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업종별 공업용수의 한계생산가치 및 가격탄력성 추정 연구

The Study on the Marginal Product Value and Price Elasticity of Disaggregated Industrial Water

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Abstract

This paper estimates the output and price elasticities of disaggregated industrial water in order to afford some information for improving the efficiency of government water policy. This paper uses the marginal productivity method for estimating the output and price elasticities of industrial water. The estimated output elasticity shows that the value of industrial water is much higher than the average price of industrial water and the estimated price elasticity shows that the water pricing policy is effective for controlling the demand of industrial water.

keywords : marginal product value, price elasticity, industrial water

요 지

본 연구는 수자원정책의 효율성 제고를 위한 판단 자료 제공을 목적으로 업종별 공업용수의 한계생산가치 및 공업용수의 가격탄력성을 추정하였다. 두 가지 형태의 생산함수를 설정하여 추정한 공업용수의 한계가치 및 가격탄력성을 추정 결과를 보면 공업용수의 한계가치는 산업별로 차이가 있으나 공업용수의 평균 가격에 비하여 매우 큰 것으로 추정되었으며 가격탄력성 추정결과는 가격 현실화 정책 효과가 있음을 보여주고 있다.

핵심용어 : 한계생산가치, 가격탄력성, 공업용수

1. Introduction

Korea may face serious shortages of water in the near future. It is important, therefore, to design a policy of water demand management that would secure adequate water. Until the 1990's, the government kept the price of water lower than its production cost in order to subsidize industry and lower income households. However, these policies confronted some difficulties. Namely, environmentalists who speak against dam construction on environmental grounds and some economists who insist that the lower water price policy is inefficient. As a result, the focus of water policy has shifted towards water demand management to resolve the problem of water shortage in the future.

Until recently, water demand management policy has been mostly focused on municipal water by propagating water-saving devices and by adjusting the municipal water prices to average cost level. However, in the industrial water area, demand management policy has never been applied system-

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atically due to a set of limiting factors. Since industrial water is supplied from various sources such as piped line water, subterranean and sea water, it is difficult to estimate the exact amount of water use and thus, it is rather difficult to implement a policy of demand management for industrial water. In addition to the difficulties associated with the construction of a reliable database for research on the industrial water use, another reason that results in the insufficient demand management policy for industrial water is the fact that the share of expenses held by industrial water relative to the other production factors in most enterprises is rather low. That is, industrial water has rarely been the point of major concern by the firm management. Therefore, in order to meet the expected increasing water demand given the fact that the Korean economy is going to grow quickly in the near future, it will be necessary to develop a mechanism for the efficient use of industrial water.

Several methodologies are currently being used for the purpose of estimating the value of marginal product and price elasticity of water. Among them, the residual method has been most frequently used for estimating the value of marginal product of irrigation water used in agricultural crops. However, if there is any bias in the estimation of the value of marginal products and quantities of the other factors, estimating the magnitude of industrial water's contribution using the residual method is subject to a serious bias.

As a consequence, in order to minimize the effect of the limitations caused by this sort of bias, econometric estimation techniques can be applied to the data on the behavior of industrial water customers or the data on actual developments in the market for industrial water in order to estimate the marginal product value of industrial water. However, this method for estimating the marginal product value of water considered as an input factor in agricultural and industrial sectors is not used as frequently as the residual method. The main reason is that on the one hand, there exist no markets where water could be given price and on the other hand, it is hard to obtain secure and reliable data.

The previous research aimed at estimating the price elasticity of industrial water output was mainly based on estimates of the demand function. Another method to estimate price elasticities of industrial water is to calculate them on the basis of estimates of the cost function that includes labor, capital, industrial water and other intermediate production factors as its arguments(Renzetti, 1992; World Bank, 1995; Min, 2005; Lee, 1997).

However, in the method based on the demand function, the average price estimates are employed rather than the values of marginal prices and marginal costs themselves, which may result in biased estimates. In that case the method based on the estimates of the production function may be better suited for inferring the values of marginal product and the price elasticity of industrial water(Wang and Lall, 2001; Min, 2006).

