Determinants of water pricing – a regression analysis with cross-country data

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Abstract

As water has become a scarce resource, international organisations predict that the problem of water scarcity will become acute. This study investigates the role of socio-political factors such as the forward-looking water pricing hypothesis and the impact of globalisation as determinants of water pricing in 22 selected countries. Our statistical estimation results have two important policy implications. First, the statistical significance of the variable for the forward-looking water pricing hypothesis indicates the need for further debate and discussion about current and predicted water shortage problems at an international level. Second, the estimation results also indicate that globalisation via membership of international environmental organisations and promoting the activities of multinational companies should be encouraged, so that countries can enjoy positive information spill-overs and mutual knowledge acquisition through their interaction with the rest of the world.

Keywords: Globalisation; Regression analysis; Water pricing; Water scarcity

1. Introduction

Water has become a scarce resource mainly because of population growth (demand) and industrial activity, given the inflexible nature of its supply capacity. Moreover, the discharge of pollutants such as wastewater has constrained the supply of clean water. As water has become a scarce resource, more attention has been placed on policies for demand management. Consequently, the issue of water pricing has become the focus of debate among academics and policy makers.

There are two important aspects of water pricing. One is the “function” of a flexible water price on the demand for water. This has stimulated a large number of statistical estimations of the price elasticity of demand for water (Hanemann, 1998a). This approach highlights water price as a determinant of water use. A higher estimated elasticity would justify policies that raise the water price to avoid the waste of resources. However, most of the existing literature and statistical estimations have assumed strict exogeneity of water pricing in the system. The other issue relates to the “formation” of water pricing. This approach regards water pricing as an endogenous variable and attempts to find factors determining the price and influencing water rates (Mee Jr., 1998, Hanemann, 1998b). In particular, neoclassical microeconomic theory advocates a marginal cost pricing strategy. However, a marginal cost approach can be justified from the perspective of efficiency in allocating resources only if producers are seeking profit maximisation.

The water pricing mechanism is more complicated than is believed by neoclassical economists because most countries regard water as a (partially) public good and governments are therefore involved in the pricing process. The main objective of this paper is to investigate the determinants of the minimum level of metric-based water price for domestic supply from cross-sectional survey data. As a result, we focus more on the role of socio-political factors in determining the water

price rather than on a traditional cost-based approach. In particular, we focus on investigating the forward-looking water pricing policy and international impact hypotheses.

This paper differs from earlier studies in that earlier works were devoted to studying the impact of price on water use (Dalhuisen *et al.*, 2003; Agthe & Billings, 2002). Traditional econometric studies of water problems emphasise demand estimation by treating water price as an exogenous variable (Agthe & Billings, 2002). The main feature of their estimation models is summarised by the Marshallian demand equation, implying that quantity demanded is a function of commodity price and income¹. However, this traditional estimation of the demand function fails to capture the endogeneity of the price variable. Water price may be determined within the water management system. This study also differs from Dinar & Subramanian (1998) in that it analyses the relationship between vectors of explanatory variables and the introduction of a minimum level of consumption-based water price using statistical methodology.

2. Water pricing

Hanemann (1998b) emphasised the economic aspect of determining water rates. He recommended that generating revenue, allocating costs and providing incentives should be taken into consideration. Generating revenue allows a utility to cover its production costs. Allocating costs focuses on maximising efficiency of allocation among different types of users and incentives can be used to promote the efficient use of water.

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¹ Typical statistical work for common commodities involves simultaneous estimation of supply and demand systems of equations. Alternative econometric work includes estimating costs of water supply using $\text{costs} = f(\text{quantity, other physical and economic factors})$.

However, the factors affecting water pricing can be more complex than this suggests, as water has now become a scarce resource, given the nature of (partially) public goods in a global era. This paper attempts to investigate two important research hypotheses. The first question of interest to us is whether or not the expected scarcity of water resources drives governments to increase its price.

Debate about the predicted water shortage problem at international forums has facilitated policy reforms in a number of countries. The UN Commission on Sustainable Development indicates that around 1 billion [10^9] people will be without access to safe water in the next decade (UN, 1997). The US National Intelligence Council predicts that within the next two decades, more than half the world's population will suffer from a shortage of water, which is defined as yearly per capita consumption less than 1,700 m^3 (NIC, 2000). Moreover, it predicts that more than 30 countries will need to import more than one-third of their water requirements within 20 years.

This poses the interesting question of whether or not water pricing is influenced by the predicted shortage of water. In other words, the issue is whether or not governments have taken notice of the information about the expected water shortage that has been provided by international organisations and are reforming their water pricing systems as a result. We call this the hypothesis of forward-looking water pricing, which argues that governments will increase the price of water if the predicted water scarcity problem intensifies.

