INEFFICIENCY IN JAPANESE WATER UTILITY FIRMS: A STOCHASTIC FRONTIER APPROACH

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Abstract
I examine inefficiencies in Japanese water utility companies. Efficiency in this context is defined as a firm's capacity to maximize output given a fixed level of inputs. The findings suggest that the average operation rate, customer density and size variables are associated with lower levels of inefficiency (or higher levels of efficiency), while water purification (a conditioning variable capturing low initial water quality), subsidies and outsourcing are associated with higher levels of inefficiency. Since inefficiency exists, there is an opportunity to improve Japanese water utilities by working on emulating "best practice" firms whenever possible and by providing a regulatory framework that can set appropriate incentive schemes to do so.

JEL Codes: L51, L95.

1. Introduction

Benchmarking is an important and relevant tool equipping managers and decision makers with powerful information in the form of performance-based rankings. Once performance-based rankings are established, an obvious question arises: What is behind predicted differences in efficiency between firms in an industry? What characterizes firms that perform better than others? What can governments do to increase the efficiency of firms?

Efficiency in this context is defined as a firm's capacity to maximize output given a fixed level of inputs. Specifically, a firm is considered to be efficient when it is producing the maximum amount of output given its input endowment (reflecting past investment and operating decisions). This is a very important policy issue, because the need for water in day-to-day activities must be brought into line with society's limited resources. Can the supply of water be improved with existing resources by tackling the inefficiencies of firms rather than by increasing expenditures? If yes, the starting point is to figure out where these inefficiencies lie. This could be followed by the establishment of mechanisms to incentivize the "best practices" associated with higher efficiency levels and with policies that motivate firms to emulate efficient entities, thereby encouraging them to obtain more output for a given set of inputs. According to Horn and Saito (2011), several countries have adopted the characteristics of successful water utilities ("best practices") to promote performance efficiency. Examples abound: the UK imposed incentive-enhancing regulations (price caps), the Netherlands merged small water utilities to form large water utilities, and France allowed for private sector participation.

The findings of this paper identify major sources of inefficiency for the Japanese water utility sector. Specifically, water purification (a conditioning variable capturing lower initial water quality), subsidies, and outsourcing are associated with higher inefficiency levels, whereas customer density, average operation rate, and size are associated with less inefficiency. Given that Japan currently has a system that essentially entails self-regulation, this paper provides a quantitative study rather than a benchmarking one. A benchmarking study would focus on reasonable targets for developing regulatory incentives, but this is hard to do in Japan given their current regulatory environment. The pattern of inefficiency presented in this paper provides policy makers information on the range of water utility performance; the framework documents the need to develop a regulatory regime that implements cost-containment as an objective, using benchmarking tools.

To my knowledge, this is the first paper to examine factors influencing the inefficiency of Japanese water utility firms using the one-step Stochastic Frontier Analysis (SFA) inefficiency effects model proposed by Battese and Coelli (1995). Other studies have examined Japanese water utilities using several Data Envelopment Analysis and Stochastic Frontier Analysis techniques. The majority of these studies are, however, only available in Japanese, had access to less data, and used older datasets.

2. Background: Japanese Water Utilities and Form of Regulation

In 2005, Japanese water utilities had coverage of 97.2% of total population (Ueda and Benouahi 2009). Water services in Japan are provided by a very large number of suppliers, many of which are very small. The ten largest suppliers provide 28% of output, while the other 1,180 firms provide the remainder. This is a consequence of ownership structures: utilities are mainly owned by the local governments of cities, towns and villages (Ueda and Benouahi 2009). They operate under a municipality-owned principle that promotes independent local monopolies. The distribution of ownership of Japanese water utilities was as follows for the year 2008: 0.3% of firms were owned by prefectures, 1.3% by ordinance designated cities, 52.4% by cities, 42.3% by towns and villages, and 3.7% by wide-range cooperatives (Marques, Berg, and Yane 2011).

Regulation of the water and sanitation sector is the responsibility of the Ministry of Health, Labor and Welfare, Ministry of Land Transportation and Tourism, and Ministry of the Environment. In theory, each utility is supposed to be self-supporting and operate in an efficient manner under the Water Laws, but in practice suppliers engage in self-regulation because there is no oversight function (Marques, Berg, and Yane 2011). Each utility follows a self-supporting accounting principle, meaning that the costs for building their facilities and managing daily operations are covered by the charges paid by water users. In practice these operating revenues are accompanied by subsidies. Under the Water Works Law, Japanese water utility firms are required to follow rules regarding the rates that can be charged and these rates must be "reasonable." Whenever the water rates change, these changes require the approval of the Ministry of Health, Labor, and Welfare (Kusuda 2011). Specific oversight regarding firm performance and widespread use of benchmarking tools does not seem to exist at this point. Each firm operates "independently" from other firms and there is no independent regulatory commission to provide oversight.

