 14). In other words, sector-specific averages are substituted into equations 3 and 4 above in order to calculate marginal values and elasticities, and therefore to make policy recommendations regarding the scope for and potential effectiveness of water pricing strategies.

## 3. Data collection

Data for estimating the production function were obtained via a structured questionnaire (see Appendix for a copy of the questionnaire and accompanying cover letter; as well as previous deliverables for a detailed commentary on the design of the questionnaire). In order to maximise the response rate, questionnaires were distributed in various ways, including via direct correspondence with companies, and indirectly via municipalities; while respondents had the option either to complete the survey online, or to return the questionnaire by email or fax. Twenty-four municipalities were contacted for assistance with distributing questionnaires to companies in their jurisdiction (see list of municipalities contacted on the spreadsheet accompanying Deliverable 3). Specifically, we contacted the department responsible for distributing rates and water accounts, with a request to include a copy of the questionnaire (or at least a link to the online questionnaire) in the next round of accounts distributed to companies (or via a separate correspondence).

In addition, over 1,000 emails were sent directly to companies by the project team (see list of companies contacted on the spreadsheet accompanying Deliverable 3). Initially, these emails were accompanied by introductory and follow-up phone calls to explain the purpose of the research, obtain contact details for the relevant person within the organisation, and obtain buy-in. However, given the large number of respondents required for the research, it soon became evident that it would not be possible to make telephone contact with every potential respondent. It therefore became necessary to rely on emails. Where possible, emails were directed to the best possible person in the organisation (such as an environmental, sustainability, or corporate social responsibility manager), based on information obtained from company websites, annual reports, sustainability reports, or online environmental directories such as http://www.enviropaedia.com. We focused initially on companies that participate in the JSE Socially Responsible Investment (SRI) Index (http://www.jse.co.za/Products/SRI.aspx); as it was assumed that those companies would be most willing and able to respond to the questionnaire. Once these options were exhausted, emails were sent to the ‘general enquiries’ address of a large number of manufacturing companies, obtained from the online business directory, http://www.brabys.co.za.

Following the submission of Deliverable 3, at which stage only 27 responses had been received, follow-up emails were sent to all 1,000-plus companies, reminding them to complete the questionnaire if they had not already done so. This persistence paid off, with the number of responses increasing rapidly in response to the follow-up emails. In total, 56 responses were received via the various channels; with 40 responses received via the online platform, 15 responses by email, and one response by fax. Of these responses, 28 had to be omitted for various reasons:

- Some responses were received from companies operating in sectors outside of the scope of the study (e.g. retail)
- Some questions had been left unanswered or had been answered in such a way that it was not possible to convert the response into usable data for the process of estimating a production function

This left a total of 28 valid responses.

This sample size was not considered sufficient for statistically significant results. Econometric theory suggests that the more explanatory variables included a model (in our case, there are 14 explanatory variables, including quadratic and interaction terms); the more observations are required to ensure adequate degrees of freedom. In order to assess whether this sample size would be sufficient, a preliminary run of the regression model was conducted, based on data obtained from the 28 respondents. Although reasonable regression results were obtained ($R^2$ was 0.76, suggesting that the explanatory power of the model is fairly high), the adjusted $R^2$ value (which takes into account the number of explanatory variables included in the model) was only 0.5, suggesting that much of the apparent goodness of fit resulted from the large number of variables included in the model (including the various quadratic and interaction terms).

It was therefore assumed that the model results could be improved by the inclusion of more observations in the sample. It was therefore deemed necessary to supplement the primary data obtained from survey respondents with secondary data for companies that had not responded. For many publically listed companies, particularly those participating in the SRI Index (see above), data on the variables required for estimating the production function could be found in their annual and sustainability reports, which in many cases are freely available on companies' websites. These reports, where available, were therefore used to boost the number of observations in the sample. Although the original project plan focused on the use of primary data; it was felt that secondary data should not be ignored if such data would add value to the analysis and could be obtained relatively easily.