The second issue of interest here is the international impact hypothesis. Mutual learning via globalisation has been a driving force in reforming water management systems in many countries. The mechanism that links water price determination with globalisation is as follows: increased interaction with the rest of

the world provides more information and knowledge about global trends and thus leads to changes in perceptions about water, which in turn prompts consumers and producers to accept global trends. Historical evidence enables us to consider a mutual learning hypothesis in which individual countries influence one another, although deeply rooted cultural differences may remain. Western societies adopting the Japanese just-in-time system in the 1980s and the introduction of an Anglo-American type of corporate governance system by Japanese companies such as Sony after the 1997 Asian financial crisis are examples of mutual learning. The eastern states in the USA adopted some aspects of the prior appropriation doctrine while the western states tempered that doctrine by adopting certain concepts that historically are riparian in origin (Deason *et al.*, 2001). We expect that the price of water will rise if this international impact hypothesis is valid.

3. Data and selection of variables

Dinar & Subramanian's (1998) paper provided survey data for 22 countries. This included ranges for variable (metric-based) and fixed prices for domestic users, industry and agriculture. We chose the variable price for domestic supply owing to the limited number of observations for other price scenarios. The variable charge in the data set has a wide range of values, depending on consumption tier, monthly rental value per dwelling, dwelling size and location. Given our research objective, our estimations were confined to a minimum level of metric charge². All other variables were taken from the Environmental Sustainability Index (ESI), 2002, produced jointly by the Geneva-based World Economic Forum, Center for International Earth Science Information Network at Columbia University and the Yale Center for Environmental

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² The estimation based on average value showed similar results.

Law and Policy and the *International Financial Statistics Yearbook*³. All variables, apart from population and ESI indicator scores, are per capita and exchangeable variables are converted into US\$ values for direct comparison.

Table 1 summarises the calculations and the values of the variables used in the estimation model. The price and water availability per capita variables were taken from Dinar & Subramanian (1997, 1998), supplemented slightly by Min (2004).

In order to investigate our research hypothesis of a forward-looking water pricing policy, we manipulated the data for water availability per capita by calculating the ratio variable. Thus, we divided water availability per capita in 1990 by expected availability in 2025 (Tables 1 and 2)⁴. The expected sign of the variable's (WAPCA) coefficient is therefore positive.

We also took into consideration the fact that the determination of the price of utility goods is closely related to changes in people's perceptions about water and thus influenced by institutional arrangements through internationalisation (IT). The price of water is a function of institutional change, which in turn is determined by the political debate that occurs in conjunction with people's changing perceptions about water. We note in particular that information and knowledge about global trends have influenced reforms in some countries. The expected sign of internationalisation (IT) is positive, assuming that globalisation facilitates conceptual confluence in a way that leads to an appreciation of water as a resource that needs to be managed efficiently.

In order to assume the nature of water as a (partially) public good, three important factors need to be considered here. The first issue is subsidies (*SUB*) from governments. Water has traditionally been regarded as a necessity for human survival and for maintenance of the environment (Hoekstra, 1998). Thus there is a need to

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³ In order to use the same data source, we had to eliminate Taiwan from our calculations.

provide a certain level of water supply to provide for basic human and environmental needs such as drinking and cooking. It is the duty of public authorities to ensure this basic supply of water. Subsidies from governments to the poor to meet this basic demand can be justified in these terms. In order to capture this feature, we include government deficits from the previous year in the estimation model. The expected sign of the coefficient is negative because we assume that the increased subsidy (deficit) in the previous year provided room for the utility to cut the water price as it reduces marginal production costs.

The second issue is the failure of the market in the case of common resources, as reflected in the case of environmental pollution (EP). To the extent that individuals in a society regard water as a common resource, the market fails to internalise the individual agent's production and/or consumption costs (Tietenberg, 1990).

Individuals often ignore the social costs of their production and/or consumption behaviour. For instance, pumping ground water can deplete and pollute aquifers, and excess water consumption can cause salinity problems, as witnessed in Australia, resulting in environmental degradation. The discharge of pollutants is closely related to population growth and industrial activity. The expected role of government is to prevent environmental damage and encourage voluntary efforts to reduce the discharge of pollutants. We include various pollution variables: the index of water quality, total investment on house construction, and total fixed capital formation. The expected sign of the coefficient is positive in all cases. We also include GDP per capita (GDPCA in Table 1) to control demand-pull inflation of water prices.

4. Estimation results

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⁴ The data for Korea were for 1993 and 2021 (Min, 2004 and references therein).

Table 3 summarises the results of our estimations of the determinants of metric-based water pricing in the 22 selected countries. Ordinary least square (OLS) methodology was used for the calculations. We begin with model specifications for the estimation model (1) to investigate the forward-looking water pricing hypothesis, captured by WAPCA (Table 3). We expect that declining water availability in the future will force governments to raise the water price with a view to managing demand.

