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Consolidation and Scale Economies in the Japanese Sewerage Industry

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Abstract

This study empirically examines cost reductions in the Japanese sewerage industry through mergers by modeling the costs of sewage disposal. The cost model is specified in a translog form, and treats capital as a quasi-fixed input. Employing the parameters estimated by the model, the long-run cost function is derived, which indicates that most sewerage operators should be merged to attain scale advantages. Furthermore, while the cost reductions through actual sewerage mergers are estimated to be 37.9 billion yen, a counterfactual simulation shows that a more far-reaching consolidation could achieve cost savings through scale advantages amounting to 190 billion yen.

Keywords: consolidation, cost function, cost reduction, scale economies, sewerage
JEL Classification: L11, L95

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1 Introduction

Although for public utilities such as electricity, gas, water, and sewage disposal, regional monopolies are frequently justified, the scale of such monopolistic public utilities is not always optimal. The optimal scale of public utilities depends on various geographical and demographic factors, and therefore varies significantly within and between areas and over time. Yet, adjusting the scale of public utilities to changes in demographic characteristics and the size of the market takes time and may be impeded by institutional constraints, which may give rise to an inexplicit gap between the actual and the optimal scale of a utility. This gap, in turn, may result in higher costs than would otherwise be the case.

In the Japanese sewerage industry, the scale of sewerage utilities in urban regions may not be optimal. In 2004 and 2005, in what is often referred to as "the great Heisei mergers," Japan experienced a large wave of municipal mergers that also resulted in the merger of numerous municipal sewerage companies. The aim of the Municipality Merger Promotion Law, which was the trigger for the large wave of mergers, was to create public utilities that operate at an efficient scale. However, there were few mergers involving municipalities in densely populated urban regions, which are the regions that have seen the largest demographic changes since sewerage systems were first developed, so that the actual scale of sewerage operations may not be optimal in these regions. This means that sewerage utilities in densely populated urban regions may fail to exploit potential cost advantages.

Whether or not the scale of public utilities is optimal depends on the existence of scale economies. However, when it comes to the sewerage industry, the literature is ambiguous with regard to the existence of scale economies. For example, while Knapp (1978) and Bottasso et al. (2011), examining the sewerage industry in England and Wales, find evidence that scale economies exist in the industry, Saal and Parker (2000) and Stone and Webster Consultants (2004) find no such evidence. Focusing on developing countries, Nauges and van den Berg (2007, 2008) and Iimi (2008) find that significant scale economies exist in some, but not all developing countries.[1] Finally, for Japan, Nakayama (2002), using a small sample of firms in the sewerage industry, also finds no significant evidence of scale economies.

The purpose of this study is to examine whether scale economies exist in the Japanese sewerage industry and to estimate the cost reductions achieved through mergers of sewerage utilities.[2] To this end, a cost model specified in translog form is developed that treats capital as a quasi-fixed input. Using data on Japanese sewerage operators from 1999 to 2008, the translog variable cost function is then estimated employing Zellner's (1962) seemingly unrelated regression method. Furthermore, the long-run cost function based on the estimated short-run variable cost function is computed. Calculated short-run and long-run scale economies indicate that scale economies exist both in the short and in the long run.

The next part of the analysis consists of an assessment of the cost reductions achieved through mergers of sewerage utilities. The results show that the cumulative actual cost reductions achieved through sewerage utility mergers during the period from 1999 to 2008 amount to 37.9 billion yen, or 2.4% of the expenditure on sewage disposal during the period. The consolidation is generally the result of municipal mergers involving small towns and villages, which may have led to an increase in the scale of sewerage utilities.

In a further step, in order to examine the cost advantages through economies

[1]Nauges and van den Berg (2008), for instance, find evidence of economies of scale in Moldova, Romania, and Vietnam, but suggest that there are no significant scale economies in Brazil.

[2]The few studies on the sewerage industry that do exist tend to test only the existence of scale economies, but none of these estimate the cost reduction achieved through mergers of sewerage operators.

of scale that could potentially be attained, a counterfactual scenario in which it is assumed that sewerage operators merge within their respective prefectures is considered. The cost reductions that could have been achieved through these counterfactual mergers amount to 190 billion yen, or 12% of expenditure on sewage disposal in 2008. This result suggests that sewerage utilities in neighboring municipalities should cooperate in order to reduce their costs.