This study analyzes three sub sectors in manufacturing: Raw material sector, Material Processing sector and Consumption goods sector. For each sector I estimate output elasticities of industrial water along with their marginal products. Using the estimated elasticities, the implicit price of water will be estimated. I use these estimates to calculate price elasticities of water in order to analyze the effects of industrial water demand management policies. Section 2 explains a theoretical model based on the Cobb-Douglas and Translog specifications of the production functions, followed by section 3 where I estimate output elasticities and marginal products of industrial water in case of both specifications. This makes it possible to arrive at estimates of water price elasticity of demand. Section 4 summarizes the findings of this study.

2. The Marginal Product and Price Elasticity of Water

This study estimates a production function using a database constructed in 2003. Based on these estimates, this study also estimates output elasticities and marginal product value of industrial water as well as its price elasticity. In order to estimate, the Cobb-Douglas and Translog specifications of the production function are employed.

The relationship between output and the production factors is specified in the following way:

$$Q = f(K, L, W, m) \tag{1}$$

where Q is the output volume, K is capital, L is labor, W is the amount of water input, and m is the intermediate input.

The Cobb-Douglas production function is specified in the following way:

$$Q = AK^{\alpha_1}L^{\alpha_2}W^{\alpha_3}m^{\alpha_4} \tag{2}$$

Taking logs of both sides in the above equation results in the following representation of our production function:

$$\text{In}Q = \text{In}A + \alpha_1\text{In}K + \alpha_2\text{In}L + \alpha_3\text{In}W + \alpha_4\text{In}m \tag{3}$$

In this equation the coefficients' estimates for each variable represents this variable's elasticity. Therefore, the coefficient of water input represents the elasticity of industrial water:

$$\alpha_3 = \frac{\partial Q/Q}{\partial W/W} \tag{4}$$

The equation below represents the Translog specification of the production function:

$$\begin{aligned}\text{In}Q = &\text{In}A + \alpha_1\text{In}K + \alpha_2\text{In}L + \alpha_3\text{In}W + \alpha_4\text{In}m \\ &+\alpha_5\text{In}K\cdot\text{In}L + \alpha_6\text{In}K\cdot\text{In}W + \alpha_7\text{In}K\cdot\text{In}m \\ &+\alpha_8\text{In}L\cdot\text{In}W + \alpha_9\text{In}L\cdot\text{In}m + \alpha_{10}\text{In}W\cdot\text{In}m \\ &+\alpha_{11}(\text{In}K)^2 + \alpha_{12}(\text{In}L)^2 + \alpha_{13}(\text{In}W)^2 + \alpha_{14}(\text{In}m)^2\end{aligned} \tag{5}$$

Differentiating the above equation by the industrial water variable (W), the value of the output elasticity of water can be inferred in the following way:

$$\varepsilon = \alpha_3 + \alpha_6\text{In}K + \alpha_8\text{In}L + \alpha_{10}\text{In}m + 2\alpha_{13}\text{In}W \tag{6}$$

By substituting the estimates of the industrial water output elasticity along with the output volume and the amount of industrial water used in the production process into the equation below, the value of the marginal product of industrial water can be estimated:

$$\rho_T = \frac{\partial Q}{\partial W} = \varepsilon(Q/W) \tag{7}$$

Assuming that the water's price is equal to its value of marginal product, equation (6) and (7) can be used in order to derive the estimates of industrial water's price elasticity.

$$\gamma_T = \frac{\partial \text{In}W}{\partial \text{In}P} = \frac{\partial \text{In}W}{\partial \text{In}\rho_T} = -\frac{\varepsilon}{\varepsilon - \varepsilon^2 - 2\alpha_{13}} \tag{8}$$

3. Empirical Results

3.1 The Data

The data comes from the comprehensive survey of Korean Manufacturing enterprises that is conducted by the Korean statistical office every five years. The data employed in this study is for the year 2003. The survey aims at enumerating the current amount of factor inputs and output levels employed in and produced by the manufacturing sectors. All monetary values in this survey were measured in millions of Korean won (approximately, in $1,000 units). In the case of the enterprises where the level of industrial water usage is smaller than one million Korean won, these levels were set to zero. This made it impossible to include the data for these enterprises in the analysis. Also excluded were those enterprises that use subterranean water or sources of water other than municipal and industrial water. In the case of water other than municipal and industrial water, the amount of water used is reported by enterprises instead of metering them. Inclusion of such data could potentially result in a serious estimation bias, so we excluded these data points from our analysis.[1]

Table 1 reports the means and standard deviations of each variable I use in the present analysis. Following the Korean central bank, we classified

1) Because of this kind of exclusion, this sample may not represent the population.