The Ministry of Internal Affairs and Communication is in charge of collecting data and providing performance indicators for water utilities. These performance indicators consider just one characteristic at a time, and include variables such as water losses, financial performance, and revenue collection. Because these indicators examine just one characteristic at a time, they do not allow for direct comparisons between firms. As noted by Marques, Berg, and Yane (2011, p.6) "if estimates are to be used by policy-makers to reward or punish firms, they must control for elements beyond managerial control." Japan presents an interesting case in a regulatory sense because it offers lots of transparency in regards to data availability and collection but the government has done very little in regards to firm accountability and data-driven performance analysis.

Recent studies analyzing Japanese water utilities use a variety of techniques. Marques, Berg, and Yane (2011) apply non-parametric Data Envelopment Analysis (DEA) to the same dataset used in the present paper using a new technique that takes into account exogenous variables one at a time. Aida et al. (1998) evaluate the performance of water suppliers in Japan using a range-adjusted measure of efficiency for the year 1993. Yane and Berg (forthcoming 2013) use a translog production function to examine the robustness of efficiency score rankings using different distributional assumptions in a Stochastic Frontier Analysis setting[1]. Mizutani and Urakami (2001) study water utilities in Japan with an emphasis on size and scale economies. They conclude that the optimal size of a water supply system in Japan is more than 10 times greater than the average size of even the large water supply systems at the time, so they note that scale is an issue. Urakami and Parker (2011) examine the effects of consolidation amongst Japanese water utilities, using translog cost functions with a sample from 1996 to 2006. They find that consolidation had a small but beneficial impact on cost effectiveness; they believe that the cost savings were offset by extra expenditures incurred by having to supply water to areas with low population density. Horn and Saito (2011), estimate cost efficiency and scale economies using SFA for a sample from 1999-2008. This paper differs from Horn and Saito (2011) in that it examines a production function (rather than a cost function) and analyzes

[1] The focus of the Yane and Berg (forthcoming 2013) paper is on the robustness of efficiency score rankings across different specifications for SFA models. The present paper focuses on policy implications of inefficiency effects. The Yane and Berg paper does not explore specific policy implications for the Japanese water utility sector because it focuses on the methods used and robustness when different distributional assumptions are utilized in correcting for heteroscedasticity. Yane and Berg narrowly focus on error terms associated with doubly heteroscedastic SFA.

inefficiency effects in addition to inputs. The main contribution of this paper to the benchmarking literature of water utilities in Japan consists on identifying factors contributing to inefficiency. This is followed by policy implications.

3. Stochastic Frontier Models.

The majority of studies measuring technical efficiency use either DEA, a non-parametric method or SFA, a parametric method. Stochastic frontier models were first developed by Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977). The main difference between SFA and Ordinary Least Squares (OLS) lies in the presence of a one-sided error term. In SFA there are two error terms: the OLS random error term representing noise and an additional error term representing productive inefficiency. Unlike OLS, these models assume that firms can be inefficient and predict efficiency scores for each firm[2].

An obvious next step in this regard is to try to understand the factors influencing these inefficiencies. Two approaches have been followed in the literature when trying to explain firm inefficiencies: a one-step and a two-step approach. Earlier studies focus on a two-step approach consisting of a stochastic frontier model in the first stage typically followed by a regression of the inefficiency effects predicted by that first stage against exogenous variables such as firm size, age of employees, etc. in the second stage. These models attempt to provide an explanation for the *predicted* inefficiencies affecting the firm. For example, Pitt and Lee (1981) study firm ownership, age, and size as sources of inefficiency for the Indonesian weaving industry.

This approach is no longer recommended because it results in a contradiction of an important statistical assumption. The first stage involves specifying and estimating a stochastic frontier function and predicting technical efficiency effects assuming that these efficiency effects

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[2] If all firms were able to operate at the frontier (i.e., be fully efficient), SFA would not be required.

are identically distributed, but the second stage involves specifying a regression model for the *predicted* technical efficiency effects, contradicting the assumption of identically distributed efficiency effects in the stochastic frontier (Battese and Coelli 1995). According to Coelli et al. (2005), failing to include environmental variables in the first stage can lead to biased estimators of the parameters and to biased predictors of efficiency.

Schmidt and Wang (2002) examine one-step and two-step approaches and provide Monte Carlo evidence in favor of one-step approaches. They also find that two-stage approaches lead to biased estimates, and that these biases are substantial. Both authors suggest a one-step approach. In a one-step approach, environmental variables are allowed to directly affect the stochastic component of the production frontier (Coelli et al. 2005). In these models, both the stochastic frontier and the way in which the one-sided error depends on environmental variables can be estimated in a single step (Schmidt and Wang 2002). There are several studies examining efficiency effects using a one-step approach. For instance, Iraizoz et al. (2005) examine the influence of age, debt, and other variables on inefficiencies for the Spanish beef sector in the 1990s. Zhu, Karagiannis, and Lansink (2011) examine the impact of income transfers, farm size, degree of specialization, and other variables on the technical efficiency of Greek olive farms. To my knowledge, this is the first paper applying this method to Japanese water utility firms.

