# The economic value of water in Korean manufacturing industry

Se Ju Ku*, Seung Hoon Yoo**

## Abstract

It is quite important for manufacturing firms to stably secure water, because industrial water is used for a variety of purposes as one of the important inputs in the production process. Despite the significance of industrial water use and the increase of industrial water demand, relatively little has studied regarding the industrial water use in Korea.

This paper employs the marginal productivity approach in order to estimate the economic value of water in Korean manufacturing industry, and we use the information of 53,912 factories surveyed in 2003. The result of the likelihood ratio test shows that Trans-log is an appropriate model for estimating the data of this study. In Trans-log function model, the industry-wide output elasticity of water is 0.0104, and the marginal value is KRW 1,156 per ton. The estimated values differ across the sectors and these values range from the high value of about KRW 13,760 per ton in the transportation equipment sector to low values of KRW 428 per ton in the precision instrument sector.

The research provides useful information to help policy-makers in developing and implementing more appropriate policies regarding the management and distribution of water resources by estimating the value of water resources by sector. In addition, Korean government enables the drafting of future water pricing scenarios based on the estimated value information.

Key words: Industrial water, Economic value, Marginal productivity approach

## 1. Introduction

Manufacturing firms use water for a variety of purposes. First, it can be used for cleansing and transporting intermediate inputs as well as inclusion in final output (the production of food and beverage). Second, water can be used to cool intermediate inputs (the production of petroleum-based fuels). Third, water is used for a variety of miscellaneous purposes such as plant cleaning and personal sanitation (Dupont and Renzetti, 2001). Therefore, it is quite important for manufacturing industries to stably secure water.

In the case of Korea, future industrial water use is expected to rise substantially as industrial development continues. The demand of it is 2.60 billion ton per year in 2003 and expected to be 3.56 billion ton in 2016. However, despite the significance of industrial water use and the increase of industrial water demand, relatively little has studied regarding the industrial water use in Korea. Also, until recently, the value of industrial water has not been estimated separately with the value of residential water, even though the value of industrial water is different from that of residential water. It is because that it is difficult to obtain the data available to estimate demand equations, and the price of water is under control by

* 정회원 · 고려대학교 경제학과 박사과정 · E-mail : heroseju@korea.ac.kr
** 정회원 · 호서대학교 사회과학대학 해외개발학과 교수 · E-mail : shyoo@hosed.edu

government and there has a limit to apply demand function approach. Moreover, the cost of water is relatively lower than those of other input factors in Korean firms, so the industrial water is of little interest than residential water. To plan, develop and manage the water resources projects, it is needed to estimate the exact value of industrial water using the information of water consumption and cost in the production process.

This paper employs the marginal productivity approach in order to estimate the economic value of water in Korean manufacturing industry. We use the information of 53,912 factories surveyed in 2003, and consider Cobb-Douglas production function and Trans-log production function.

## 2. Model

### 2.1 Cobb-Douglas function Model

A marginal productivity function of water can be developed by taking a routine derivative of a production function. A production function can be constructed as $Q=f(K,L,W,M)$ where $Q$ is production or output, $K$ is capital, $L$ is labor, $W$ is water, and $M$ is intermediate inputs. The marginal productivity of water then is $\partial Q/\partial W$ .

To be specific, a production function with capital, labour, water, and materials as inputs can be specified as:

$$\ln Q = \ln A + \alpha_1 \ln L + \alpha_2 \ln W + \alpha_3 \ln M + \alpha_4 \ln K \qquad (1)$$

The elasticity of production with respect to each factor of production is calculated by taking the partial derivative of output with respect to the factor under consideration. For the water case, the elasticity can be derived as:

$$\varepsilon_{CD} = \frac{\partial Q / Q}{\partial W / W} = \alpha_2 \qquad (2)$$

The marginal productivity of water in industrial production then is:

$$\rho_{CD} = \partial Q / \partial W = \varepsilon_{CD} \cdot (Q / W) \qquad (3)$$

### 2.2 Trans-log function Model

After taking logarithms of both sides of the Cobb-Douglas production and the second-order of Taylor's expansion, Trans-log function is as follows.