Table 1. Summary Statistics for the variables

Sector	Variable	Units	Mean	SD
Raw material Sector	Output(Q)	Billion Won	16,098	121,444
	Capital(K)	Billion Won	8,269	76,347
	Labor(L)	Number	40	157
	intermediate input(m)	Billion Won	9,054	67,021
	Water(W)	ton	83,376	957,359
	water average price	won	566	237
	Firm	Number	5,240	
Material Processing Sector	Output(Q)	Billion Won	25,740	333,600
	Capital(K)	Billion Won	11,571	184,156
	Labor(L)	Number	69	550
	intermediate input(m)	Billion Won	14,229	195,576
	Water(W)	ton	59,397	841,212
	water average price	won	561	236
	Firm	Number	5,175	
Consumption Good Sector	Output(Q)	Billion Won	4,682	17,964
	Capital(K)	Billion Won	1,977	10,590
	Labor(L)	Number	28	66
	intermediate input(m)	Billion Won	2,210	8,530
	Water(W)	ton	41,876	217,099
	Water average price	won	593	229
	Firm	Number	6,797	

enterprises into three categories as follows: raw material goods sector, material processing sector and consumer goods sector. As demonstrated by Table 1, firms in the raw material goods sector and firms in the materials processing on average produce 16.1 and 25.7 billion wons' worth of output, which differs significantly from the value of 4.7 billion won for the consumer goods enterprises. However, the consumer goods sector enterprise uses 41,876 tons of industrial water on average, which is about 70% of industrial water used by the materials processing manufacturing. The raw material goods sector used the largest amount of industrial water of all three sectors at 83,376 tons. Since the data for this survey spans large-, medium- and small-sized enterprises, the standard deviation of each variable we employ is rather large.

3.2 Estimation

This study used the cross-section analysis based on the cross section data. In order to eliminate the effect of different regions and industries, the dummy variables for region and sub-manufacturing sector are included for each production function specification. The independent variables include capital, intermediate inputs, labor and the amount of industrial water employed in the production process.[2)]

Table 2~4 present the results of our estimates of the relationship between the dependent and independent variables according to the two specifications of the production function in three sectors. The estimated values of the coefficients for the input factors in case of the Cobb-Douglas production function are equal to the corresponding output elasticities. The magnitude of those estimates appears to be similar for the same inputs across the three manufacturing sectors in this study. Output elasticity of the intermediate inputs is estimated to be the highest compared to output elasticities of the other factors. That is, the output elasticity of the inter-

2) Based on the assumption of the no price discrimination of any goods, this paper use money value instead of quantity variable in the production function. In addition, I assume that the quality of labor over the industries are the same.

Table 2. Estimations for Raw Material Sector

Dependent variable: Ln Q	Cobb-Douglas	Translog
Ln K	0.0494(12.20)***	-0.0380 (-1.62)**
Ln L	0.3810 (46.13)***	0.8697 (20.71)***
Ln W	0.0354 (8.9)***	0.0943 (3.29)
Ln m	0.6125 (134.61)***	0.2900 (11.86)***
Ln K*Ln L		0.0056 (0.85)**
Ln K*Ln W		-0.0042 (1.24)*
Ln K*Ln m		-0.0141 (-4.45)***
Ln L*Ln W		-0.0025 (-0.39)
Ln L*Ln m		-0.1596 (-22.01)***
Ln W*Ln m		-0.0129 (-3.79)
Ln K*Ln K		0.0109 (5.17)***
Ln L*Ln L		0.0965 (11.67)***
Ln W*Ln W		0.0001 (0.03)
Ln m*Ln m		0.0740 (29.16)***
Adj R2	0.9589	0.9681
F statistic	5,500.48***	4,824.11***
SSR	556.04	444.68
No. of data points	5,240	

