Valuing water for South African industries: A production function approach

Background Information Document

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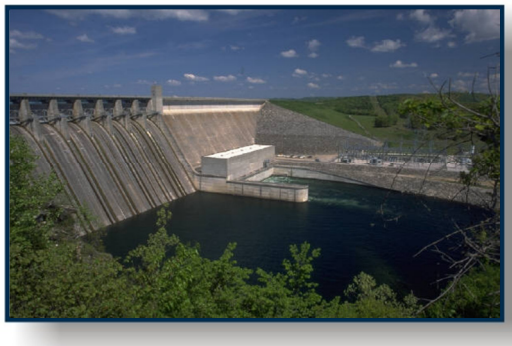
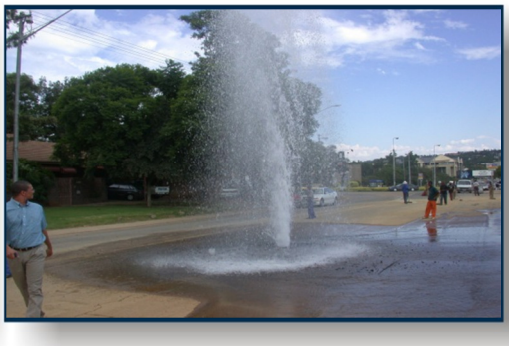

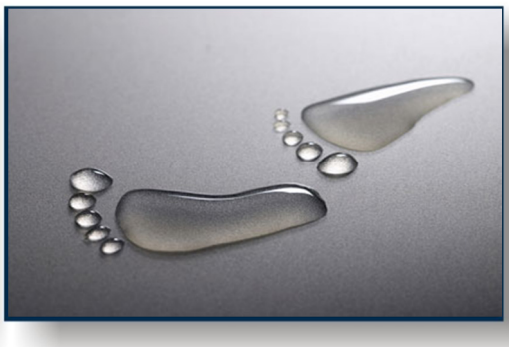

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1. Purpose of this document

This document presents the results of an economic assessment of the value of industrial water use in South Africa. The project was funded by the Water Research Commission (WRC) and conducted by the Council for Scientific and Industrial Research (CSIR). It originated in the context of the National Water Act (Act 36 of 1998) (Department of Water Affairs and Forestry, 1998); which emphasises demand-side approaches to water management and conservation; specifically, the economic principle of encouraging more efficient water use by means of water pricing.

Appropriate (fair and efficient) water pricing requires information on

- the ***marginal value*** of water use (i.e. the increase in economic value generated per unit increase in water use (Gibbons, 1986)); in order to assess the *scope* for changes in water prices; and
- the ***price elasticity of demand*** for water, i.e. the responsiveness of users to changes in water prices; in order to assess the potential *effectiveness* of changes in water prices in terms of its impact on water use behaviour.

This project estimated the marginal value of industrial water use in South Africa, along with the associated price elasticity of demand, in order to inform the setting of appropriate water tariffs for industrial water users. The focus was on companies in the secondary sector (manufacturing, processing, etc); companies in the primary and tertiary sectors were excluded. The results will be presented to various stakeholders at a series of meetings, where the results will be discussed and stakeholders' feedback obtained. This feedback will in turn inform the recommendations with respect to industrial water pricing policy which will be made in the final report.

2. Method

The marginal value of industrial water use in South Africa was estimated using a production function approach; specifically, the marginal productivity approach developed by Wang and Lall (1999, 2002). This approach requires the estimation of a *production function* for a large cross section of companies. Production functions describe the technical relationship between *outputs* (products) on the one hand, and the *inputs* used to produce them on the other (Miller and Meiners, 1986). Mathematically, they take the following general form:

$$O = f\ (K, L, W, E, \text{etc}) \qquad (1)$$

Where O reflects the value or quantity of *output* produced; and K, L, W, and E are the quantities of inputs (respectively *capital, labour, water* and *energy*) used in producing the output. The f indicates that the value or quantity of output produced is a *function* of the quantities of inputs used, among other things.

A production function can be estimated by using ordinary least squares regression techniques. Doing so requires collecting data on outputs and inputs for a large sample of companies. The estimated production function is then used to calculate the marginal value of water use, and the price elasticity of demand for water, for the companies in the sample. This information

can then be used to make policy recommendations regarding the scope for and potential effectiveness of water pricing strategies.

The marginal value of industrial water use reflects firms' maximum *willingness to pay* for water, and can be compared with prevailing water prices (i.e. what firms actually pay), to assess the scope for changing water prices. If the marginal value of water use is higher than actual water prices, it means that users could pay more for water as compared to what they are currently paying; i.e., that there is scope for increasing water prices to better reflect firms' willingness to pay.