For the purposes of obtaining secondary data, companies were selected on the basis of participation in the SRI Index, since participation in this initiative involves reporting on sustainability (including environmental) performance, such that data on these companies' water and energy use was likely to be obtainable. A list was therefore compiled of all companies participating in this initiative over the previous 3 years (2009-2011). Companies in sectors not forming part of this research (primary sectors such as agriculture and mining, as well as tertiary sectors such as finance and retail) were ignored. A search was then conducted for the latest (generally the 2011) annual and sustainability reports (or, in some cases, the 'integrated annual report') of each of the remaining companies (i.e. those in secondary/manufacturing sectors). In some cases, sustainability reports could not be obtained (some of the companies were no longer participating in the SRI initiative, and were therefore no longer producing such reports); while in other cases the reports did not present data on water and/or energy use, at least not in a format that could be utilised in the production function.

In obtaining data from companies' annual and sustainability reports, care was taken to ensure that companies that had already responded to the survey were excluded, so as to avoid duplication of data. Since questionnaire responses were anonymous, this was done by cross-checking all data obtained from annual/sustainability reports with the data obtained from survey respondents. Three cases were identified where it was clear that the company had already responded to the survey (i.e. the data from a specific company's annual/sustainability reports exactly matched that of a company who had already responded to the survey). These duplicates were eliminated.

In this way, a full set of secondary data was obtained from 30 companies who had not responded to the survey. This was added to the original data set of 28 survey respondents, giving rise to a total sample size of 58 companies. A second run of the regression model yielded much improved results ($R^2$ = 0.88, adjusted $R^2$ = 0.84), suggesting a good fit between the model and the data. The regression results will be described in more detail below.

## 4. Data analysis

Data obtained from the survey responses and annual/sustainability reports were captured in a spread-sheet based model (available on request) designed prior to the survey being conducted. The model was designed in such a way as to convert raw data obtained from the survey responses into a format for estimation of the production function. Raw data was captured in the first worksheet, which contained a dedicated column for each question in the survey where a response could be provided. The second worksheet contained conversion factors for converting the raw data (which was provided in various units, particularly in the case of water and energy) into consistent units.

For example, for many companies, the consumption volume of different forms of energy was reported in varying units. These were all converted to a common energy unit (megajoules, MJ) based on the calorific values of different fuel types, published by the Department of Energy (2009). In some cases, where liquid fuel use was reported in terms of mass rather than volume, it was necessary to convert from mass to volume as an intermediate step, based on the density of the different fuel types (also from DoE 2009). In other cases, energy usage was reported in terms of Rand values spent per fuel type, rather than physical units used (e.g. kilowatt-hours or litres); in these cases, rand values were converted back to physical units based on prices per fuel type as per the Department of Energy (2010) Energy Price Report, plus VAT. Finally, once the consumption of the various fuel types had been converted into MJ, these were aggregated to obtain the total energy consumption for each company.

The converted data appears in the third worksheet. Finally, in the fourth worksheet, all data pertaining to each variable required for estimating the production function was gathered and aggregated into a single column (i.e. one column for each of the five variables output, capital, labour, water and energy).

In order to calculate sector-specific marginal values and elasticities, it was necessary to define sector classifications for the sample and to allocate each firm to a specific sector. Initially, it was deemed preferable to adopt the same classifications as those used in the NATSURV reports, in order to ensure consistency with previous WRC research. However, many of the companies in the sample operated in sectors not covered by the NATSURV reports, such as pharmaceuticals, electronics, automobiles, etc.[4]

It therefore became necessary either to develop new categories to supplement the existing NATSURV classification, or to use an alternative classification system. For the sake of consistency, and to ensure that a recognised classification system was used throughout rather

