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The effects of subsidies on the cost structure of Japanese water supply organizations

by

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The effects of subsidies on the cost structure of Japanese water supply organizations

[Abstract] The purpose of this study is to identify the effects of subsidies on the cost structure of Japanese water supply organizations by estimating the translog cost function. Geographical conditions, such as network density and water sources, are also controlled in this model. The empirical results indicate that low network density, lack of own water sources and increasing subsidies lead to higher costs. It has also been found that subsidies have caused wasteful use of labor, capital and other input factors, and have diminished scale economies.

[JEL Classification] **L95 , L11**

[Key Words] **water supply organization, subsidy, translog cost function**

1. Introduction

Recognizing the role of adequate safe water supplies in society, Japan has been developing water supply systems throughout the country since 1887 when the first modern water works was introduced. At first, the objective of water supply was to supply safe drinking water for preventing epidemics of cholera and typhoid fever, and a later objective was to provide water for fire fighting. At that time, the Japanese government decided that the ownership of water supply organizations should go to local governments for the purpose of carrying out the aforementioned objectives, so now a great portion of water needed in

urban areas has been supplied by public water utilities.

It is the general principle that water supply finance should be self-supported in Japan, but on the other hand the national subsidy has been given for water resources development, reorganization of water supply bodies, sludge treatment facilities at purification plant and small water supply systems based on the government subsidizing criteria.

The necessity of this large amount of subsidies is mainly because of geographical conditions in Japan. Due to environmental and geographical constraints, water utilities have had to adapt to various situations. For example, a water supply system composed of water production facilities and transmission facilities has to obtain water from various sources such as surface water, groundwater and so on. And to make matters worse, the construction cost of these facilities has been getting higher. Consumers, however, can't afford these costs, so the government subsidizes the water utilities that in turn have to bear the burden.

Over the past few decades a considerable number of studies have tried to measure some economic indices for water supply organizations using the cost function approach, but unfortunately almost all of them have failed to account for subsidies, water sources and other geographical conditions.

The purpose of this study is to identify the effects of subsidies on the cost structure of Japanese water supply organizations by estimating the translog cost function. Geographical conditions, such as network density and water sources, are also controlled in this model.

This article is organized in the following manner: Section 2 describes an overview of the Japanese water industry. Section 3 and 4 presents the method and data of our analysis. Section 5 presents the results of our analysis. Concluding remarks are summarized in Section 6.

2. An Overview of the water industry

Because of geographical and historical restrictions, it has become difficult for Japanese water utilities to get water sources. Table 1 shows variations of sources of water supply with different ownership. In Japan, almost all of the water supply systems are owned by a municipal government such as prefecture, city, town and village, and some are jointly owned by municipal governments. Water companies in Japan obtain their water mainly from surface water (dam and non-dam) and well. If they don't have their own water sources, they must buy from other water companies or wholesale agencies. As we can see from Table 1, up to 60 % of water utilities owe their water to mixed sources.

Furthermore, the construction costs of assets of water supply systems are very high and consumers can't afford to bear these costs as water charges. Therefore, water utilities have received large amount of subsidies from the government. Table 2 shows the criteria of governmental subsidizing.

Table 1 Number of water supply systems for different water sources in FY2000							
		Water sources					
		Purchased water	Surface water (non-dam)	Surface water (dam)	Well	Mix	Total
Ownership	Prefecture	0	0	0	0	4	4
	City	41	22	5	103	423	594
	Town and Village	102	78	10	409	623	1,221
	Joint	9	9	2	11	47	78
	Total	152	109	17	523	1,097	1,898
(Source): Annual Statistics of Local Public Corporations							
(Note):							
(1)Mix means water companies which obtain water from a combination of surface water (non-dam), surface water (dam) and well.							
(2)Joint means a water company which is jointly owned by some municipal governments.							

Table 2 Governmental Subsidies to Construction Works	
Subsidized Works for Construction	Subsidy Rate
Water Resources Facilities	1/3, 1/2
Regional Water Works Facilities	1/4, 1/3
Advanced Purification Facilities	1/4, 1/3
Water Storage Facilities for Emergency	1/3
Sludge Treatment Facilities	1/4
Equipment at Regional Laboratories	1/4
Modernization of pipe systems	1/3, 1/4
Small Scale Water Supply Systems	1/4, 1/3, 4/10
(Source): Japan's water works yearbook 2003/2004	

We also believe that these geographical and environmental constraints cause higher costs to water utilities. Table 3 shows the cost of water supply according to water sources.

Table 3 Cost of water supply according to water sources			
Main water sources	More than average of density of delivered water	Less than average of density of delivered water	average
dam	203.30 (47)	216.03 (82)	204.15 (129)
purchased	184.46 (207)	224.03 (323)	192.51 (530)
surface	165.53 (87)	194.01 (249)	174.23 (336)
other sources (groundwater, etc.)	139.54 (239)	164.57 (666)	150.75 (905)
total	180.04 (580)	192.02 (1,320)	182.92 (1,900)
(Source): Management indices of water utilities, FY2001.			
(Note): Number in the parentheses show the number of water utilities			

We can see from this table that the costs of water are different among different water sources. It indicates that the ground water and surface water have cost advantages, whereas dam water and purchased water have cost disadvantages. The reason for this is that the construction costs of water resource's assets and purifying costs from dam water

and purchased water might be higher than that of ground water and surface water.