Note: ( ) is t-value.
*** significant at 0.01 significance, ** 0.05 significance, * 0.1 significance

Table 3. Estimations for Material Processing Sector

Dependent variable: Ln Q	Cobb-Douglas	Translog
Ln K	0.0504 (12.54)***	0.0811 (3.02)**
Ln L	0.4136 (48.30)***	0.7121 (14.64)***
Ln W	0.0333 (7.18)***	-0.0043 (-0.12)*
Ln m	0.5646 (118.26)***	0.2861 (9.94)**
Ln K*Ln L		0.0244 (3.88)***
Ln K*Ln W		-0.0105 (-2.82)
Ln K*Ln m		-0.0188 (-5.64)*
Ln L*Ln W		0.0250 (3.49)
Ln L*Ln m		-0.1528 (-22.42)***
Ln W*Ln m		-0.0146 (-3.52)***
Ln K*Ln K		0.0099 (4.83)**
Ln L*Ln L		0.0511 (6.28)***
Ln W*Ln W		0.0069 (2.60)***
Ln m*Ln m		0.0759 (30.37)***
Adj R^2	0.9542	0.9622
F statistic	26,285.00***	3,766.23***
SSR	581.8607	479.2567
No. of data points	5,175	

Note: ( ) is t-value.
*** significant at 0.01 significance, ** 0.05 significance, * 0.1 significance

Table 4. Estimations for Consumption Goods Sector

Dependent variable: Ln Q	Cobb-Douglas	Translog
Ln K	0.0480 (11.97)***	0.0007 (0.04)
Ln L	0.4439 (52.06)***	0.9514 (24.16)***
Ln W	0.0064 (1.50)*	0.0889 (2.93)**
Ln m	0.5740 (139.59)***	0.1685 (7.96)***
Ln K*Ln L		0.0064 (1.21)***
Ln K*Ln W		0.0082 (2.98)
Ln K*Ln m		-0.0191 (-7.66)***
Ln L*Ln W		-0.0156 (-2.93)
Ln L*Ln m		-0.1546 (-29.50)***
Ln W*Ln m		-0.0019 (-0.61)***
Ln K*Ln K		0.0061 (3.55)***
Ln L*Ln L		0.0884 (12.92)***
Ln W*Ln W		-0.0036 (-1.75)
Ln m*Ln m		0.0818 (44.90)***
Adj R^2	09296	0.9503
F statistic	3,451.82***	3,607.75***
SSR	1,085.1961	765.4141
No. of data points	6,797	

Note: ( ) is t-value.
*** significant at 0.01 significance, ** 0.05 significance, * 0.1 significance

mediate inputs is the highest in the raw material sector 0.6125, followed by 0.5740 in the consumption goods sector and 0.5646 in the material processing sector. The second largest value of output elasticity pertains to the labor input with the estimates of 0.4439 for the consumption goods production, 0.4136 for the material processing sector and 0.3810 for the raw material goods sector. In contrast, the estimates of output elasticities for industrial water are much smaller. The output elasticity of industrial water appears to be relatively high in the raw material sector at an estimated 0.0354 compared to the value of 0.0333 in the processing material sector. The estimated t-values for those two elasticities are 8.9 and 7.18 respectively, both being statistically significant. The lowest estimated output elasticity for industrial water is estimated at 0.0064 in the consumer goods sector with the associated t-value of 1.50 corresponding to the 10% significance level.

We employ equation (5) in order to compute the value of water's output elasticity for Translog specification of the production function. The value of output elasticity of water is estimated at 0.0274 for the raw materials sector and 0.0235 for the material processing sector. These values are lower compared to the value obtained with the Cobb-Douglas specification. In contrast, the Translog specification-based estimate of 0.0192 for the consumption goods sector marginally exceeds the Cobb-Douglas one which is the lowest in magnitude across the three sectors.