The remainder of this paper is organized as follows. Section 2 provides a brief overview of the Japanese sewerage industry. Section 3 presents the theoretical framework employed, while Section 4 describes the dataset. Section 5 then provides the specification of the short-run variable cost function and derives the long-run cost function from the estimated variable cost function. Next, Section 6 examines the cost reductions resulting from actual mergers in the sewerage industry and provides the results of the simulation exercise. Finally, Section 7 concludes.

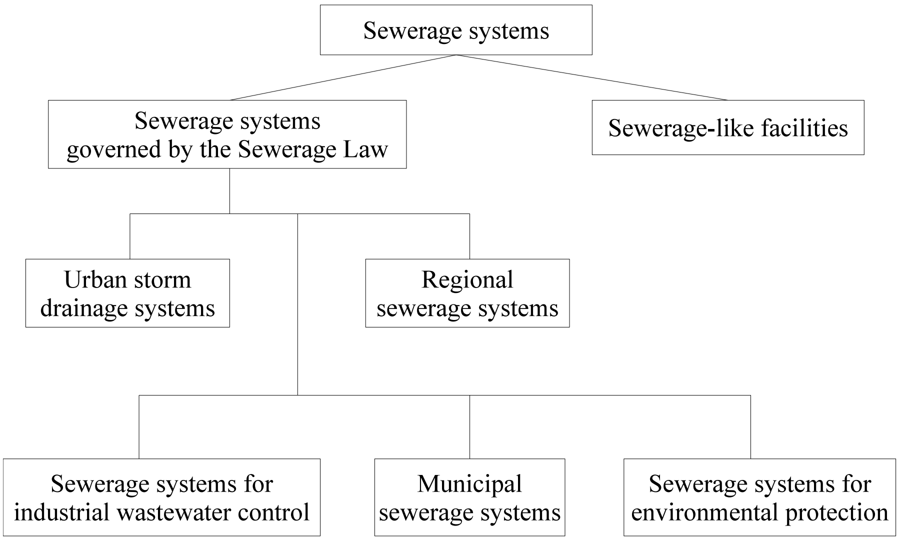
2 Industry Background

2.1 Types of sewerage systems

Sewerage operators in Japan provide their services for certain areas and purposes. Figure 1 depicts the range of services provided by sewerage operators. Sewerage systems can be broadly distinguished according to whether or not they are governed by the Sewerage Law. The Sewerage Law divides sewerage systems into five categories: urban storm drainage systems, regional sewerage systems, sewerage systems for industrial wastewater control, sewerage systems for environmental protection, and municipal sewerage systems.[3] Urban storm drainage systems mainly perform rainwater drainage outside the coverage area

[3]Sewerage utilities not governed by the Sewerage Law include individual sewage disposal utilities such as septic tanks.

Figure 1: The structure of the Japanese sewerage industry



of municipal sewerage systems. Regional sewerage systems focus only on final sewage treatment. The other sewerage systems can be distinguished in terms of their main service areas. When sewage from industrial plants makes up more than two thirds of the total sewage in a service area, the sewerage system is classified as a sewerage system for industrial wastewater control, although such sewerage systems also remove and treat sewage from households living in the service area. Sewerage systems for environmental protection aim at protecting the environment within nature parks and remove and treat sewage from households within nature parks. The coverage area of municipal sewerage systems is restricted to urban areas and is separate from the coverage areas of sewerage systems for industrial wastewater control and sewerage systems for environmental protection. Municipal sewerage systems can consign final sewage treatment to regional sewerage systems. This study focuses on municipal sewerage systems.