[4] NATSURV reports have been produced for the following sectors: malt brewing (NATSURV 1 TT 29 / 87), metal finishing (NATSURV 2 TT 34 / 87), soft drink and carbonated waters (NATSURV 3 TT 35 / 87), dairy (NATSURV 4 TT 38 / 89), sorghum malt and beer NATSURV 5 TT 39 / 89, edible oil (NATSURV 6 TT 40 / 89), red meat (NATSURV 7 TT 41 / 89), laundry (NATSURV 8 TT 42 / 89), poultry (NATSURV 9 TT 43 / 89), tanning and leather finishing (NATSURV 10 TT 44 / 90), sugar (NATSURV 11 TT 47 / 90), pulp and paper (NATSURV 12 TT 49 / 90), textiles (NATSURV 13 TT 50 / 90), wine (NATSURV 14 TT 51/90), oil refining and re-refining (NATSURV 15 TT 180 / 05) and power generating industries (NATSURV 16 TT 240 / 05).

than adding categories to the existing NATSURVE classification on an ad-hoc basis, it was decided to adopt the FTSE/JSE Industrial Sector Classifications (http://www.jse.co.za/Products/FTSE-JSE/Classification-System.aspx) throughout. Each company in the sample was allocated to one of these Industrial Sectors on the basis of their responses to questions 1 and 2 of the questionnaire; or, in the case of companies for which secondary data was obtained, on the basis of the company's product offering as described on their websites or in their annual reports. The resulting sector categories, as well as descriptive statistics (number of companies in the sample, and average value of each variable; both per sector and for the whole sample), are summarised in Table 1.

**Table 1: Sectors (as per the FTSE/JSE Industrial Sector Classifications) and summary statistics for the sample**

| Sector | N | Sample averages | | | | |
|---|---|---|---|---|---|---|
| | | Y (Rands) | K (Rands) | L (no.) | W (KL) | E (MJ) |
| Food producers and processors | 12 | 60 095 027 506 | 17 772 497 567 | 31 239 | 96 763 203 | 11 494 296 992 |
| Beverages | 3 | 80 050 262 000 | 23 282 816 333 | 25 060 | 24 240 344 | 8 470 754 903 |
| Chemicals | 2 | 62 696 850 000 | 6 242 737 000 | 4 200 | 1 581 429 | 3 098 082 500 |
| Diversified industrials | 7 | 30 682 977 571 | 3 937 631 325 | 14 197 | 485 312 | 853 372 110 |
| Household goods and textiles | 5 | 66 420 660 | 19 630 260 | 298 | 54 938 | 14 766 359 |
| Electronic & electrical equipment | 7 | 208 762 265 881 | 31 897 205 132 | 29 161 | 16 396 728 | 3 201 635 777 |
| Steel and other metals | 5 | 9 597 200 000 | 6 044 217 400 | 3 182 | 7 835 490 | 45 502 958 195 |
| Forestry and paper | 3 | 38 748 373 333 | 20 531 303 333 | 13 200 | 204 367 324 | 103 135 255 365 |
| Pharmaceuticals & biotechnology | 4 | 96 428 590 500 | 25 799 911 250 | 29 884 | 109 470 425 | 21 390 380 519 |
| Construction & building materials | 3 | 23 895 000 000 | 5 145 200 000 | 21 662 | 986 079 | 9 808 352 716 |
| Automobiles and parts | 4 | 850 582 698 500 | 161 398 024 750 | 220 392 | 3 771 783 814 | 31 501 248 190 |
| Oil and gas | 3 | 1 185 473 916 667 | 394 829 750 000 | 42 403 | 120 926 523 | 564 242 481 726 |
| **ALL RESPONDENTS** | **58** | **178 336 493 957** | **44 604 784 333** | **34 694** | **308 595 267** | **46 011 007 859** |

In the sample, the category 'food producers and processors' is dominated mainly by poultry producers, fruit and vegetable processors, etc. The category 'household goods and textiles' consists mostly of clothing manufacturers. 'Diversified industrials' includes firms in sectors not elsewhere classified, such as arms manufacturers, as well as manufacturers of industrial textiles and materials (plastics, etc). The other categories are self-explanatory.