Based on the estimates of the two specifications of the production function, I test the hypothesis of linear homogeneity that states the sum of the estimated output elasticities for the Cobb-Douglas specification has to be equal to unity by means of the F-test. The estimated values of the F-statistic are 1957.07 for the raw materials sector, 952.77 for the material processing sector and 2322.90 for the consumption goods sector, all of which allow me to reject the hypothesis of homogeneity at 1% significance level.

In order to infer if it is the Cobb-Douglas or Translog production function specification that represents the production technology in the most appro-

Table 5. Value of marginal product and Price Elasticity

	VMP(won/ton)	Price Elasticity
Raw Material Sector	5,286	-1.04
Material Processing Sector	10,188	-2.55
Consumption Goods Sector	2,144	-0.74
Industry-Wide	5,794	-0.84

priate way, I tested the hypothesis of all additional coefficients in the Translog specification to be jointly zero. The F-statistics for this test are estimated to be equal to 130.86 in case of the raw materials sector, 110.47 for the material processing sector and 283.34 in case of the consumption goods sector, rejecting the hypothesis at the 1% significance level in all three cases. Therefore, compared to the Cobb-Douglas specification that imposes stronger restrictions on the production technology, the Translog specification appears to be representing the production technology more accurately.

Table 5 shows estimates of the marginal product and price elasticity by sectors of manufacturing based on the Translog production function. It appears that the value of the marginal product differs significantly across the manufacturing sectors. The value of the marginal product of industrial water per one ton is estimated to be 5,794 Korean won industry-wide. In the case of the raw material sector, it is 5,286 Korean won, while the consumption goods sector appears to suffer the lowest value of 2,144 Korean won. Surprisingly, in material processing firms where consumption of industrial water is rather small compared to output, the value of the marginal product of water is estimated to be the highest at 10,188 Korean won per one ton.

Using our estimates of the Translog production function specification and substituting the derived output elasticities and consumption levels of industrial water into equation (8) I arrive at the estimates of price elasticities of the water, which are -1.04 for the raw materials sector, -2.55 for the material processing sector, -0.74 for the consumption goods sector and -0.84 for the whole industry. The estimate for the whole industry slightly exceeds the value of -0.67 estimated by Min (2005). In that study the author had to approximate the marginal price with the average price of water for lack of data availability, which resulted in some bias in the estimates. Using the methodology developed in this study circumvents the constraints imposed by the data availability.

4. Conclusion

This study estimated the values of the marginal product and of the price elasticities of industrial water for Korea. These estimates are important for designing a policy of efficient water resource management since no systematic research has been conducted in this area so far in Korea. The calculations were based on the estimates of the Cobb-Douglas and Translog production function specifications. This study shows that the more general Translog specification represents the production technology more properly than the more restrictive Cobb-Douglas specification. The material processing sector that employs relatively little industrial water compared to its total output is characterized by the highest value of the marginal product of water. The consumption goods sector is estimated to have the lowest value marginal product of water. If there is a need to allocate water for lack of water resources one can use estimates of the value marginal product of industrial water for each sector in order to design a policy of efficient water distribution.

Under the assumption that the price of industrial water is equal to its marginal product, the price elasticities of water by sectors of manufacturing were estimated based on the production function. In the case of the methodology based on the demand function, a marginal price data set is needed to calculate price elasticities. However, average price is usually used as an alternative to estimate price elasticities since it is difficult to get marginal data for each firm. Then, the estimates from the methodology based on the demand function may be biased. In this case, the methodology applied in this study can serve as a sound alternative.

The results of our study indicate that the value of marginal product of water is higher than the water's average price, so we believe it is both necessary and appropriate to raise the price level of water to the level that corresponds to its productivity. Until now, in order to spur the industrial activity, to avoid social unrest and for the sake of price stability the Korean Government has been keeping the price of water below its average production cost by extending subsidies. However, such a policy violated the beneficiary-pays principle bringing about inefficient practices of water consumption. This will exacerbate the problem of water shortages in the future.

From the estimates of price elasticities of industrial water obtained in this study, I suggest that the Government can achieve a reduction in the demand for water by raising the water price, thus solving the problem of inefficient practices of water consumption. For that purpose, in accordance with the beneficiary-pays principle, the price of industrial water should be raised to the level that reflects the average social cost incurred in the process of industrial water production.

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