2.2 Sewerage and urban planning

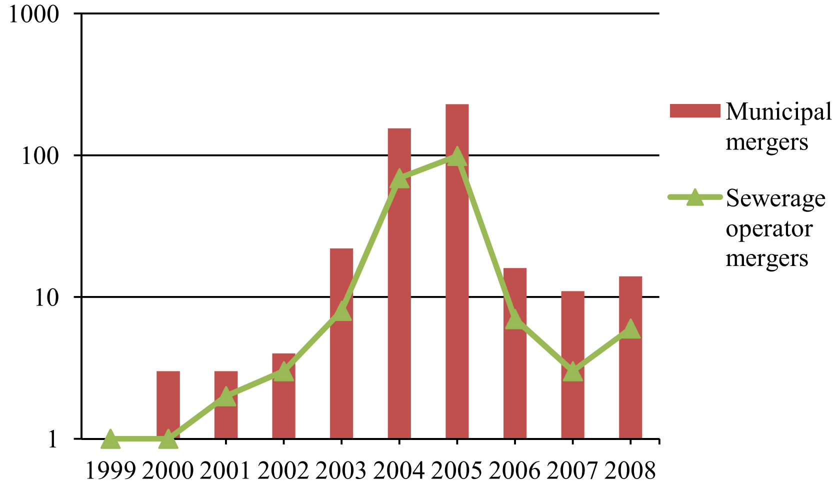
Sewerage forms part of urban infrastructures and has been developed based on the following two laws. The first is the Act on Emergency Measures Concerning the Construction of Sewerage Systems, which was in effect from 1967 to 2003. The act promoted the speedy development of sewerage, because the development of sewerage lagged behind that of other urban infrastructure during the period of rapid economic growth. Then, in 2004, with the sewerage infrastructure fully developed, the Act on Priority Plan for Social Infrastructure Development was put in place, replacing the Act on Emergency Measures Concerning the Construction of Sewerage Systems. This second act aims at promoting the development of sustainable urban infrastructures. ince urban plans under these two acts are five-year plans, sewerage projects have been based on these five-year plans.[4]

2.3 Municipal mergers and the consolidation of sewerage operators

Figure 2 depicts he number of municipal mergers as well as mergers of sewerage operators from 1999 to 2008. The number of both municipal and sewerage operator mergers increased sharply after 2003 and peaked in 2005. After 2005, the number of municipal mergers fell back to levels somewhat below those seen in 2003, resulting also in a drop in mergers of sewerage operators.

[4] The construction of new sewerage infrastructure typically takes at least a few years. Based on quinquennial sewerage projects, sewerage operators need to conduct land surveys, make detailed plans for building sewer pipes, work out a budget, and then lay the pipes. Finally, individual households need to be connected to the sewer pipes.

Figure 2: Number of municipal mergers and sewerage operator mergers, 1999-2008



Data source: *Local Public Enterprise Yearbook*.

3 Model

3.1 Short-run and long-run cost functions

In order to examine the cost structure of sewerage utilities in Japan, a short-run equilibrium model is employed. Sewerage utilities form part of the urban infrastructure and the capital used in the sewerage industry is of a fixed nature and is subject to urban planning, meaning that capital input is not instantaneously adjustable to the desired level.

The short-run equilibrium model is used to analyze the cost structure of sewerage operators by estimating the associated cost function. Each operator is assumed to choose the amount of labor and capital that minimizes the cost of disposing of a given amount of sewage, y, where capital is assumed to be a quasi-fixed input restricted to a certain level, $\bar{K}$. An operator's short-run variable costs therefore are represented by

$$VC = VC(y, w; \bar{K}, Z),$$

where w is the wage rate and Z is a vector of control variables. The short-run cost function is the sum of short-run variable costs and fixed costs,

$$STC(y, w, r; \bar{K}, Z) = VC(y, w; \bar{K}, Z) + r\bar{K},$$

where r is the user cost of capital.

The long-run cost function is the lower envelope of the short-run cost function (Varian, 1992). Let K^* be the optimal choice of the capital level at output level y, so that the first order condition is as follows:

$$\frac{\partial STC}{\partial K} = \frac{\partial VC}{\partial K} + r = 0. \tag{1}$$

Since $VC(y, w; K^*, Z)$ is the long-run optimal choice of the variable factors, the long-run cost function is given by

$$LTC = VC(y, w; K^*, Z) + rK^*. \tag{2}$$

Hence, the relationship between the short-run and long-run cost function is

$$LTC = STC(y, w, r; K^*, Z).$$

3.2 Economies of scale

Scale economies are frequently measured by the elasticity of costs with respect to output, which in the case here is the proportional change in costs resulting from the proportional change in the sewage disposal amount. Following Christensen and Greene (1976), the extent of scale economies is defined as unity minus the cost elasticity. According to this definition, short-run scale economies are given by

$$SSE := 1 - \frac{\partial \log(STC)}{\partial \log(y)} = 1 - \frac{\partial \log(VC)}{\partial \log(y)}. \tag{3}$$

Similarly, long-run scale economies are given by

$$LSE := 1 - \frac{\partial \log(LTC)}{\partial \log(y)}. \tag{4}$$

If SSE (LSE) is positive, the sewerage operator exhibits positive scale economies in the short run (long run). If SSE (LSE) is negative, scale diseconomies in the short run (long run) are present. Furthermore, both SSE and LSE are in percentage terms.