From this discussion, it is natural to assume that due to different water sources and network density conditions water utilities are burdened by high production costs, so it is possible that water sources and network density would affect the cost structure of water supply organizations. To analyze this, we apply the cost function approach and investigate the influences of cost with respect to subsidy, water sources and network conditions.

3. Methodology

3.1 Cost function

The functional form of the cost function is specified as translog cost model. We specify the cost function as a long run cost function with control variables (subsidy, network density and water sources). The model is as follows:

$$\begin{aligned}
\ln C = & \alpha_0 + \alpha_Q(\ln Q) + \sum_i \beta_i(\ln P_i) + \gamma_S(\ln \text{Sub}) + \sum_k \delta_k(\ln Z_k) \\
& + 1/2 \alpha_{QQ}(\ln Q)(\ln Q) + 1/2 \sum_i \sum_j \eta_{ij}(\ln P_i)(\ln P_j) \\
& + 1/2 \gamma_{SS}(\ln \text{Sub})(\ln \text{Sub}) + 1/2 \sum_k \sum_l \theta_{kl}(\ln Z_k)(\ln Z_l) \\
& + \sum_i \lambda_{Qi}(\ln Q)(\ln P_i) + \mu_{QS}(\ln Q)(\ln \text{Sub}) + \sum_k \mu_{Qk}(\ln Q)(\ln Z_k) \\
& + \sum_i \eta_{iS}(\ln P_i)(\ln \text{Sub}) + \sum_i \sum_k \pi_{ik}(\ln P_i)(\ln Z_k) \\
& + \sum_k \rho_{Sk}(\ln \text{Sub})(\ln Z_k)
\end{aligned} \tag{1}$$

where C , total costs; Q , amount of water delivered(thousand square meter); P_i , input factor price(i (or j) = L (labor), K (capital), O (other)); Sub , subsidy; Z_k , control variables(k (or l) = Den (network density), Sou (water sources)).

In this model, we also impose restrictions on input factor prices such that $\sum_i \beta_i = 1$, $\sum_i \lambda Q_i = 0$, $\sum_j \eta_{ij} = 0$, $\sum_i \mu_i S = 0$, $\sum_i \eta_{ik} = 0$. Furthermore, we apply Shepherd's Lemma from equation (1) and obtain the input share equations:

$$S_i = \beta_i + \lambda Q_i(\ln Q) + \sum_j \eta_{ij}(\ln P_j) + \mu_i S(\ln Sub) + \sum_k \eta_{ik}(\ln Z_k) \quad (2)$$

where S_i , input i 's share of cost function.

3.2 Some Economic Indices

We can get some economic indices from the parameter estimates of the cost function.

Firstly, we can get the return to scale measure (RTS) as follows:

$$\begin{aligned} RTS &= 1/(\partial \ln C / \partial \ln Q) \\ &= 1/\{\alpha_Q + \alpha_{QQ}(\ln Q) + \sum_i \lambda Q_i(\ln P_i) + \mu_Q S(\ln Sub) + \sum_k \eta_{Qk}(\ln Z_k)\} \end{aligned} \quad (3)$$

Secondly, we can get the cost elasticity of subsidy (ϵ_{ch}) as follows:

$$\begin{aligned} \epsilon_{ch} &= \partial \ln C / \partial \ln Sub \\ &= \gamma_S + \gamma_{SS}(\ln Sub) + \mu_Q S(\ln Q) + \sum_i \mu_i S(\ln P_i) + \sum_k \eta_{Sk}(\ln Z_k) \end{aligned} \quad (4)$$

Thirdly, we can get the elasticity of demand for the j th factor with respect to subsidy as follows:

$$\begin{aligned}\epsilon_{iS} &= \partial \ln X_i / \partial \ln \text{Sub} \\ &= \epsilon_{CS} + \eta_{iS}/S_i\end{aligned}\tag{5}$$

Finally, we can get the elasticity of scale economies with respect to subsidy as follows:

$$\begin{aligned}\epsilon_{RTSS} &= \partial \ln RTS / \partial \ln \text{Sub} \\ &= -\rho_{QS} \cdot RTS\end{aligned}\tag{6}$$

4. Data

All of the data used in this study were collected from *The Yearbook of Public Firms*, (*Chihou Kouei Kigyo Nenkan, in Japanese*), edited by Research Association of Local Public Firm Management (Chihou kouei Kigyou Keiei Kenkyu Kai, in Japanese) . It reports quantitative and financial data for all of the municipal water utilities in Japan. The total number of observation is 1,803 in FY2001.

The variables used for the estimation of the total cost function are shown in Table 4 and defined as follows: Total cost (C) is the sum of labor, capital, and other costs. As for

output measure, we use the annual total amount of delivered water (Q). We define three kinds of input factor prices. Firstly, labor price (P_L) is defined as the average annual salary per employee. Secondly, capital price (P_E) is obtained by the sum of depreciation expenditures divided by the depreciation assets and interest expenditures divided by the amount of corporate loans. Finally, the price of other costs (P_O), such as chemicals, purchase of water, and tax payments is 1 as a numeraire.

