Identifying scale economies for different types of water supply organizations in Japan

by

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[Abstract] Although water supply systems include activities such as water intake; water purification; and water distribution, many water supply organizations are not always equipped with all three activities. In fact, Japan has two types of water companies: one that operates water intake and water purification (Type 1); and the other which mainly operates water distribution (Type 2). Many previous studies have attempted to identify scale economies for water supply organizations, but have failed to take into account which water supply systems operate. In this analysis we categorize Japanese water supply organizations into three types: Type 1 - which operates water intake and water purification; Type 2a - which not only operates water distribution, but also operates water intake and water purification; and Type 2b - which operates water distribution, but purchases water from type 1 companies. After that, we estimate scale economies for each type of water supply organization using the translog cost function. Furthermore, we take into account their water sources, especially Type 1 and Type 2a, because we consider that differences of water sources might affect the cost structure of water supply systems.

[JEL Classification] L95, L11

[Key Words] water supply systems, translog cost function, scale economy

1. Introduction

This paper analyzes differences of economic indices such as scale economies and minimum efficient scales, etcetera among different types of water supply systems. It is generally considered that water supply systems have at least three activities such as water intake, water purification and water delivery, but in fact all water supply systems don't have all of these three activities. For example, in Japan, bulk water supply systems have the water intake and water purification activities, but don't have the water delivery activity. Further, some parts of large the water supply systems have only the water delivery activity, and consequently have to purchase water from bulk water supply systems or other large water supply systems. Therefore, it is easy to assume that the water supply systems which have different kinds of activities could have different cost structures, or that their minimum efficient levels might also differ. Importantly, over the past few decades a considerable number of studies have attempted to measure some economic indices for water supply organizations using the cost function approach, but unfortunately almost all of these studies have failed to account for differences of activities among the water supply systems. Therefore, this paper categorizes the water supply systems into three types and shows some economic indices for each type by estimating the translog cost function. Furthermore, we take into account their water sources, because we consider that differences in water sources might affect the cost structures of the water supply systems.

Therefore, this article is organized in the following manner: Section 2 describes preceding research and 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. The concluding remarks are summarized in Section 6.

2. Preceding research and an overview of the Japanese water industry

2.1 Preceding research

Economists have rigorously scrutinized the cost structure of the water industry world wide. Several studies are worth noting. Kim(1987, 1995), Kim and Clark(1988), Saal and Parker(2000) and Garcia and Thomas(2001) estimated the multiple-output translog cost function and mainly measured the economies of scale and scope between some outputs. Bhattacharyya et al.(1995) and Nakayama(2003) estimated the stochastic cost frontier whose functional form was approximated by the translog function. They mainly measured the cost inefficiencies of the water supply systems. Bhattacharyya et al(1994,1995) and Nakayama(2001) estimated the non-minimum generalized cost function whose functional form was also approximated by the translog function. They incorporated an allocative inefficiency between input factors into the cost function and mainly measured the allocative distortions. Bhattacharyya et al(1995) and Mizutani and Urakami(2001) estimated the translog cost function with hedonic output function and mainly measured scale economies adjusted by some water service qualities.

Despite the large number of papers, almost all of them have failed to account for differences of activities among the water supply systems. Therefore, this paper categorizes the water supply systems into three types and shows some economic indices for each type by estimating the translog cost function.

2.2 Overview of the Japanese water industry

The water supply systems in Japan are categorized into four types by the Water Act. Table 1 shows the number and definitions of each type of water supply system. There are a large amount of the water supply systems in Japan, however the majority of them are very small, especially in the area of the small water supply and the small private water supply systems. It is worth mentioning that almost all of the water supply systems are owned by local governments, or by water authorities that are owned by some local governments. Further ten are owned by privately owned companies in the large water supply category. In contrary to the US or Europe where many private companies have a major role in the water industry, the ten private companies in Japan are very small and are owned by local developers. In addition, all of them receive a request to supply water from their local government, so that they don't have any competitive power against the public water supply organizations.

<Table 1>

Table 2 shows the number of total population and population supplied according to the different water supply systems. It is worth mentioning that of almost all of the number of population supplied, (94.5%) are supplied by large the water supply systems.

<Table 2>

Table 3 shows varieties of water sources of large and bulk water supply systems. About 35% are supplied from surface water, 40% from dams, and approximately 20% from underground water sources.

<Table 3>

Table 4 shows the average costs of water supply in the large and bulk water supply systems with respect to water sources. The average costs from dam water in both the large and bulk water supply systems is the highest, whereas the underground water is the lowest. It is easy to assume that differences of water sources might affect cost structures of the water supply systems, thus we should take this into account when we estimate the cost functions and investigate some economic indices.