3.3 Minimum efficient scale

The minimum efficient scale (MES) is defined as the level of output at which the average cost is minimized. When y^* is MES, the following is satisfied:

$$\frac{d}{dy}\left(\frac{LTC}{y}\right) = 0. \tag{5}$$

If $y < y^*$, average costs are declining to the left of y^*, so that

$$\frac{d}{dy}\left(\frac{LTC}{y}\right) \leq 0.$$

4 Data

The yearly data used for the analysis are mainly taken from the 1999 to 2008 editions of the *Local Public Enterprise Yearbook* (Chiho Koei Kigyo Nenkan) published by the Ministry of Internal Affairs and Communications. The *Yearbook* contains data on the financial and managerial accounts of sewerage operators. However, for most sewerage operators, data on capital stock are not available.[5] Following Garcia and Thomas (2001) and Nauges and van den Berg (2008), the length of sewer pipes under the control of a particular operator is therefore used as a proxy for its capital stock.

Next, information on the rental price of capital is obtained from the Japan Industrial Productivity (JIP) Database 2011. The JIP Database contains nominal rental price data not only for sewage disposal services but also for other public services, such as public waste disposal services, port and water traffic control, airport and air traffic control, and public administration.

In order to adjust these data for inflation, three additional sets of data were used. The first is gross domestic expenditure from the *National Accounts of Japan* (Cabinet Office, Government of Japan) to adjust annual operation and maintenance costs for sewage treatment. The second set of data consists of real wage indices from the *Monthly Labour Survey* (Ministry of Health, Labour and Welfare) to adjust labor expenses, while the third set consists of investment goods indices from the *Price Indexes Quarterly* (Bank of Japan) to adjust the nominal rental price of capital.

After deleting observations with missing or implausible values, the resulting panel dataset contains 11,199 observations. A summary of the definitions of variables and their basic statistics is provided in Table 1.

[5] Most sewerage operators are not governed by the Local Public Enterprise Act and employ an accounting system that does not clearly state capital account balances.

Table 1: Basic statistics and definition of variables

Variable	Mean	S.D.	Definition
$\log(VC)$	12.22	1.24	Logarithm of annual operation and maintenance costs for sewage treatment (¥1,000)
$\log(y)$	7.53	1.69	Logarithm of sewage disposal amount per year (1,000m^3)
$\log(w)$	8.20	0.67	Logarithm of wage rate (¥1,000/person)
$\log(\bar{K})$	4.79	1.19	Logarithm of sewer pipe length (km)
$\log(Dens)$	3.45	0.67	Logarithm of population density (person/ha)
$\log(Pump)$	0.004	0.045	Logarithm of the density of pumping stations (no./ha)
r	68.31	15.85	Rental price of capital (¥1,000)

Data sources: JIP Database 2011, *Local Public Enterprise Yearbook*, *National Accounts of Japan* (SNA), *Monthly Labour Survey*, and *Price Indexes Quarterly*.
Notes: The wage rate is defined as labor expenses divided by the total number of employees. Since many sewerage operators have no pumping stations, one is added to the number of pumping stations per hectare before calculating the logarithm.

5 Cost Estimation

5.1 Specification

Following Christensen et al. (1973), a translog variable cost function, which is a flexible function in the sense that it provides a second-order linear approximation to any cost function, is specified:

$$\log(VC_{it}) = \alpha_0 + \sum_j \alpha_j \log(X_{it}^j) + \frac{1}{2}\sum_{h,k} \alpha_{hk} \log(X_{it}^h)\log(X_{it}^k) + \epsilon_{it}, \quad (6)$$

where X is a vector consisting of sewage disposal amount y, wage rate w, quasi-fixed capital stock $\bar{K}$, population density $Dens$, and the density of pumping stations in the coverage area, $Pump$. In addition, linear homogeneity in input factor prices is assumed, i.e., $\alpha_{hk} = \alpha_{kh}$.