4. Empirical Model

Battese and Coelli (1995) Model

This paper follows a one-step stochastic frontier approach for measuring inefficiency effects proposed by Battese and Coelli (1995). The general form of the model, presented in Battese and Coelli (1995), considers a stochastic frontier production function for panel data of the form:

$$Y_{it} = \exp(x_{it}\beta + V_{it} - U_{it}) \quad (1)$$

Where Y_{it} denotes the production at the t-th observation (t = 1,2, … T) for the i-th water utility firm (i= 1, 2, …N);

x_{it} is a (1 x k) vector of values of known functions of inputs;

β is a (k x 1) vector of unknown parameters to be estimated;

the V_{it}'s are assumed to be i.i.d. $N(0,\sigma^2_v)$ random errors, independently distributed of the U_{it}'s;

the U_{it}'s are non-negative random variables, associated with technical inefficiency of production, which are assumed to be independently distributed, such that U_{it} is obtained by truncation (at zero) of the normal distribution with mean, z_{it} and variance σ^2. $U_{it} \geq 0$ reflects the fact that the output of each water utility firm should be either on or below its frontier. When $U_{it} = 0$, the production unit lies on the frontier. When $U_{it} > 0$, the production unit is not fully efficient and must be operating somewhere below the frontier (Iraizoz et al. 2005).

As mentioned earlier, the stochastic frontier production function is given by equation (1). The technical inefficiency effects (given by U_{it}'s) are assumed to be a function of a set of explanatory variables (z_{it}'s) and an unknown vector of coefficients (δ) to be estimated (Battese and Coelli 1995). The technical inefficiency effects in the stochastic frontier model presented in (1) have the following specification:

$$U_{it} = z_{it}\delta + w_{it} \qquad (2)$$

Where z_{it} is a (1 x m) vector of explanatory variables associated with technical inefficiency of production of firms over time;

δ is an (m x 1) vector of unknown parameters to be estimated; and

w_{it} is a random variable defined by the truncation of the normal distribution with 0 mean and variance σ^2 (Coelli 1996).

This model uses the maximum likelihood method for simultaneous estimation of the parameters of the stochastic frontier and the model for technical inefficiency effects (Battese and Coelli 1995). Battese and Coelli (1995) define the technical efficiency of production for the i-th firm at the t-th observation as follows:

$$TE_{it} = \exp(-U_{it}) \tag{3}$$

In this context, technical efficiency is defined as a variable taking a value between 0 and 1 and measuring the output "of the i^{th} firm relative to the output that could be produced by a fully efficient firm using the same input vector" (Coelli et al. 2005). Recall that a fully efficient firm that is lying on the frontier has $U_{it} = 0$. This implies a technical efficiency score of 1 since $TE_{it} = \exp(0) = 1$. Firms with technical efficiency scores closer to 1 are more efficient, while firms with technical efficiency scores closer to 0 are less efficient.

Alternative models that have been used to estimate production functions include DEA and OLS. The main merit of using a one-step SFA approach when compared to OLS is that OLS assumes that all firms are efficient. This is a very strong assumption to make, particularly in the Japanese water utilities sector, which is characterized by independent local monopolies.

Lovell (1994) and Coelli et al. (2005) suggest that both DEA and SFA have advantages and disadvantages and that neither approach strictly dominates the other. The main merit of using a one-step SFA approach when compared to DEA is that it accounts for noise and allows for statistical inference. The main demerit is that the researcher must specify a distributional and functional form. DEA does not require the researcher to impose distributional and functional forms. Newhouse (1994) criticizes SFA specifically because there is no a priori justification for using any particular distribution when estimating technical inefficiency effects. A common approach is to utilize a specification based on how often it is used in the literature, but this approach does not really solve the problem (Rosko and Mutter 2008).

The two most commonly assumed functional forms for SFA production functions are Cobb-Douglas and translog. This paper utilizes a Cobb-Douglas specification, but it is important to note that other functional forms could have been adopted. Using a "wrong" (or inappropriate) functional form would result in unreliable estimates. According to Coelli et al. (2005), when choosing a functional form, preference is usually given to those that are flexible, linear in the parameters, regular, and parsimonious. The translog functional form is more flexible than the Cobb-Douglas functional form, but increased flexibility comes at a cost in the form of having more parameters to estimate which can give rise to econometric difficulties (Coelli et al. 2005). For this specific dataset and model, an alternative translog specification was tested, but the estimations did not converge[3].

Yane and Berg (forthcoming 2013) use a different SFA model assuming a translog production function to examine the robustness of efficiency score rankings using different distributional assumptions with a similar dataset to the one in this paper but encompassing a shorter time span. An important conclusion of that paper is that governments should apply incentives in a manner that can be supported by *performance patterns* rather than individual scores. Their paper underscores the potential sensitivity of efficiency scores to

[3] These models are estimated using the maximum likelihood method. The "maximum likelihood estimate of an unknown parameter is defined to be the value of the parameter that maximizes the probability (or likelihood) of randomly drawing a particular sample of observations" (Coelli et al. 2005). For a well-behaved linear function, maximization usually involves taking first derivatives with respect to unknown parameters and setting them equal to zero. However, because these specific problems cannot be solved analytically (given the existing non-linearities and the large number of parameters) iterative optimization procedures are used. Essentially, a computer program selects starting values for these unknown parameters and updates them until the values that maximize the log likelihood function are obtained (Battese and Coelli 2005). Unfortunately, sometimes iterative optimization procedures do not converge to a maximum at all. In other words, the computer program is unable to find the values that maximize the log likelihood function, which is what happened with the translog specification for this paper using the selected distributional assumptions.

heteroscedasticity correction schemes for the translog specification. The present study uses more years and the Cobb-Douglas specification to avoid this problem. Note that a single study of Japanese utilities is unlikely to provide a definitive calculation of individual utility efficiency scores, but patterns can be identified that shed light on factors affecting efficiency.