The price elasticity of demand for water 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 in changing water use behaviour. Price elasticity of demand is usually a negative number: as prices increase, demand can be expected to decrease. A price elasticity of demand between zero and -1 indicates that demand is not very responsive to changes in price; and therefore that changes in prices will not have a significant impact on behaviour. However, if the price elasticity of demand is high in absolute value terms (highly negative, e.g. -2 or -3), this means that 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. This would imply that a demand-side management strategy based on higher water prices could be highly effective in reducing water demand.

3. Data collection and analysis

We obtained data for estimating a production function for companies in the secondary sector in South Africa via an anonymous survey questionnaire (see Appendix). Over 1,000 emails were sent directly to companies, while a number of municipalities were contacted for assistance with distributing questionnaires to companies in their jurisdiction. In total, 56 responses were received. Of these responses, 28 had to be omitted for various reasons; leaving 28 valid responses. This data was supplemented with information from the annual reports and sustainability reports (or integrated annual reports) of a further 30 companies, giving rise to a total sample size of 58 companies.

When calculating marginal values and elasticities, and providing recommendations regarding water pricing, it is useful to classify the companies into specific manufacturing or processing sectors. We therefore defined sector classifications based on the FTSE/JSE Industrial Sector Classifications (http://www.jse.co.za/Products/FTSE-JSE/Classification-System.aspx); and allocated each firm in the sample to a specific sector. The resulting sector categories, as well as descriptive statistics per sector (sample size (n) and averages for each variable), are summarised in Table 1.

In the sample, the category 'food producers and processors' consists mainly of 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.

Table 1: Sectors and summary statistics for the sample

Sector	n	Sample averages				
		Output (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**

The production function was estimated by means of an ordinary least squares (OLS) regression using EViews, an econometric software package. The regression results are presented in Table 2. The R^2 of 0.88 suggests that 88% of the variation in the dependent variable (output) is explained by the independent variables (the various inputs) included in the model, indicating an excellent fit of the model to the data. 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)		Date: 08/20/12 Time: 11:42	
Method: Least Squares		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			

4. Results and Discussion

On the basis of the sample averages for the different variables (Table 1) and the estimated coefficients (Table 2); the marginal value of water use, as well as the price elasticity of demand for water, was calculated. The results of these calculations are presented in Table 3.

The third column of Table 3 provides the calculated marginal value (MV) of water use per sector; while the last column provides the price elasticity of demand for water use. Among all firms in the sample (bottom row of the table), the marginal value of water use was calculated at R369.10 (column 3). This implies that, for each additional kilolitre 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 the maximum amount that firms would (in theory) be willing to pay for an additional KL of water.

Given that this is significantly higher than current water tariffs, these results suggest that there is scope for increasing water tariffs for industrial users. However, it must be borne in mind that this implication arises purely on the basis of the economic analysis conducted as part of this project for a particular sample of companies. Various other sources of information (including stakeholder engagement) must also be consulted before the results can be generalised and policy recommendations made.

Table 3: Marginal value and elasticity calculations

Sector	N	MV per KL of water	Elasticity
Food producers and processors	12	-115.77	-0.78
Beverages	3	6270.71	1.10
Chemicals	2	31778.11	-5.69
Diversified industrials	7	35366.18	-2.45
Household goods and textiles	5	583.03	-2.08
Electronic and electrical equipment	7	8202.19	-3.05
Steel and other metals	5	955.28	-5.08
Forestry and paper	3	157.62	-6.81
Pharmaceuticals and biotechnology	4	485.79	-2.41
Construction and building materials	3	13936.47	-2.54
Automobiles and parts	4	147.27	-3.13
Oil and gas	3	7689.30	-5.19
ALL RESPONDENTS	**58**	**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; although once again this is subject to feedback from stakeholders and other sources of information.

Looking at marginal values and elasticities per sector rather than for the sample as a whole, 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[1].

The results of this research therefore suggest that, purely on the basis of the sample and 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.

References

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (1998) National Water Act No. 36 of 1998, Pretoria, Statutes of the Republic of South Africa: Water

GIBBONS, D.C. (1986) The economic value of water. Resources for the Future. Washington DC

MILLER, R.L. & MEINERS, R.E. (1986) Intermediate Microeconomics (3rd Ed.), Singapore, McGraw-Hill.

WANG, H. & LALL, S. (1999) Valuing water for Chinese industries: A marginal productivity assessment. The World Bank Development Research Group

WANG, H. & LALL, S. (2002) Valuing water for Chinese industries: A marginal productivity assessment. Applied Economics, 34, 759-765

[1] 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.

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: wdelange@csir.co.za, or
    - fax: 021 886 6518 (for attention Willem de Lange)

Please return your questionnaire by 30 April, 2012. Many thanks in advance for participating in this exciting and ground-breaking research!

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Water Use Questionnaire

CONFIDENTIAL

WATER RESEARCH COMMISSION

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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:*			
OR: 7b	TOTAL ENERGY USE				

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.)

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

Thank you for completing the questionnaire!

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