Furthermore, a convenient feature of the cost function is that the derived input demand functions can be easily computed by partially differentiating the cost function with respect to the input prices, known as Shephard's lemma

(Shephard, 1953). In the translog cost function, Shephard's lemma is represented as follows:

$$\frac{w_{it}L_{it}}{VC_{it}} = \frac{\partial \log(VC_{it})}{\partial \log(w_{it})} = \alpha_w + \sum_h \alpha_{hw} \log(X_{it}^h), \tag{7}$$

where L_{it} is the labor input of sewerage operator i in year t.

5.2 Estimation results: short-run variable cost function

The next step is to estimate the translog variable cost function (6) along with the cost share equation (7).[6] Following the traditional industrial organization literature (e.g., Nerlove, 1963, and Christensen and Greene, 1976), the set of these equations is estimated using seemingly unrelated regression employing Zellner's (1962) technique.

Table 2 presents the estimation results for two different specifications. Specification (6.1) employs the explanatory variables introduced above, while specification (6.2) drops $\log(Pump)$ and cross-terms containing $\log(Pump)$ from the explanatory variables.[7] The two different specifications yield virtually identical results. The discussion below therefore focuses mainly on the results for specification (6.1).

Looking at the estimation results, the first-order and second-order coefficients on the sewage disposal amount are positive and significant. This result indicates that the short-run variable cost function is monotonically increasing in the sewage disposal amount, which is consistent with economic theory, which suggests that cost functions are usually monotonically increasing in output.

[6] An often used specification test is the Breusch-Pagan test for independent equations (Breusch and Pagan, 1980). The Breusch-Pagan test statistic is significant at the 1% level, indicating that the correlation of the residuals in equations (6) and equation (7) is not zero.

[7] The reason is twofold. First, because many sewerage operators have no pumping stations, it was necessary to add one to the number of pumping stations per hectare to take the logarithm and obtain $\log(Pump)$. And second, the cross terms with $\log(Pump)$ are not significant.

Table 2: Estimation results of the short-run variable cost function

	(6.1)		(6.2)	
Variable	Coef.	(S.E.)	Coef.	(S.E.)
const.	6.696^{***}	(0.197)	6.660^{***}	(0.197)
$\log(y)$	0.164^{**}	(0.065)	0.172^{***}	(0.065)
$\log(w)$	0.085^{**}	(0.035)	0.079^{**}	(0.035)
$\log(Dens)$	0.199^{**}	(0.088)	0.207^{**}	(0.087)
$\log(Pump)$	-6.508^{*}	(3.549)		
$\log(\bar{K})$	0.431^{***}	(0.083)	0.437^{***}	(0.083)
$(\log(y))^2$	0.081^{***}	(0.007)	0.081^{***}	(0.007)
$(\log(w))^2$	0.057^{***}	(0.004)	0.058^{***}	(0.004)
$(\log(Dens))^2$	0.018^{*}	(0.011)	0.021^{*}	(0.011)
$(\log(Pump))^2$	-1.691^{***}	(0.392)		
$(\log(\bar{K}))^2$	-0.063^{***}	(0.013)	-0.061^{***}	(0.013)
$\log(y)\log(w)$	-0.051^{***}	(0.008)	-0.050^{***}	(0.008)
$\log(y)\log(Dens)$	0.010	(0.009)	0.006	(0.009)
$\log(y)\log(Pump)$	0.746	(0.551)		
$\log(y)\log(\bar{K})$	0.024^{***}	(0.008)	0.025^{***}	(0.008)
$\log(w)\log(Dens)$	-0.023^{**}	(0.011)	-0.022^{**}	(0.011)
$\log(w)\log(Pump)$	0.108	(0.361)		
$\log(w)\log(\bar{K})$	0.008	(0.011)	0.005	(0.011)
$\log(Dens)\log(Pump)$	0.823	(0.547)		
$\log(Dens)\log(\bar{K})$	-0.029^{**}	(0.012)	-0.027^{**}	(0.012)
$\log(Pump)\log(\bar{K})$	-0.161	(0.748)		

Notes: Specification (6.1) employs the explanatory variables introduced in the text. Specification (6.2) drops $\log(Pump)$ and cross-terms containing $\log(Pump)$ from the explanatory variables. ***, **, and * denote significance at the 0.01, 0.05, and 0.10 level respectively. The number of observations is 11,199.