The signs of all coefficients are as expected and significant at a 5% significance level. The significance of WAPCA implies that governments tend to raise the consumption-based water price in order to prepare for an anticipated future water shortage, supporting the forward-looking policy hypothesis.

The expected sign of GDP per capita (GDPCA) is also positive. This is because water price is assumed to be positively correlated with living standard, or GDP per capita. The significance of GDPCA indicates that water price is positively influenced by GDP per capita. High living standards coupled with diversified water demand, such as demand for water for gardening, could be one cause of demand-pull inflation of water prices. This is also consistent with the observation that a high level of water prices coexists with high GDP per capita.

Model (2) aimed to investigate the role of government subsidies. The expected sign of the coefficient is negative if subsidies in the previous year pushed the marginal production cost curve downward. The sign of the coefficient was as expected, but was not significant. This result is puzzling because most (central) governments currently provide water subsidies explicitly and/or implicitly. However, the insignificance of this variable (but correct sign) is understandable if subsidies for water are a minimal component of the overall government budget.

Models (3) and (3)' were designed to analyse whether or not water price is influenced by water pollution. We used a number of variables alternatively. First, all of the ESI indicators of water quality, reducing water stress and reducing waste and consumption pressure were tried, but none was significant. We therefore tried real numbers instead of indicators in order to capture polluting behaviour by households and industry. Households and industry are generally the most important sources of wastewater discharge (Min, 2004). In contrast to our expectations, the results of models (3) and (3)' show negative relationships. This counter-intuitive result may imply a complicated political response to voters' views⁵. A price cut is possible if politicians are concerned about their popularity with voters. Political decisions are often influenced by lobbying by stakeholders. The industry variable, represented by gross fixed capital formation in (3)', is also not significant. This implies that industry activities, or pollution discharges, are not directly related to the domestic water price. This is understandable if the government is reluctant to introduce a pollution tax to curb pollution by industry because it does not want to reduce industry competitiveness.

Estimation models (4) and (5) aimed to investigate the impact of globalisation on water pricing. As awareness of expected water shortages increased, countries began to modernise their water management systems through measures such as the introduction of mechanisms to rationalise the water price. The estimation result from model (4) confirms that the water price tends to rise if a country increases its interactions with the rest of the world. The result therefore supports knowledge spill-over effects on institutional reform. This is consistent with the forward-looking water pricing hypothesis, given the fact that international organisations predict that water

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⁵ The theory indicates that the effect of economic instruments will be enhanced if the water

scarcity will increase. In our estimation model, the level of globalisation was alternatively measured by foreign direct investment flows. We also used a trade intensity variable in place of this direct investment variable, but the level of significance declined. This result is consistent with the general belief that foreign direct investment creates a stronger spill-over effect across borders than trade does. In contrast to trade, where knowledge is embodied in products and services, foreign direct investment is accompanied by the transfer of a “package” that includes human resources.

Model (5) includes all explanatory variables. A number of interesting facts were observed here. First of all, variables WAPCA and IT are consistently significant with correct signs. This result confirms that the forward-looking water pricing hypothesis is robustly valid. Exchange of knowledge about modernising water management systems through internationalisation is also an important factor in determining the water price across countries. Second, the significance of the water demand variable has important policy implications for demand management. Third, in contrast to the results in (2), the government deficit variable is significant at the 10% significance level with the correct sign. This may imply that government subsidies cut production costs and thereby reduce the minimum level of metric-based water price. However, the result was not robust as the estimation results in model (2) fail to support this. Fourth, explanatory power, measured by *R*-square and standard error of estimation, was noticeable. The *R*-square value is 0.457, which is higher than the generally accepted level of 0.35 for cross-section data (Studenmund & Cassidy, 1987).

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management system is combined with comprehensive reforms such as legal reforms (Muys, 1995) and stakeholder participation in decision making (Glasbergen, 2000).

Another interesting question is whether or not the introduction of a fixed charge, combined with a metric-based variable price, affects the minimum level of the metric-based price. Nine of the countries studied introduced a fixed charge as well as a metric-based water price. Microeconomic theory indicates that a monopolistic firm should appropriate a two-part tariff in order to transfer consumer surplus to its profit function. In particular, the firm should set the fixed charge (entry fee) and the variable price (usage fee) strategically, depending on the number (different preferences) of consumers (Oi, 1971). While designing an optimal two-part tariff requires more information than marginal cost and aggregate demand, the theory indicates that the firm should drop the variable price to marginal cost and make the fixed charge high if consumers' levels of demand for the products/services are similar⁶. Furthermore, the variable price in this case should be lower than the traditional monopoly price⁷. Thus, we expect the sign of the coefficient to be negative.

$$\begin{aligned}
 MINPD = & -0.157 \cdot \text{constant} + 0.152 \cdot WAPCA + 9.88 \cdot GDPCA - 189.5 \cdot GDEF - \\
 & (0.156) \quad (0.016)** \quad (0.059)* \quad (0.092)* \\
 & 1.889 \cdot HOUSE - 29.35 \cdot GFKI + 312.3 \cdot IT - 0.013 \cdot DUMMY \\
 & (0.369) \quad (0.212) \quad (0.051)* \quad (0.422)
 \end{aligned}$$

where $R^2 = 0.458$ and $SE = 0.156$.