The production function (see Equation 2) was estimated statistically by means of an ordinary least squares (OLS) regression using EViews, an econometric software package. This was done by importing the data from the Excel spreadsheet into a new EViews workfile, and specifying the following in the equation estimation dialog box:

log(y) c log(k) log(l) log(w) log(e) (log(k)^2)/2 (log(l)^2)/2 (log(w)^2)/2 (log(e)^2)/2
log(k)*log(l) log(k)*log(w) log(k)*log(e) log(l)*log(w) log(l)*log(e) log(w)*log(e) (6)

Where 'log(y)' etc are the variables ('lnY,' etc) as per the above mentioned production function (note that in EViews, 'log' refers to the natural logarithm, ln); and 'c' is the constant (intercept term).

The regression results are presented in Table 2. The $R^2$ of 0.88 suggests that 88% of the variation in the dependent variable is explained by the model, indicating an excellent fit of the model to the data, while the significance of the F-statistic (probability = 0.0000) suggests that the independent variables are collectively statistically significant. In short, the regression model performs well.

**Table 2: Regression results**

| | | | | |
|---|---|---|---|---|
| Dependent Variable: LOG(Y) | | | | |
| Method: Least Squares | | | | |
| Date: 08/20/12 Time: 11:42 | | | | |
| Observations: 58 | | | | |
| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
| C | 4.282915 | 11.18913 | 0.382775 | 0.7038 |
| LOG(K) | -0.292453 | 2.279054 | -0.128322 | 0.8985 |
| LOG(L) | 1.175433 | 2.299878 | 0.511085 | 0.6119 |
| LOG(W) | -0.821084 | 1.623923 | -0.505618 | 0.6157 |
| LOG(E) | 1.227449 | 1.418530 | 0.865296 | 0.3917 |
| (LOG(K)^2)/2 | 0.112909 | 0.294302 | 0.383651 | 0.7031 |
| (LOG(L)^2)/2 | 0.009165 | 0.360158 | 0.025447 | 0.9798 |
| (LOG(W)^2)/2 | 0.018142 | 0.109520 | 0.165646 | 0.8692 |
| (LOG(E)^2)/2 | 0.048679 | 0.067387 | 0.722370 | 0.4740 |
| LOG(K)*LOG(L) | 0.031509 | 0.291017 | 0.108273 | 0.9143 |
| LOG(K)*LOG(W) | 0.026341 | 0.150011 | 0.175595 | 0.8614 |
| LOG(K)*LOG(E) | -0.095437 | 0.137092 | -0.696156 | 0.4901 |
| LOG(L)*LOG(W) | -0.047211 | 0.149616 | -0.315551 | 0.7539 |
| LOG(L)*LOG(E) | -0.037841 | 0.167648 | -0.225716 | 0.8225 |
| LOG(W)*LOG(E) | 0.010893 | 0.082328 | 0.132307 | 0.8954 |
| R-squared | 0.880025 | Mean dependent var | | 22.14047 |
| Adjusted R-squared | 0.840963 | S.D. dependent var | | 3.613357 |
| S.E. of regression | 1.440988 | Akaike info criterion | | 3.786533 |
| Sum squared resid | 89.28714 | Schwarz criterion | | 4.319406 |
| Log likelihood | -94.80945 | Hannan-Quinn criter. | | 3.994098 |
| F-statistic | 22.52905 | Durbin-Watson stat | | 1.875809 |
| Prob(F-statistic) | 0.000000 | | | |

## 5. Results and Discussion

On the basis of the estimated coefficients (Table 2) and the sample averages for the different variables (Table 1), the marginal value of water use, as well as the price elasticity of demand for water use, both for all firms in the sample, as well as for each specific sector, can be calculated, using Equations 3-5 in Section 2. This allows for policy recommendations to be made regarding the scope for and potential effectiveness of increasing water tariffs in order to reduce water use. The results of these calculations are presented in Table 3.