5.3 Estimation results: long-run cost function

Next, the long-run cost function is derived from the estimated short-run variable cost function. Once the parameters of the short-run variable cost function are estimated, equation (1) can be solved with respect to K to obtain the long-run cost function. However, in the translog functional form, it is impossible to derive a closed-form solution of equation (1) for K. Therefore, equation (1) is solved numerically using the Newton-Raphson method. Using the numerical solution of equation (1), the long-run cost function is then obtained from equation (2).

Table 3 presents the results for the estimated first-order coefficients of the

Table 3: Estimated first-order coefficients of the long-run variable cost function

	(6.1)		(6.2)	
Variable	Coef.	(Std. Err.)	Coef.	(Std. Err.)
const.	8.003	(0.073)	8.065	(0.069)
$\log(y)$	0.387	(0.012)	0.400	(0.012)
$\log(w)$	0.155	(0.003)	0.123	(0.002)
$\log(Dens)$	-0.065	(0.014)	-0.042	(0.013)
$\log(Pump)$	-7.991	(0.079)		

Notes: Specification (6.1) employs the explanatory variables introduced in the text. Specification (6.2) drops $\log(Pump)$ and cross-terms containing $\log(Pump)$ from the explanatory variables.

long-run variable cost function. The absolute value of the first-order coefficients on the sewage disposal amount in the long-run variable cost function is greater than that in the short-run variable cost function. This result indicates that the increase in costs resulting from a small increase in the sewage disposal amount is greater in the long run than in the short run. The coefficient on $\log(Dens)$ in the long-run cost function is negative, although that in the short-run variable cost function is positive. The reason for this is that although capital stock is fixed in the short run, it is variable in the long run.

5.4 Measuring scale economies

The estimated cost parameters can be used to measure the extent of scale economies. Using the estimated cost parameters obtained in specification (6.1) in Tables 2 and Table 3, short-run and long-run scale economies are calculated. The results indicate that while the average of short-run scale economies is 0.49, the average of long-run scale economies is 0.39. Testing the null hypothesis that the calculated scale economies are zero, the hypothesis can be rejected at the 1% significant level. This means that scale economies exist both in the short and in the long run. The absolute value of the extent of scale economies is greater in the short run than in the long run. This is consistent with the view that sewerage utilities should be subject to increasing returns to scale, given the large fixed costs involved.

This result is in contrast with the one obtained by Nakayama (2002), who found no evidence of significant scale economies. A possible reason for the different results is that Nakayama used panel data consisting of only 270 observations covering the period from 1991 to 1999 and limited to relatively large-scale sewerage operators, and directly estimated the long-run cost function. However, sewerage operators cannot instantaneously adjust their capital inputs to the desired level. Direct estimation of the long-run cost function using yearly data ignores that sewerage operators are subject to urban planning regulations.

5.5 Measuring minimum efficient scale

Next, the MES for the sewage disposal amount is estimated. Having estimated the parameters of the long-run cost function, equation (5) can be solved to obtain the MES. However, as above, in the translog functional form, it is impossible to derive a closed-form solution of equation (5), so that equation (5) again is solved numerically employing the Newton-Raphson method. Then, using the numerical solution of equation (5), the MES is obtained.[8]

The average estimated MES for sewage disposal amounts is 237.6 million m^3. While Osaka, Nagoya, Yokohama, and the 23 special wards of Tokyo exceeded this figure in 2008, the amount of sewage disposal in all other municipalities fell well below it and the average for all municipalities was only 9.5 million m^3. This means that the scale of most sewerage operators is only a fraction of the estimated MES.

This result indicates that most operators outside the major metropolises

[8] The long-run average cost function is not always U-shaped. If it is not U-shaped, the MES for the sewage disposal amount does not take a positive value. However, as indicated above, scale economies are positive and significant, meaning that the long-run average cost function is U-shaped.

should merge with neighboring operators to attain scale advantages. In the sewerage industry, capital costs, especially the costs of laying sewer pipes, are quite high, while marginal costs associated with sewage disposal are comparatively small. The merged entities could achieve economies of scale and reduce fixed costs by closing duplicate departments or operations.

6 Consolidation among Sewerage Operators

This section assesses actual and potential cost reductions through the consolidation of sewerage operators. The first part of the analysis focuses on the actual consolidation of sewerage operators as a result of municipal mergers. The second part then examines the implications of a more far-reaching counterfactual consolidation to attain scale advantages.