<Table 4>

3. Methodology

3.1 Cost function

The functional form of the cost function is specified as the translog cost model. We specify the cost function as a long run cost function with dummy variables (dam and underground). The model is as follows:

$$\ln C = \alpha_0 + \alpha_Q(\ln Q) + \Sigma_i \beta_i(\ln P_i) + \Sigma_k \delta_k DUM_k$$

$$+ 1/2\alpha_{QQ}(\ln Q)(\ln Q) + 1/2\Sigma_i\Sigma_j\, \eta_{ij}(\ln P_i)(\ln P_j) + \Sigma_i \lambda_{Qi}(\ln Q)(\ln P_i) \quad (1)$$

where C, total costs; Q, amount of water delivered(thousand square meter); Pi, input factor price(i(or j) = L(labor), K(capital), W(water), O(other)); DUMk, dummy variables(k = Dam(dam water), Und(underground water)).

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

$$S_i = \beta_i + \lambda_{Qi}(\ln Q) + \Sigma_j\, \eta_{ij}(\ln P_j) \quad (2)$$

where Si, input i's share of the cost function.

3.2 Some Economic Indices

We are able to obtain some economic indices from the parameter estimates of the cost function. Firstly, we can calculate the return to scale measure (RTS) as follows:

$$RTS = 1/(\partial \ln C/\partial \ln Q)$$

$$= 1/\{\alpha_Q + \alpha_{QQ}(\ln Q) + \Sigma_i\lambda_{Qi}(\ln P_i)\} \quad (3)$$

Secondly, we can obtain the minimum efficient scale (MES) as follows:

$$\partial AC/\partial Q = (\partial AC/\partial lnAC)(\partial lnAC / \partial lnQ)(\partial lnQ / \partial Q)$$

$$= (AC / Q)\ (\partial lnAC / \partial lnQ) = 0 \qquad (4)$$

Because AC>0 and Q>0, the above equation is rewritten as follows:

$$\partial lnAC / \partial lnQ = \partial lnC / \partial lnQ - \partial lnQ / \partial lnQ$$

$$= \alpha Q+\alpha QQ(lnQ) +\Sigma i\lambda Qi(lnPi) - 1= 0 \qquad (5)$$

From this equation, we can obtain MES = $(1 - \alpha Q)/ \alpha QQ$ by holding other variables, except for the output variable at the sample mean points.

Finally, we can calculate the average cost (AC) at MES by holding other variables, except for the output variable at the sample mean points as follows:

$$AC = \exp \{\alpha 0 + (\alpha Q-1)(lnQ) + 1/2\alpha QQ(lnQ)(lnQ) \} \qquad (6)$$

4. Data

All of the data used in this study was collected from *The Yearbook of Public*

Firms,(Chihou Kouei Kigyo Nenkan, in Japanese), edited by the Research Association of Local Public Firm Management (Chihou kouei Kigyou Keiei Kenkyu Kai, in Japanese) . The Yearbook reports quantitative and financial data for all of the municipal water utilities in Japan. The number of observations are: 132 for type 1; 1,924 for type 2a; and 290 for type 2b in FY2001-2002.

The variables used for the estimation of the total cost function are shown in Table 5 and defined as follows: Total cost (C) is the sum of labor, capital, and other costs. As for the output measure, we used the annual total amount of delivered water (Q). Further, we defined four kinds of input factor prices. Firstly, the labor price (P_L) defined as the average annual salary per employee. Secondly, the capital price (P_E) obtained by the multiplication of the sum of depreciation expenditures divided by the depreciation assets and interest expenditures divided by the amount of corporate loans, and the deflator of capital stock assets. Thirdly, the price of water (P_W) defined (but only for type 2b) as the expenditure for purchased water in relation to the amount of purchased water. Finally, the price of other costs (P_O), such as chemicals and tax payments, is 1 as a numeraire.

In addition, we defined two dummy variables (DUM_{DAM} and DUM_{UND}). Both are defined as 1 when the water supply systems obtain water from dam water or underground water, and as 0 for other sources.

<Table 5>

5. Results

The results from the estimation of the cost function are shown in Table 6. The estimation method is the ML (Maximum Likelihood Estimation) for the cost model with input share equations. The goodness-of-fit in these regressions are acceptably high for each model. The estimated cost models meet almost all of the required properties. Firstly, symmetry and homogeneity in input factor prices are satisfied because of the restrictions imposed on input factor prices. Further, monotonicity and concavity conditions in the cost model are satisfied at least locally. The first-order coefficients in the cost model show the correct sign.

<Table 6>

The coefficients of the underground water dummy variable for type 1 and type2a shows -0.505 and -0.019, and are statistically significant at 1% and 5%, indicating that supply from underground water sources leads to cost savings. The coefficients of the dam water dummy variable for type 2a shows 0.163, and is statistically significant at 1%. On the other hand, the variable for type 1 shows -0.089 which is not that statistically significant. However, this indicates that supply from dam water sources leads to cost burdens for type 2a.