It is important to emphasize that this model differs from other SFA models in that the U_{it}'s are a function of explanatory variables (z_{it}'s)[4]. This allows for the estimation of inefficiency effects for the firms being studied. I estimate the following Cobb-Douglas stochastic frontier production function:

$$lnY_{it} = \beta_0 + \beta_1 \ln(K_{it}) + \beta_2 \ln(L_{it}) + \beta_3 \ln(O_{it}) + \beta_4 \ln(P_{it}) + V_{it} - U_{it} \quad (4)$$

where the technical inefficiency effects are assumed to be defined by:

$$U_{it} = \delta_0 + \delta_1(aveop_{it}) + \delta_2(watpurif_{it}) + \delta_3(rout_{it}) + \delta_4(rsubp_{it}) + \delta_5(cusden_{it}) + \delta_6(size_{it}) + \delta_{7to12}(Regional\ dummies) + W_{it} \quad (5)$$

where ln denotes the logarithm with base e.

The variable definitions for the production function are as follows:

Output:

Y	Total delivered water volume in a year [1000m^3]

Inputs[5]:

K	Length of pipe [1,000m]
L	Total number of full time equivalent staff (including estimated staff from outsourcing[6])

[4] The z_{it}'s are referred to as the "inefficiency effects model variables" throughout this paper.

[5] This paper uses the same output and inputs as Yane and Berg (forthcoming, 2013). For input observations that have original values of zero, I adopt the standard practice of calculating log values by adding one to these original values.

O	Self-produced intake water capacity (total intake water capacity minus purchased water capacity[7]) [1,000m^3]
P	Purchased water capacity [1,000m^3]

The definitions for the inefficiency effects variables are as follows:

Regional dummies	Dummies for Japanese regions.
Aveop	Average operation rate, defined by average delivered water volume per delivered water capacity [%]
Watpurif	Water purification, defined by raw water and purification chemical expenditures per intake water volume [¥/1000m^3]
Rout	Outsourcing ratio, defined by the ratio of number of staff based on outsourcing to the number of total staff [%]
Cusden	Customer density, defined by the number of customers per length of pipe [person/1000m]
Size	Intake water volume [1000m^3]
Rsubp	Subsidy ratio on profit and loss account, defined by the sum of subsidies on profit and loss account per water supply revenue.

Length of pipe was used as a proxy for capital. A typical water utility's capital stock consists of pipes, pumps, storage and treatment facilities, buildings, and equipment. Given that data on these are seldom available, length of pipe is often used to proxy for each firm's capital stock. According to Corton (2011), the rationale for using network length as a proxy for capital in the water sector is that the amount of capital needed to lay down pipes is significantly higher

[6] Estimated staff from outsourcing is calculated following Yane and Berg (forthcoming, 2013). Virtual staff is calculated by dividing outsourcing expenditures by payment per employee in each prefecture.

[7] Total Intake Water Capacity = Self-produced capacity + Purchased water capacity

when compared to the capital needs of other types of network developments such as installing pumps or treatment facilities. Some limitations of this approach are that it assumes that the quantities of other capital items are used in proportion to pipes and that it does not account for differences between old and new pipes.

The focus of this paper is on the identification and policy implications of the inefficiency effects and not on identifying the most efficient producers or providing rankings of Japanese utility firms. I use a balanced panel consisting of 1,190 water utility firms over a four year period totaling 4,760 observations for the years 2004-2007. The data are from the "Annual Statistics of Public Enterprises" publication (Chihou Kouei-Kigyou Nenkan). Summary statistics are provided in Table 1. The model was estimated using Frontier 4.1. software developed by Tim Coelli. Table 2 presents estimates using OLS. Recall that OLS assumes that all firms are efficient (i.e., all firms are operating at the frontier). The coefficients estimated for both the production function and inefficiency effects model are presented in Table 3.

The first step is to test whether Stochastic Frontier Analysis is necessary. Since in stochastic frontier models the composite error is given by $V_{it} - U_{it}$, one can essentially test whether the U_{it} part of the model is necessary. If it is not necessary, OLS would provide consistent estimates, because there would not be a need for an inefficiency component. The estimate for gamma[8] is 0.29 (t-stat 5.09). Thus, gamma is statistically different from zero at the 1% level. This means that at least some of the variation in the composite error term is due to the inefficiency component, and that SFA is preferred over OLS.

[8] Where gamma is defined as $\gamma = \sigma_u^2 / \sigma^2$ and varies from 0 to 1. A gamma value of 0 would indicate that OLS provides consistent estimates.