6.1 Cost reductions through actual mergers

This subsection examines cost reductions achieved through the actual consolidation of sewerage operators. A complicating factor in this context is that the amount of sewage produced and disposed in any given service area fluctuates from year to year. This means that the amount of sewage disposed of by post-merger entities is not necessarily simply the sum of the amount of sewage disposed of by individual pre-merger entities. Because data on the amount of sewage disposal in a particular pre-merger service area after the merger has taken place are not available, it is therefore necessary to assume that any changes in sewage disposal amounts affect all pre-merger service areas of a merged entity in equal proportion. Based on this assumption, the reduction in long-run average costs through actual sewerage mergers can be computed as follows:

$$y_h \frac{y'}{y_h + y_k} d\left(\frac{LTC_h}{y_h}\right) + y_k \frac{y'}{y_h + y_k} d\left(\frac{LTC_k}{y_k}\right). \tag{8}$$

where y' is the amount of sewage disposed of by the newly merged operator following the merger between sewerage operators h and k.

Using the estimated cost parameters, equation (8) is calculated for the 192 mergers that took place between 1999 and 2008. The average decrease in long-run average costs as a result of the mergers is 15,000 yen/1,000^3 or 8.6% to 173,900 yen/1,000m^3. The total cost reduction resulting from the 192 mergers thus is estimated to be 37.9 billion yen, which is 2.4% of the total current expenditure on sewage disposal in Japan.[9] This result indicates that the 192 mergers achieved a slight cost reduction.

The likely reason that the cost reduction was relatively minor is that the entities created by many municipal mergers were still comparatively small-scale. The municipal mergers that took place between 1999 and 2008 mainly involved small towns or villages that merged or were absorbed into larger cities and there were few mergers involving municipalities in densely populated urban regions. As a consequence, the consolidation of sewerage operators observed during this period resulted only in relatively minor changes in operational scale.

6.2 Counterfactual simulation

To examine the potential scale advantages that could be attained, this subsection considers the counterfactual case in which sewerage operators merge within their respective prefectures. Computing wage rates at the post-merger entities as the weighted average of the wage rates of each pre-merger operator, where the sewage disposal amount of each operator is used as the weight,[10] the advantages of scale can be calculated employing the following procedure. The procedure starts by focusing on the largest sewerage operator in a prefecture and merges this with neighboring sewerage operators as long as its long-run average cost

[9] In 2008, the total current expenditure on sewage disposal in Japan was 1.58 trillion yen.

[10] Calculating post-merger wage rates by simply using the wage rate of the largest pre-merger operator in the post-merger entity yields virtually identical results.

decreases as a result of such mergers. The order in which sewerage operators with which the largest operator is to be merged is determined by which operator provides the most cost reductions. Once such mergers no longer provide any cost reductions, the focus shifts to the largest remaining (non-merged) operator in the prefecture, for which the procedure is repeated. The overall procedure is repeated until no sewerage operators remain whose long-run average costs can be reduced through mergers.

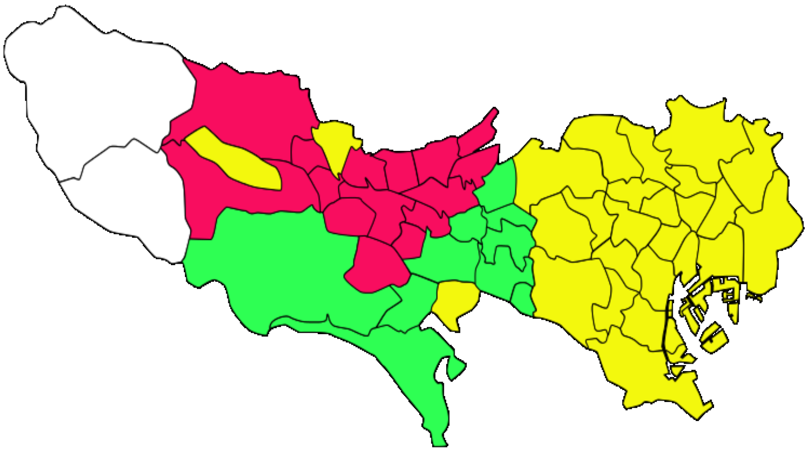
6.3 Cost reductions in the counterfactual simulation