The fourth column of Table 3 provides an estimate of the marginal value of water use for each sector and for all firms in the sample; while the last column provides the price elasticity of demand for water use, as calculated using the marginal productivity approach described in this report. Among all firms in the sample (bottom row of the table), the marginal value of water use is R369.10 (column 4). This implies that, for each additional KL of water used, an additional R369.10 worth of output is generated. The 'value' to firms of an additional KL of water is therefore R369.10; i.e., this is what firms would be willing to pay for an additional KL of water. Given that this is an order of magnitude higher than current water tariffs, this suggests that there is certainly scope for increasing water tariffs for industrial users.

**Table 3: Marginal value and elasticity calculations**

| Sector | N | $\sigma_w$ | MV (ρ) per KL of water | Elasticity (γ) |
|---|---|---|---|---|
| Food producers and processors | 12 | -0.19 | -115.77 | -0.78 |
| Beverages | 3 | 1.90 | 6270.71 | 1.10 |
| Chemicals | 2 | 0.80 | 31778.11 | -5.69 |
| Diversified industrials | 7 | 0.56 | 35366.18 | -2.45 |
| Household goods and textiles | 5 | 0.48 | 583.03 | -2.08 |
| Electronic and electrical equipment | 7 | 0.64 | 8202.19 | -3.05 |
| Steel and other metals | 5 | 0.78 | 955.28 | -5.08 |
| Forestry and paper | 3 | 0.83 | 157.62 | -6.81 |
| Pharmaceuticals and biotechnology | 4 | 0.55 | 485.79 | -2.41 |
| Construction and building materials | 3 | 0.58 | 13936.47 | -2.54 |
| Automobiles and parts | 4 | 0.65 | 147.27 | -3.13 |
| Oil and gas | 3 | 0.78 | 7689.30 | -5.19 |
| **ALL RESPONDENTS** | **58** | 0.64 | 369.10 | -3.00 |

In addition, the price elasticity of demand for all respondents of -3.00 (bottom row, last column) suggests that companies in the sample are highly responsive to changes in water prices (the negative sign indicates that, as expected, an increase in water prices would lead to a reduction in water use; while a price elasticity of demand which is higher than 1 in absolute terms can be considered 'highly elastic'). This suggests that increasing water tariffs can be an effective strategy for reducing water use among industrial users.

Looking at marginal values and elasticities per sector, it is evident that a similar trend emerges: the marginal value of water use is generally at least an order of magnitude higher than prevailing water prices, suggesting that there is scope for increasing water tariffs; while the price elasticities of demand for water use are generally negative and higher than 1 in absolute terms, suggesting that increases in water tariffs are likely to lead to a significant reduction in water use[5]. The results of this research therefore suggest that, purely on the basis of the analysis presented here, there is scope for increasing water prices for industrial water users, and that doing so is likely to be effective in terms of reducing water use.

However, water pricing is a sensitive issue, affecting various stakeholders. As such, policy recommendations cannot be made on the basis of this analysis alone. In particular, stakeholder consultation is essential. The next phase of this research will involve meetings with various stakeholders in national government, local government and business to obtain their feedback regarding the preliminary results presented above, which will feed into the final report and recommendations.

[5] The exceptions are 'food producers and processors,' for which marginal value is negative, and 'beverages,' for which elasticity is positive; although these results can perhaps be considered statistical anomalies.

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## Appendix: Cover letter and questionnaire distributed to companies

# Water use questionnaire

Water is becoming an increasingly scarce and expensive input in industrial production processes. Improved water use efficiency has therefore become an important way of managing water-related risks and reducing production costs. In addition, customers and shareholders are increasingly concerned with companies' environmental performance, including their water footprint.

The CSIR is conducting research to help companies manage these costs and risks, and to benefit from the competitive advantage of an improved water footprint. You are invited to participate in this important research by completing a brief questionnaire aimed at helping companies take advantage of these opportunities. The questionnaire consists of just seven questions, takes approximately fifteen minutes to complete, and is completely anonymous and confidential - we will not ask you to provide your company's name or contact details.