As noted earlier, one of the disadvantages of SFA is that different distributional assumptions can result in different predictions of technical efficiency. Since this model specification does not have the Battese and Coelli (1992) model as a special case and is non-nested, it does not have a set of restrictions that can be defined to permit a test of one specification versus another (Coelli 1996). A few alternative specifications are available from the author upon request.

The mean efficiency score for Japanese firms in the four year sample was 0.54. Figure 1 provides a graphical representation of the distribution of efficiency scores for the year 2004. The least efficient firm had a score of 0.09, while the most efficient firm had a score of 1 (i.e., fully efficient). The score for the least efficient firm is extremely low, indicating that the firm could reduce usage of inputs by 91%. Since that particular firm's performance is probably driven by omitted variables, such an extreme outcome illustrates why the focus here is on "patterns" rather than on specific scores. Summary statistics for predicted efficiencies are available in Table 4.

Production Function

As expected, the inputs have a positive impact on output. All inputs are statistically significant at conventional levels. An increase of 1% in length of pipe (K), for instance, is associated with an increase in total delivered water volume of 0.33%.

Inefficiency Effects

As mentioned earlier, the main focus of this paper consists on analyzing the factors contributing to inefficiencies in Japanese water utility companies. Several factors influence technical inefficiency according to the estimates from Table 3. The average operation rate, customer density and size variables are associated with lower levels of inefficiency (or higher levels of efficiency). The water purification, subsidy and outsourcing ratio variables are associated with higher levels of inefficiency. The numbers in Table 3 show only the direction of the effects and should not be interpreted as marginal effects.

The subsidies variable (rsubp) is positive and significant, implying that firms with higher levels of subsidies are more inefficient. Currently, the subsidy schemes for investments and operations come from two separate sources of funds and do not seem to be directed at rewarding strong performance. Scotti et al. (2012) rule out the possible endogeneity between inefficiency and airport subsidies, based on the decision for subsidies being mainly a political one (and not one that is taken on the basis of efficiency reasons). I check for patterns in subsidy distribution and efficiency by examining the top 40 and bottom 40 firms efficiency-wise (available upon request). There is no visible pattern, suggesting that subsidy decisions are not based on efficiency levels. The results of this paper seem to be consistent with subsidies causing inefficiency, but it is important to note that causation has *not* been proven. Furthermore, because these are public utility firms providing an essential service, bankruptcy is politically infeasible and subsidies would be expected to flow as needed. Based on the literature examining stochastic frontier analysis efficiency effects models, it is expected that subsidies will decrease technical efficiency. Rezitis, Tsiboukas, and Tsoukalas (2003) find that European Union subsidies for farmers are associated with decreases in technical efficiency. This is attributed to subsidies decreasing farmers' incentives to achieve higher productivity and profitability, in turn reducing their motivation for improving efficiency in the production process. Zhu, Karagiannis, and Lansink (2011) study direct income transfer subsidies on Greek olive farms and find a negative impact on technical efficiency. They suggest that the motivation for improving technical efficiency is lower when subsidies are available. The findings for Japanese water utilities are consistent with the literature.

The average operation rate variable (aveop) is a measure of capital utilization. It is expected that the more a utility uses its capacity the more efficient the firm will be (Horn and Saito 2011). This variable has a negatively significant coefficient, indicating that firms with more average water delivered per delivered water capacity tend to be less inefficient (more efficient). This result is expected, since these are firms that are operating at a higher capacity level and thereby making better use of their available resources. These results are consistent with the Urakami and Parker (2011) study which finds that high capacity utilization has a positive impact on cost savings of 26% per year.

The customer density variable (cusden) has a negative coefficient. According to this model, firms with greater customer density tend to be less inefficient (more efficient). Again, this result is as expected. Assuming a fixed network length, for instance, adding more and more customers should translate into higher levels of output given these fixed input levels.

In relation to scale (size), larger firms are expected to be more efficient (at least up to a point) if economies of scale are present. The results are negatively significant, implying that larger firms tend to be less inefficient (more efficient) than smaller sized firms for the sample studied. This result is consistent with Mizutani and Urakami's (2001) study which finds that firms in Japan are much smaller than the optimal size. More recently, Urakami and Parker (2011) also find that there are economies of scale for water utilities in Japan. Horn and Saito (2011) find economies of scale for small water utilities but suggest that scale diseconomies are likely to be present for larger utilities. It is important to note that the government of Japan has already started to address this issue: Urakami and Parker (2011) mention that consolidation efforts have taken place for political rather than economic reasons. Specifically, in 1999 under the Great Heisei Era Consolidation, the Japanese "Municipal Merger Law" was amended so that local governments could be consolidated into large authorities. Thanks in part to this law, the number of Large Water Suppliers fell from 1,958 in the year 2000 to 1,602 in 2005 (Urakami and Parker 2011). The results of this paper suggest that further consolidation may be beneficial.