Using the estimated cost parameters and data for the year 2008, the implications of the counterfactual merger of sewerage operators are examined. For illustration, Figure 3 presents the geographical pattern of sewerage services in Tokyo Prefecture after the counterfactual merger. The two municipalities on the far left indicated in white, Hinohara and Okutama, have never operated a municipal sewerage system. Next, the operators in the areas shaded in green and in red were merged into two large-scale operators covering the geographic areas indicated. Finally, the sewerage operators in the municipalities of Hinode, Inagi, and Mizuho, and the 23 special wards of Tokyo, were not merged in the counterfactual simulation.[11]

Table 4 presents the results of the simulation, showing by how much the number of sewerage operators would decrease and the change in costs this would bring about. Specifically, there were 1,058 sewerage operators in Japan in 2008, of which 136 remained "independent" even after the counterfactual consolidation, while 922 were merged. The consolidation among these 922 operators leads to a drastic fall in their number to 141 operators.

[11] If the two merged large-scale operators were merged with Hinode, Inagi, or Mizuho, their long-run average cost would increase. Moreover, the scale of the 23 special wards of Tokyo exceeds their estimated MES, so that their long-run average cost would also increase as a result of a merger with neighboring sewerage operators.

Figure 3: Geographical pattern of sewerage services in Tokyo Prefecture after the counterfactual consolidation



Notes: The municipalites of Hinohara and Okutama on the far left (in white) have never operated municipal sewerage utilities. The operators in the remaining municipalities were merged into two large-scale operators, indicated in green and red. The severage operators of the municipalities of Hinode, Inagi, and Mizuho, and the 23 special wards of Tokyo were not merged in the counterfactual scenario.

The resulting long-run cost reduction is quite dramatic. The average decrease in long-run average costs as a result of the counterfactual mergers is 93,900 yen/1,000 m^3 or 42.9% to 218,700 yen/1,000m^3. The sum of long-run total costs after the counterfactual mergers is 722.7 billion yen, meaning that the total cost reduction through the counterfactual mergers is 190 billion yen, 12% of the total current expenditure on sewage disposal in Japan.

7 Concluding Remarks

This study examined cost reductions as a result of mergers among sewerage operators in Japan. Using data on Japanese sewerage operators from 1999 to 2008, translog variable cost functions which regard capital as a quasi-fixed

Table 4: Estimated costs before and after the counterfactual consolidation

	Before	After
No. of sewerage operators	922	141
Avg. of long-run average costs (1,000 yen/1,000m^3)	218.7	124.8
Sum of long-run total costs (billion yen)	722.7	532.7

Notes: The result does not include sewerage operators which were not merged in the counterfactual scenario. The long-run costs are calculated using the estimated parameters from specification (6.1) in Tables 2 and 3.

input are estimated. Employing the parameters estimated using the model, the derived long-run cost function indicates that most sewerage operators should be merged to attain scale advantages. Furthermore, while the cost reductions achieved through the actual consolidation of sewerage operators that took place between 1999 and 2008 amount to 37.9 billion yen, the counterfactual simulation showed that a more far-reaching merger to attain scale advantages would yield cost reductions of a further 190 billion yen. This result suggests that sewerage utilities in neighboring municipalities should cooperate in order to reduce their costs.

Finally, some shortcomings of this study should be mentioned. First, the capital stock measured here consists only of sewer pipes and does not include final sewage treatment plants. Sewerage utilities can consign final sewage treatment to regional sewerage utilities. This means that sewerage utilities stand in a vertical relationship to each other. f, as a result of consolidation, final sewage treatment plants are combined and closed, there may be changes in such vertical relationships, which may have cost implications not considered in this study.

Second, the analysis may have underestimated cost reductions through the actual mergers of sewerage operators. The long-run cost curve is likely to have shifted following the mergers. However, sewerage operators would have been unable to instantly adjust their labor and capital, because sewerage projects are typically based on five-year plans. This means that during the observation period sewerage operators still would have been in transition to the new long-run equilibrium and had not fully minimized their costs.

Finally, cost reductions through mergers depend on changes in wage rates. This study focuses on scale advantages and assumes that wage rates after mergers are the weighted average wage rates of pre-merger operators, where the amount of sewage disposal prior to the mergers is used as weights. However, mergers might result in a considerable drop in wage rates, leading to more drastic cost reductions.

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