$$\begin{aligned} \ln Q &= \ln A + \alpha_1 \ln L + \alpha_2 \ln W + \alpha_3 \ln M + \alpha_4 \ln K + \alpha_5 \ln L \ln W + \alpha_6 \ln L \ln M \\ &+ \alpha_7 \ln L \ln K + \alpha_8 \ln W \ln M + \alpha_9 \ln W \ln K + \alpha_{10} \ln M \ln K + \alpha_{11} (\ln L)^2 + \alpha_{12} (\ln W)^2 \\ &+ \alpha_{13} (\ln M)^2 + \alpha_{14} (\ln K)^2 \end{aligned} \qquad (4)$$

Eq. (5) is derived by taking partial differentiation of Eq. (4), and we can estimate the productivity elasticity of water.

$$\varepsilon_{TL} = \frac{\partial Q / Q}{\partial W / W} = \alpha_2 + \alpha_5 \ln L + \alpha_8 \ln M + \alpha_9 \ln K + 2\alpha_{12} \ln W \quad (5)$$

Using $\epsilon_{TL}$ in Eq. (5), the marginal productivity of water in industrial production is like this.

$$\rho_{TL} = \partial Q / \partial W = \varepsilon_{TL} \cdot (Q / W) \quad (6)$$

## 3. Empirical Study

### 3.1 Data

The data used in this paper is Industrial Census (IC) conducted by Korean National Statistical Office every 5 years. We used IC 2003 which is the latest data available now. The IC 2003 includes the information of 113,297 Korean manufacturing firms. However, we used the information of 53,912 firms for the analysis; because the survey unit is 100 million Korean won, and too many companies have zero responses (The zero value means that the value is less than 100 million Korean won, but the exact values are not presented on the survey). So, we excluded companies which responded zero value of variables used in this study. Table 1 presents descriptive statistics on the variables used in the models.

Table 1. Variables for empirical analysis

| Variables | Attribute | Mean | S.D. |
|---|---|---|---|
| Q | Total value-added (Unit: billion Korean won) | 3,073 | 61,361 |
| L | Average number of workers employed (Unit: people) | 31 | 224 |
| K | Value of fixed assets at the end of the year (Unit: billion Korean won) | 3,469 | 67,886 |
| M | Total intermediate input (Unit: billion Korean won) | 5,043 | 89,038 |
| W | Total amount of industrial water consumed (Unit : ton) | 27,581 | 436,687 |

Also, we classified 11 industries to compare with value of industrial water among industries; Food and beverage & tobacco, Textile apparel & leather, Wood, paper & publishing, Petroleum refining, Non metallic mineral & primary industry, General machinery, Electrical apparatus, Electronic & communication equipment, Precision instrument, Transport equipment, and Furniture & other manufacturing. This industry classification is based on the Korean water plan by Ministry of Land, Transport and Maritime Affairs.

### 3.2 Estimation

The industry wide estimation results of two models are presented in Table 2. All the parameters in the Cobb-Douglas function model are statistically significant at the 1% level.

Labor, capital, intermediate input, and water all have positive significant elasticity. Adjusted $R^2$ is 0.84, which means that 84% of the total variation in the dependent variable accounted for by the explanatory variables. In the Trans-log function model, all coefficients, except for $\ln K$ and $\ln K \ln W$, are statistically significant at the 1% level. Adjusted $R^2$ is 0.86, which is higher than those in Cobb-Douglas model. In addition, the computed F-statistics are large enough to reject the null hypothesis that all coefficients are zero in both of two models.

In the case of Cobb-Douglas function model, the industry-wide average output elasticity of water is 0.0196, and the marginal value of the Korean manufacturing industry is KRW 2,182 per ton. In Trans-log function model, the industry-wide output elasticity of water is 0.0104, and the marginal value is KRW 1,156 per ton, a little bit lower than the result of Cobb-Douglas model.