Water purification (watpurif), a conditioning variable capturing lower initial water quality, is positively significant. This result implies that firms with higher purification expenditures (i.e., firms with lower initial water quality) are more inefficient. This is expected since higher water purification expenditures would indicate that relatively more resources are needed for water purification. Lower initial water quality is, thus, associated with lower measured efficiency.

Outsourcing was also examined. According to Ueda and Benouahi (2009), outsourcing in Japanese water companies takes place for (1) routine operation and maintenance of treatment plants and network pipes, (2) checking and executing repair works, (3) engineering design and construction supervision, (4) information and telecommunication technology services, and (5) metering and billing. Entire operations can be outsourced to other utility companies or to private companies. There are several hypotheses regarding both the advantages and disadvantages of outsourcing and privatization in the literature. On the one hand, it is expected that contracting out services to private firms would increase the efficiency of water utilities by allowing them to concentrate their energies on core tasks. Outsourcing arrangements may also provide access to technology, equipment, and expertise not available in the water utility (Lee and Jouravlev 1997 cited in Baumert and Bloodgood 2004). On the other hand, when water supply activities are outsourced, local governments face problems of information asymmetry and incomplete contracts (Williamson 1976 cited in Perard 2009). This situation can lead to high transaction costs.

Theories about ownership in the case of monopoly markets remain ambiguous and cannot completely explain the choice of privatization/delegation in the water supply industry (Perard 2009). The analyses of water utility outsourcing functions, concessions and privatization have seen mixed results over the years. As stated by Perard (2009), privatization is considered advantageous due to benefits stemming from efficiency in a *fully competitive market* where private ownership would be more efficient than public ownership. However, this conclusion is not as clear for less competitive markets with network scale economies, like water supply[9]. Empirical studies listed by Perard (2009) confirm mixed results for the theory. In a study of African water utilities, Estache and Kousassi (2002) find that private operators are more cost-efficient. In a different study of African utilities, Kirkpatrick, Parker, and Zhang (2004) find no significant difference between public and private water utility operators. Studies of Argentinean water utilities find both positive and negative effects in performance stemming from the introduction of private sector participation (Saltiel 2003, Rais, Esquivel and Sour 2002 and Artana, Navajas, and Urbiztondo 1999).

Outsourcing of functions of Japanese water utilities started in 2001 with an amendment to the Water Act (Urakami and Parker 2011) and has been increasing steadily over the years. Increases in outsourcing in Japan are attributed to natural attrition of in-house career staff (Ueda and Benouahi 2009). This is consistent with a 2004 report by the Ministry of Health, Labour, and Welfare presented in Water Works Vision (2004) which lists “aging workforce” as one of the challenges facing Japanese water companies. The outsourcing ratio variable (rout) is positive and significant, implying that firms with more outsourcing are more inefficient. These results

[9] Perard also discusses why introducing competition for the market doesn’t solve this problem. Readers are referred to Perard (2009) for more information on this topic and for a complete summary of the results of privatization in different countries.

suggest that policymakers should be careful when proposing outsourcing, as it is currently set up, as a solution to the "aging workforce" problem. Note, however, that it may be too early to assess the impact of outsourcing in Japan[10]. Furthermore, these results differ slightly from the Marques, Berg, and Yane (2011) study which finds that outsourcing has mixed effects for Japanese water utilities. Further studies regarding Japanese outsourcing are suggested.

Finally, the coefficients used to test differences based on regional location are for the most part negative and significant (though some regional dummies are insignificantly different from zero). Since the omitted region was region 1 (Hokkaido), these results are all relative to the northernmost island[11]. This result suggests that technical efficiency varies somewhat systematically across regions, with Hokkaido being associated with "less efficient" utilities. This is expected given the differences in weather, topography, geography, natural resources, etc. Since this factor is exogenous, labeling it as causing "inefficiency" is somewhat problematic. More resources are required in some regions to produce the same output. So, again, the inclusion of explanatory factors in the model requires some care when interpreting performance for any particular utility.

5. Policy Implications and Conclusion

This paper identifies the major sources of inefficiency for Japanese water utilities. Clearly, there is a large set of firms with efficiency indices between 0.8 and 1.0, but there are still a number with scores of less than 0.5. Of course, some of what is labeled "inefficiency" in this quantitative analysis stems from factors beyond a manager's control, like customer density or whether the utility is on Hokkaido or South Kyushu. Nevertheless, an independent water

[10] Even though anecdotal evidence suggests that the outsourcing decision is due to an aging workforce there is a possibility that inefficient firms may be precisely the ones turning to outsourcing, so causation is reversed. Therefore, it is conceivable that this result could stem from endogeneity, where firms that experience relatively high costs turn to outsourcing. More research is needed to resolve the issue of causation.