Responses will be used to assess the efficiency of water use per Rand of output generated by industry in South Africa. As such, we require information on your company's revenues, as well as various inputs (fixed capital, labour, water and energy), for the most recent financial year for which you have information. Most of this information should be available in your company's annual report or financial statements, water and electricity bills, or sustainability / corporate social responsibility report. Otherwise, please forward the questionnaire to someone in your company who may have this information.

**Again, we must emphasise that your responses will be kept strictly confidential - all information will be used for the sole purpose of calculating an industry-wide production function.**

Do try to complete the entire questionnaire - if you have insufficient information to answer a particular question, please provide an estimate, rather than leaving the answer blank. For example, if you don't know your company's annual water or electricity consumption, simply multiply the most recent monthly consumption by 12. Please feel free to contact us if any of the questions are unclear.

There are various options for completing and returning the survey to us, depending on what is most convenient to you:

1. Go to: https://www.surveymonkey.com/s/78WPJ9G to complete the questionnaire online
2. Complete the attached questionnaire and return to us by
    - e-mail: anahman@csir.co.za, or
    - fax: 021 886 6518 (for attention Anton Nahman)

Please return your questionnaire by 15 July 2012. Many thanks in advance for participating in this exciting and ground-breaking research!

ANahman

Anton Nahman
Council for Scientific and Industrial Research
PO Box 320, Stellenbosch, 7599
Tel: 021 888 2403

# Water Use Questionnaire

**CONFIDENTIAL**

| | |
|---|---|
| **1. In which sector does your company operate? (e.g. pulp and paper, automotive, food and beverage, textiles, etc)** | |
| | |
| **2. What is its core business? (e.g. paper manufacturing, motor vehicle assembly, wine making, leather products, etc)** | |
| | |
| **3. Total number of employees (including permanent, contract, full time and part-time) at the end of the last financial year:** | |
| **4. Stated revenue (as per income statement) for the last financial year (SA Rands):** | |
| **5. Book value of tangible fixed assets (property, plant & equipment) as per balance sheet / statement of financial position at end of last financial year (SA Rands):** | |

**6. Complete either 6a or 6b. You may wish to consult your water bills or sustainability report.**

**6a. Please state your annual water use from each source; OR**

**6b. Please state your total annual water use**

| | Source | Annual water use | |
|---|---|---|---|
| | | *Volume* | *Unit of measure* |
| 6a | Water purchased from a water service provider (e.g. municipality or water user association) | | |
| | Self-supplied water (water drawn directly from source; not internally recycled/re-used water) (if applicable) | | |
| OR: 6b | Total water use (intake water only; i.e. excluding internally recycled/re-used water) | | |

**IMPORTANT: Please specify the unit of measure (e.g. hL, kL, $m^3$, ML)**

**7. Complete either 7a or 7b. You may wish to consult your energy bills or sustainability report.**

**7a. Please state either your annual consumption, OR your annual expenditure, for each of your main sources of energy use.**

**7b. ALTERNATIVELY, please state your total annual energy use from all sources combined (typically reported in Joules, Megajoules or Terajoules):**

| | Source | | Annual Consumption | | OR Annual Expenditure (Rands) |
|---|---|---|---|---|---|
| | | | *Consumption* | *Unit of measure* | |
| 7a | Electricity (From National Grid) | | | | |
| | Coal (if applicable) | | | | |
| | Diesel (if applicable) | | | | |
| | Other (e.g. crude oil, LPG, paraffin, butane, propane, wood, bagasse etc.) | *Specify:* | | | |

**IMPORTANT: If stating your consumption, please specify the unit of measure (e.g. kilowatt hours (kWh), megawatt-hours (MWh), litres (L), kilolitres (kL), tonnes (t) etc.)**

| | | | | |
|---|---|---|---|---|
| OR: 7b | TOTAL ENERGY USE | | | |

**IMPORTANT: Please specify the unit of measure (Joules (J), Megajoules (MJ), Terajoules (TJ) etc.)**

*Thank you for completing the questionnaire!*

*Please return to: anahman@csir.co.za OR by fax to 021-886 6518*