The estimation results of return to scale, minimum efficient scale and average cost are shown in table 7.

<Table 7>

The estimate of the return to scale measure for type 1 is 1.083, indicating a constant return to scale at sample mean. Whereas type 2a and type 2b are 1.108 and 1.104, indicating a slight increasing return to scale at sample mean. The MES measures for Type 2a and Type 2b shows 17,414 and 11,922 indicating that the minimum efficient scale of Type 2a is larger than Type 2b, because Type 2a has the water intake and water purification activities, whereas Type 2b doesn't have these activities, and as a result it has to purchase water from a Type 1 company or from other alternative water supply systems. Both AC_{MES} and AC_{MEAN} measures of Type 2b are approximately 1.6 times higher than those of Type 2a. This indicates that Type 2a is more cost effective than Type 2b, because Type 2b water supply systems have to purchase high-priced water from Type 1 companies or other water supply systems. The measures of MSE for Type 1 are extreme in comparison to acceptable measures as shown in Type 2a and Type 2b. However, this might be caused from a statistically insignificant estimate of the αQQ parameter, so this needs to be resolved in future analysis.

6. Concluding Remarks

This paper focused on the actual condition that water supply organizations don't always have the same activities such as water intake, water purification and water delivery etc. We considered that differences of water activities within the water supply systems contributed to their cost structures, therefore we categorized the water supply systems into three types and estimated the translog cost function for each type to estimate some economic indices.

The final results obtained from this analysis are as follows: (1) the return to scale measure for Type 1 shows a slight increasing return to scale and for Type 2a and Type 2b shows a constant return to scale. (2) the MSE measure of Type 2a is larger than that of Type 2b because of their differences of activities. (3) the AC measures of Type 2b are higher than Type 2a because Type 2b might have to purchase high-priced water from Type 1 companies or other water supply systems. (4) the underground water source of Type 1 and Type 2a leads to cost savings and the Dam water source of Type 2a leads to cost burdens.

These results show that the water supply systems which have different activities have different cost structures, therefore when we estimate the cost function or investigate some economic indices, we have to categorize the water supply systems adequately, and also we should take into account the water sources.

References

Bhattacharyya, A., T.R.Harris, R. Narayanan and K. Raffiee (1995), "Allocative efficiency of rural Nevada water systems: a hedonic shadow cost function approach," *Journal of Regional Science*, Vol.35, No.3, pp.485-501.

Bhattacharyya, A., T.R.Harris, R. Narayanan and K. Raffiee (1995), “Specification and estimation of the effect of ownership on the economie efficiency of the water utilities,” *Regional Science and Urban Economics*, Vol.25, No.2, pp.759-784.

Bhattacharyya, A., E.Parker and K. Raffiee (1994), “An examination of the effect of ownership on the relative efficiency of public and private water utilities,” *Land Economics*, Vol.70, No.2, pp.197-209.

Garcia, S. and A.Thomas (2001), “The structure of municipal water supply costs: application to a panel of French local communities,” *Journal of Productivity Analysis*, Vol.16, pp.5-29.

Kim,H.Y. (1987), “Economies of scale in multi-product firms: an empirical analysis,” *Economica*, Vol.54, No.3, pp.185-206.

Kim,H.Y. (1995), “Marginal cost and second-best pricing for water services,” *Review of Industrial Organization*, Vol.10, No.3, pp.323-338.

Kim,H.Y. and R.M.Clark (1988), “Economies of scale and scope in water supply,” Regional Science and Urban Economics, Vol.18, No.4, pp.479-502.

Kobayashi,Y., and T. Hayakawa(eds)(2003), *Water Japan 2003/04 – Japan's Water Works Yearbook–*, Suido Sangyo Shimbun (Journal of Water Works Industry), Tokyo.

Mizutani, F., and T. Urakami (2001), “Identifying network density and scale economies for Japanese water supply organizations,” *Papers in Regional Science*, Vol.80, No.2, pp.211-230.

Nakayama,N.(2001), “Estimating generalized cost function in Japanese water industry,” Nihon Keizai Seisaku Gakkai Nenpo, Vol.49, pp.124-131.(in Japanese)

Nakayama,N.(2003), "Efficiency analysis in water utilities using stochastic cost frontier," *Keizai Seisaku Journal*, Vol.1, No.1/2, pp.103-110. (in Japanese)

Saal,D. and D.Parker (2000), "The impact of privatization and regulation on the water and sewerage industry in England and Wales: a translog cost function model," Managerial and Decision Economics, Vol.21, pp.253-268.

Table 1 Number of water supply systems (FY2002)		
Bulk water supply		111
Large water supply	Publicly owned	1,946
	Privately owned	10
Small water supply		8,599
Small private water supply		6,933
Total		17,599

(Source): Management indices of water utilities, FY2002.