The result calculated with a dummy variable confirmed this negative sign but was not significant. This indicates that the minimum level of metric-based price is not influenced by the introduction of a fixed charge, which implies that water suppliers in the countries studied generally did not set the price for profit maximisation purposes,

⁶ In a similar vein, the firm should charge a low fixed price and a high variable price if consumers' demand differs significantly.

⁷ The traditional monopoly supply is set where marginal revenue equals marginal cost. The price charged to consumers is determined by this monopoly supply and the consumer's demand curve.

even though countries such as the UK privatised their water supply facilities. While the levels of significance were somewhat lower, the magnitudes of other coefficients in the estimation were not much different from the previous model (5).

5. Diagnostics

While heteroscedasticity in the error term is most commonly expected when using cross-section data, the diagnostic tests failed to reject the null hypothesis of homoscedasticity⁸. Our results were based on a limited number of observations. We therefore applied the following three diagnostic tests to determine the robustness of our results. First, we examined measurement errors by applying the Hausman test. Of particular concern here was the possibility of measurement errors for the variables of pollution from households and the degree of internationalisation. We used the “ESI indicator scores” of water quality and participation in international cooperative efforts respectively for the variables. Note that these variables are measured in the form of *z*-values (see footnote in the Table 2).

The final estimation results with residual variables obtained from regression of the suspected variables on the instrument variable indicate that the *HOUSE* variable is subject to measurement error if we use a two-tailed test at the 10% significance level. However, this possible error does not affect the robustness of the *WAPCA* and *INT* coefficients⁹. In a similar vein, we repeated the process for the *INT* variable, but it was not subject to measurement error.

Appendix 1 summarises the diagnostics for validity of the assumptions for OLS estimation and the reliability of estimated coefficients. The studentised residuals

⁸ For example, the Chi-square value of Breusch-Pagan test (*d.f.* 5) was 4.46, given the critical value of 11.07.

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$$\begin{aligned} MINPD = & -0.189 \cdot \text{const} + 0.143 \cdot WAPCA + 5.08 \cdot GDPCA - 146 \cdot GDEF - \\ & (0.098)^* \quad (0.016)^{**} \quad (0.217) \quad (0.134) \\ & 14.1 \cdot HOUSE - 15.96 \cdot GFKI + 280 \cdot INT - 18.02 \cdot RESIDUAL \\ & (0.121) \quad (0.323) \quad (0.053)^* \quad (0.07)^* \end{aligned}$$

refer to the normalised residuals calculated by dividing the residual by the estimated standard deviation of the regression, $SE_i(i)$, in which the i th observation has been omitted. The figures in the table show that only one observation exceeded the cut-off, indicating that the normality assumption for residuals should not be a problem.

Statistics calculated by $(\beta - \beta(i))/SE(\beta(i))$, or called DFBETA, measure the scaled difference between the OLS estimate and the corresponding parameter that has been estimated with the i th observation omitted. The results show that observations 5, 6 and 14 are particularly influential. Overall, the regression diagnostics indicate that the error terms satisfy the OLS assumption, so that the OLS estimation results are valid. There is only one particularly influential data observation for *WAPCA*, and three for *INT*, indicating that there is little danger in relying on the estimated coefficients.

6. Conclusions and policy implications

This paper has investigated the determinants of water pricing with cross-section data for 22 countries using regression analysis. Special attention was paid to a forward-looking water pricing hypothesis, in conjunction with the impact of internationalisation, to analyse the role of socio-political factors as determinants of water pricing. The estimation results robustly support the forward-looking hypothesis, which argues that an expected water shortage would push the water price upwards. Variables for the globalisation impact hypothesis were also significant at a 5 or 10% significance level depending on model specifications. Water prices tend to rise as a country increases its globalisation activities. The effects of internationalisation seemed to be facilitated by the transfer of knowledge through international relations. The estimation results also support the use of government subsidies to cut the water price, although this affirmative result was subject to model specification. The results

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of our calculations, however, fail to confirm that water pricing reflects internalisation of the social costs of pollution.

Our results have two important policy implications. First, there is a need for further debate and discussion at an international level about current and predicted water shortage problems. Second, globalisation measures such as membership of international environmental organisations and/or promoting the business activities of multinational enterprises should be encouraged so that countries can enjoy positive information spill-overs and mutual knowledge acquisition through their interaction with the rest of the world.

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