[11] A listing of the regions is available upon request.

regulator (as opposed to a Ministry led by the party in power) could be a position to seek explanations for particular scores, placing the burden of proof on managers whose utilities have particularly weak performance. The results of this paper suggest that more comprehensive studies should be conducted to promote efficiency improvements in the water utility sector. Subsequent improvements in efficiency scores would imply that resources were being used more effectively. An autonomous regulatory agency could operate with greater transparency, perhaps helping develop subsidy schemes with better incentives than at present. An independent regulator would be able to tackle several problems commonly associated with government owned utilities such as being subject to short term political goals and provider capture. The use of independent regulators for state-owned and municipal utilities is not uncommon: independent regulators have been established in several countries. In Jamaica, for example, the Office of Utility Regulation regulates the government owned National Water Commission, and in Colombia, the Regulatory Commission for Water and Basic Sanitation Services sets tariffs for municipally owned water utilities (Groom et al 2006).

The findings of this paper suggest that water purification expenditures (indicating lower initial water quality), subsidies, and outsourcing are associated with higher inefficiency levels, while customer density, average operation rate, and size are associated with less inefficiency. As mentioned earlier, a 2004 report by the Ministry of Health, Labour, and Welfare presented in Water Works Vision (2004) lists “aging workforce” as one of the challenges facing Japanese water companies. The findings from this paper suggest that outsourcing as a strategy to combat this problem should receive closer examination. If comparable data from before 2001 become available, a study comparing inefficiency during the years before and the years after outsourcing was implemented could provide policymakers with useful information regarding this strategy.

Another important issue that calls for further examination is that of centralization, decentralization, and consolidation. Is it better to have a few large firms or many small individual firms? Ueda and Benouahi (2009) argue that one of the items that the Japanese water utility system is able to deliver is municipality-based utilities tailored to unique local settings. This is a point that requires closer examination. The benefits from having “locally tailored utility companies” must be compared to the potential benefits from economies of scale, including shared specialized infrastructure professionals and other forms of utility collaboration. Several countries have noticed this and have been involved in attempts to consolidate utility firms into larger entities. These actions were directed at improving economic performance by achieving economies of scale and scope (Urakami and Parker 2011). The results of this paper in regards to size suggest that Japan’s strategy of consolidating water utilities is a good one and that these efforts should be continued in the future. Note, however, that utilities that are extremely large could result in inefficiencies as well. As noted by Horn and Saito (2011) when utilities become larger, it is possible that their service areas also expand, which could, in turn, have negative consequences for efficiency and costs. This process could explain Urakami and Parker’s (2011) finding, which suggests that consolidation had a small but beneficial impact on cost effectiveness, given the possibility that cost savings were offset by extra expenditures incurred by having to supply water to areas with low population density. In other words, it is beneficial for water utilities to expand to an optimal size, rather than to the largest extent possible (Horn and Saito 2011).

As mentioned earlier, a limitation of this study is that the results are based on a Cobb-Douglas production function. This is an important issue because an incorrect specification of the production function would undermine the results. For this reason, it is necessary to focus on performance patterns in efficiency, and to look at these results in addition to the results of other papers examining the Japanese water utilities sector.

Benchmarking is an important activity that can “help reduce the information asymmetry between managers and those providing oversight” (Berg 2010, p.114). In this paper, I have identified major sources of inefficiencies for Japanese water utilities. Frontier inefficiency analysis has two important applications: (1) informing government policy (specifically in regards to regulation), and (2) Improving managerial performance by identifying “best practices” to be emulated (Berger and Humphrey 1997). Further examination of the variables found to be influencing technical inefficiency, particularly those that are under managerial control, is recommended[12]. Once this is carried out, firms far from the frontier could be provided with incentives to improve. In addition to this, other policies could be implemented to raise efficiency. This is particularly important for Japan, given its declining and aging population, increasing water costs, and current water utility industry forecasts: According to Data Monitor (2010), the Japanese water utilities industry is forecast to have a volume of 84.8 billion cubic meters in 2014, a decrease of 3.3%. One policy response to this forecast would be to identify inefficiencies and tackle them by providing incentives to improve performance. In order to do this, there needs to be a stronger emphasis on performance-based regulatory oversight of Japanese water utilities.

[12] Certain characteristics influencing efficiency are clearly outside of managerial control. Customer density, for instance, depends on where customers decide to live. It would be illogical to suggest improvements in efficiency based on increases in customer density to a manager, particularly in rural towns facing emigration towards the big cities.

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6. Tables and Figures

Table 1. Summary statistics

Variable	Mean	Standard Deviation	Min	Max
[Production Function in Ln form]				
LnY	8.41	1.23	4.32	14.3
LnK	5.52	1	0.19	10.18
LnL	3.13	1.24	0.11	9.17
LnO	7.88	2.66	0	14.76
LnP	4.31	4.32	0	12.91
[Production Function]				
Y	12,588.87	55,733.75	75	1,624,646
K	462.06	1,042.52	1.21	26,312.52
L	69.9	324.88	1.11	9,557.68
O	15,247.28	85,905	0	2,579,742
P	5,930.73	21,911.43	0	403,043.7
[Inefficiency Effects]				
Aveope	60.24	11.79	10.3	120.6
Watpurif	0.49	0.8	0	17.03
Rout	0.38	0.14	0	0.87
Cusden	159.78	250.23	12.74	11,463.64
Size	12,927.73	56,655.24	0	1,700,000
Rsubp	0.07	0.17	0	2.66
Regional dummies	*	*	0	1