(Note): Bulk water supply is the water supply system which supplies portable water to large/small water supply systems not to the end user. Large water supply is the system where the planned population to be supplied is more than 5,001. Small water supply is the system where the planned population supplied is between 101 and 5,000. Small private water supply is the water supply system in buildings equipped with receiving water tanks having the capacity of more than $10m^3$ and receives portable water from large/small water supply systems.

Table 2 Total population and population supplied (FY2002) (in thousand)		
Total population		127,440
Population supplied	Large water supply	116,570
	Small water supply	6,230
	Small private water supply	580
	Total	123,380
Percentage of population supplied (%)		96.8%

(Source): Management indices of water utilities, FY2002.

Table 3 Water sources of Large/Bulk water supply (FY2000) (unit:10^6m^3)		
Surface	River	51.9 (30.8%)
	Lake	2.3 (1.4%)
	River-bed	6.5 (3.8%)
Dam		66.6 (39.6%)
Underground		35.9 (21.4%)
Other		5.0 (3.0%)
Annual Intake		168.2 (100%)
(Source): Japan's Water Works Yearbook 2003/2004.		

Table 4 Average costs of water supply according to sources (FY2002) (unit: Yen/m^3)		
	Large water	Bulk water
Surface	197.8 (315)	102.8 (8)
Dam	234.5 (114)	117.6 (54)
Underground	177.6 (901)	-
Purchased	226.2 (494)	36.3 (3)
Other	204.1 (78)	104.6 (1)
Total	198.1 (1,898)	111.9 (65)
(Source): Annual Statistics of Local Public Corporations FY 2002. (Note): The figures in parentheses show the number of water supply systems. The average costs are calculated from the observations that incorporated over 50% of water from a certain water source.		

Table 5　Definition and sample mean of variables used for the estimation of cost function

Variable	Definition	Unit	Type 1	Type 2a	Type 2b
C (Total cost)	Sum of labor, capital and other costs	million yen	6,528	1,106	857
Q (Output)	Annual delivered water	thousand squared meter	67,867	7,262	4,370
P_L (Wage of driver)	Average annual salary per employee	thousand yen / employee	8,133	7,217	7,458
P_K (Capital price)	Sum of depreciation costs per assets and interest cost per corporate loans	-	18.5	17.3	17.7
P_W (Water price)	the expenditures for purchased water per the amount of purchased water	yen / m^3	-	-	22.037

Table 6 Estimation Results of the Cost Function						
	Type 1		Type 2a		Type 2b	
parameter	estimate	Standard error	estimate	Standard error	estimate	Standard error
α0	22.6581	0.136***	20.584	0.021***	20.541	0.024***
αQ	0.923	0.051***	0.902	0.009***	0.906	0.026***
βL	0.109	0.015***	0.204	0.004***	0.120	0.004***
βK	0.639	0.026***	0.509	0.006***	0.265	0.008***
βW	-	-	-	-	0.493	0.007***
βO	0.251	0.018***	0.287	0.004***	0.122	0.004***
αQQ	0.023	0.039	0.112	0.006***	0.094	0.028***
λQL	-0.018	0.008**	0.0003	0.002	0.004	0.003
λQK	0.019	0.016	-0.665	0.003**	-0.030	0.008***
λQW	-	-	-	-	0.020	0.006***
λQO	-0.001	0.012	0.631	0.002***	0.006	0.004
ηLL	0.051	0.043	0.116	0.006***	0.086	0.008***
ηLK	-0.051	0.034	-0.066	0.006***	-0.024	0.012**
ηLW	-	-	-	-	-0.035	0.003***
ηLO	0.0004	0.043	-0.050	0.006***	-0.027	0.011**
ηKK	0.094	0.060	0.095	0.942***	0.122	0.020***
ηKW	-	-	-	-	-0.071	0.011***
ηKO	-0.043	0.056	-0.029	0.007***	-0.027	0.014**
ηWW	-	-	-	-	0.144	0.009***
ηWO	-	-	-	-	-0.038	0.007***
ηOO	0.043	0.672	0.079	0.009***	0.093	0.018***
δ_{DAM}	-0.089	0.126	0.163	0.035***	-	-
δ_{UND}	-0.505	0.234**	-0.214	0.019***	-	-
R-square	0.877		0.866		0.916	
n	132		1,924		290	
***statistically significant at 1%, ** 5%						

Table 7 Return to scale, minimum efficient scale and average cost at sample mean point

	RTS	MES (thousand squared meter)	AC_{MES} (yen / squared meter)	AC_{MEAN} (yen / squared meter)
Type 1	1.083	1,910,060	89.5	101.8
Type 2a	1.108	17,414	114.6	119.6
Type 2b	1.104	11,922	181.4	190.2

AC_{MES} : average cost at minimum efficient scale point

AC_{MEAN} : average cost at sample mean point