Table 2. Estimation results

| | Cobb-Douglas function | | | Trans-log function | | |
|---|---|---|---|---|---|---|
| | Coefficient | $t$-value | $p$-value | Coefficient | $t$-value | $p$-value |
| $A$ | 2.1190 | 193.830 | 0.000 | 2.4905 | 80.609 | 0.000 |
| $\ln L$ | 0.6981 | 184.291 | 0.000 | 0.9577 | 59.978 | 0.000 |
| $\ln K$ | 0.0630 | 35.303 | 0.000 | -0.0125 | -1.445 | 0.148 |
| $\ln M$ | 0.2956 | 155.670 | 0.000 | 0.0545 | 6.522 | 0.000 |
| $\ln W$ | 0.0196 | 12.481 | 0.000 | 0.0296 | 4.726 | 0.000 |
| $\ln L \ln L$ | | | | 0.0238 | 6.364 | 0.000 |
| $\ln K \ln K$ | | | | 0.0114 | 12.235 | 0.000 |
| $\ln M \ln M$ | | | | 0.0567 | 59.865 | 0.000 |
| $\ln W \ln W$ | | | | 0.0010 | 2.137 | 0.000 |
| $\ln L \ln K$ | | | | 0.0202 | 7.194 | 0.000 |
| $\ln M \ln L$ | | | | -0.1069 | -38.176 | 0.000 |
| $\ln L \ln W$ | | | | 0.0089 | 3.755 | 0.000 |
| $\ln K \ln M$ | | | | -0.0128 | -9.653 | 0.000 |
| $\ln K \ln W$ | | | | -0.0018 | -1.559 | 0.119 |
| $\ln M \ln W$ | | | | -0.0065 | -5.239 | 0.000 |
| Adj $R^2$ | 0.84 | | | 0.86 | | |
| F-statistic | 70,240.30 | | 0.00 | 22,758.20 | | 0.00 |
| $\sigma$ | 2,181.62 | | | 1,156.12 | | |
| $\rho$ | 0.0196 | | | 0.0104 | | |

Generally, Trans-log function is preferred to Cobb-Douglas function, because Cobb-Douglas function is too restrictive and Trans-log function is a more general form of production function (Christensen et al., 1973). To test whether the application of the Cobb-Douglas production function are reliable for this study, a likelihood ratio test is carried out. The likelihood ratio test statistic asymptotically follows a chi-square distribution with ten degree of freedom. As a result of the likelihood ratio test, we can reject the null hypothesis that there is no difference between two models. Therefore, it is clear that Trans-log function which is a generalization of the Cobb - Douglas production function is an appropriate model for estimating the data of this study.

Results presented in Table 3 show large variations in the marginal value of water across sectors. In Trans-log function model, these values range from the high value of about KRW 13,760 per ton in the transportation equipment sector to low values of KRW 428 per ton in the precision instrument sector.

Table 3. Marginal value of water by sector

| | Cobb-Douglas function | | Trans-log function | |
|---|---|---|---|---|
| | Elasticity of water | Marginal value of water (KRW/ton) | Elasticity of water | Marginal value of water (KRW/ton) |
| Industry Wide | 0.0196 | 2,181.62 | 0.0104 | 1,156.12 |
| Food and beverage & tobacco | 0.0188 | 1,321.49 | 0.0080 | 562.92 |
| Textile apparel & leather | 0.0156 | 746.10 | 0.0172 | 821.49 |
| Wood, paper & publishing | 0.0220 | 2,520.02 | 0.0144 | 1,644.95 |
| Petroleum refining | 0.0287 | 2,024.78 | 0.0115 | 809.51 |
| Non metallic mineral & primary industry | 0.0415 | 3,870.20 | 0.0482 | 4,489.69 |
| General machinery | 0.0162 | 4,191.74 | 0.0067 | 1,735.23 |
| Electrical apparatus | 0.0240 | 5,199.92 | 0.0122 | 2,637.73 |
| Electronic & communication equipment | 0.0106 | 1,604.99 | 0.0110 | 1,672.53 |
| Precision instrument | 0.0121 | 3,176.11 | 0.0016 | 427.59 |
| Transport equipment | 0.0402 | 14,965.12 | 0.0369 | 13,760.12 |
| Furniture & other manufacturing | 0.0353 | 6,774.15 | 0.0250 | 4,810.50 |

## 4. Concluding remarks

This study estimates the value of marginal product, output elasticity of the industrial water using the Cobb-Douglas function and Trans-log production function. The result of the likelihood ratio test shows that Trans-log is an appropriate model for estimating the data of this study. In Trans-log function model, the industry-wide output elasticity of water is 0.0104, and the marginal value is KRW 1,156 per ton. The estimated values differ across the sectors and these values range from the high value of about KRW 13,760 per ton in the transportation equipment sector to low values of KRW 428 per ton in the precision instrument sector.

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