We define three control variables. Firstly, subsidy (Sub) is defined as the sum of national subsidy and prefectural subsidy. Secondly, network density (Den) is defined as the length of pipeline divided by population served. Finally, water source (Sou) is defined as purchased water ratio.

Table 4 Definition and statistics on variables used for the estimation of cost function						
Variable	Definition	Unit	Mean	Standard Deviation	Minimum	Maximum
C (Total cost)	Sum of labor, capital and other costs	million yen	1,369	8,614	29	310,980
Q (Output)	Annual delivered water	thousand squared meter	8,481	46,517	199	1,655,555
PL (Wage of driver)	Average annual salary per employee	yen / employee	7,380	1,515	1,919	14,001
P_K (Capital price)	Sum of depreciation costs per assets and interest cost per corporate loans	-	7.063	1.223	0.883	14.396
Sub (subsidy)	Sum of national subsidy and prefectural subsidy	million yen	30	118	0	2,760
Den (network density)	Pipeline length per population	Km / population	8.555	4.834	0.074	64.927
Sou (water source)	Purchased water ratio	-	0.260	0.351	0.000	1.000

5. Results

The results for the estimation of cost function are shown in Table 5. The estimation method is the SUR (Seemingly Unrelated Regressions) for the cost model with

input share equations. The goodness-of-fit in this regression (0.919) is acceptably high for this model. The estimated cost model meets almost all of the required properties. Firstly, symmetry and homogeneity in input factor prices are satisfied because restrictions are imposed on input factor prices. The monotonicity and the concavity conditions in the cost model are satisfied at least locally. The first-order coefficients in the cost model show the correct sign.

Table 5 Estimation Results of the Cost Function					
parameter	estimate	t-statistic	parameter	estimate	t-statistic
α_0	14.034	568.523	π_{LS}	-0.0001	-1.109
α_Q	0.906	49.956	π_{LDen}	-0.030	-7.957
β_L	0.133	40.994	π_{LSou}	-0.004	-22.085
β_K	0.389	66.521	η_{KK}	0.052	3.644
β_O	0.478	86.981	η_{KO}	-0.001	-0.062
γ_S	0.055	6.570	π_{KS}	0.0005	2.283
δ_{Den}	0.074	1.821	π_{KDen}	0.063	9.147
δ_{Sou}	0.099	8.104	π_{KSou}	-0.010	-26.685
α_{QQ}	0.074	6.325	η_{OO}	0.077	4.677
λ_{QL}	-0.005	-2.923	π_{OS}	-0.0004	-1.779
λ_{QK}	0.008	2.866	π_{ODen}	-0.032	-5.017
λ_{QO}	-0.004	-1.322	π_{OSou}	0.014	41.522
μ_{QS}	-0.001	-0.825	γ_{SS}	0.004	6.404
μ_{QDen}	-0.067	-3.522	ρ_{SDen}	-0.0002	-0.139
μ_{QSou}	-0.001	-0.743	ρ_{SSou}	-0.0003	-3.537
η_{LL}	0.127	19.808	θ_{DenDen}	0.049	1.779
η_{LK}	-0.052	-7.592	θ_{DenSou}	-0.005	-1.644
η_{LO}	-0.076	-9.492	θ_{SouSou}	0.011	6.737

The coefficients of subsidy and purchased water ratio show 0.055 and 0.099 and are statistically significant at 1%, indicating that subsidy and purchased water ratio lead to higher costs. The coefficient of network density, however, shows 0.074 and is not statistically significant.

The estimation results of return to scale, and elasticity of input factors and return to scale with respect to subsidy defined in previous section are shown in table 6.

Table 6 Return to scale, and elasticity of input factors and return to scale with respect to subsidy		
Economic index	estimate	t-statistic
RTS	1.104	49.956
ε_{CS}	0.055	6.570
ε_{LS}	0.054	6.430
ε_{KS}	0.056	6.695
ε_{OS}	0.054	6.478
ε_{RTSS}	0.0005	0.829

The estimate of the return to scale measure is 1.104 and is statistically significant at 1%, indicating increasing return to scale at sample mean. The estimates of the cost elasticity of subsidies are from 6.430 to 6.695 and are statistically significant at 1%, indicating that the introduction of subsidies is a wasteful use of resources. The estimate of the elasticity of return to scale with respect to subsidy is 0.0005, but is not statistically significant.

6. Concluding Remarks

Water utilities in Japan have faced difficult situations due to geographical and environmental constraints. For this reason, water utilities have received a large amount of subsidies from the government. Our main question is whether or not the introduction of subsidies causes a wasteful use of resources.

In our analysis, we estimate the cost function of water utilities. Based on our analytical results, we conclude that low network density, lack of own water sources and increasing subsidies lead to higher costs. It has also been found that subsidies have caused wasteful use of labor, capital and other input factors, and have diminished scale economies.

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