Notes: N=4,760

Table 2.OLS estimates

	Variable	Coefficient	t-ratio
β_0	Intercept	4.2768***	107.50
β_1	lnK	0.3360***	30.37
β_2	lnL	0.6573***	69.28
β_3	lnO	0.0172***	7.08
β_4	lnP	0.0206***	14.38

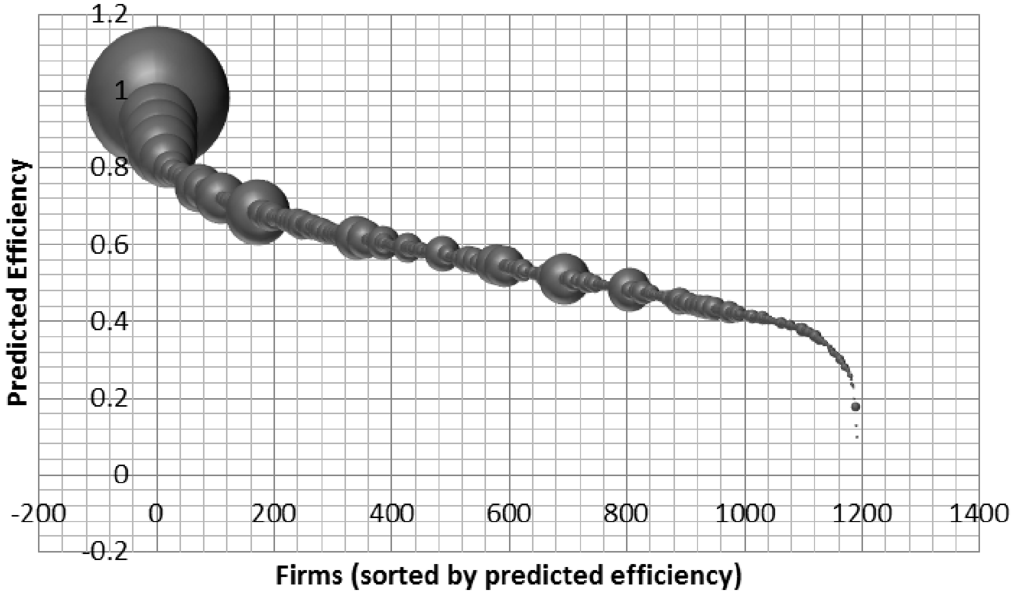
Notes: N = 4,760, R-squared = 0.9206

Table 3. Stochastic frontier estimates: Inefficiency effects model using regional dummies and allowing for delta 0

	Variable	Coefficient	t-ratio
[Production Function]			
β_0	intercept	5.0136***	72.32
β_1	lnK	0.3653***	34.54
β_2	lnL	0.5961***	71.99
β_3	lnO	0.0166***	7.29
β_4	lnP	0.0077***	5.62
[Inefficiency Effects]			
δ_0	intercept	1.0233***	17.42
δ_1	aveop	-0.0037***	-10.24
δ_2	watpurif	0.0888***	16.56
δ_3	rout	0.2201***	6.94
δ_4	rsubp	0.5536***	21.03
δ_5	cusden	-0.0003***	-20.12
δ_6	size	10^{-6} x -0.9507***	-10.59
δ_7	Region 2 dummy	-0.0372	1.52
δ_8	Region 3 dummy	-0.0746***	-3.4
δ_9	Region 4 dummy	-0.3048***	-15.41
δ_{10}	Region 5 dummy	-0.3543***	-14.36
δ_{11}	Region 6 dummy	-0.3543***	-15.15
δ_{12}	Region 7 dummy	-0.5095***	-23.22
δ_{13}	Region 8 dummy	-0.3538***	-17.12
δ_{14}	Region 9 dummy	-0.2041***	-8.8
δ_{15}	Region 10 dummy	-0.3615***	-15.25
δ_{16}	Region 11 dummy	-0.0951***	-4.6
δ_{17}	Region 12 dummy	-0.1779***	-7.36
δ_{18}	Region 13 dummy	-0.3094***	-8.69

N =4,760, T=4, cross-sections: 1,190.

Figure 1: Sample Efficiency Scores and Output for the year 2004.



Notes: A firm with an efficiency score equal to 1 is fully efficient. The observations are weighted by percent of total water delivered and firms are sorted from most efficient to least efficient.

Table 4. Summary statistics for efficiency scores and output

Variable	Mean	Standard Deviation	Min	Max
[Year 2004]				
Output	12,418.14	56,034.32	222	1,624,602
Ln Output	8.4	1.22	5.4	14.3
Efficiency Score	0.55	0.13	0.1	0.98
[Year 2005]				
Output	12,711.47	55,915.39	226	1,615,886
Ln Output	8.42	1.23	5.42	14.3
Efficiency Score	0.54	0.13	0.1	0.98
[Year 2006]				
Output	12,609.08	55,528.16	75	1,606,415
Ln Output	8.41	1.24	4.32	14.29
Efficiency Score	0.54	0.13	0.09	1
[Year 2007]				
Output	12,575.38	55,433.07	81	1,606,804
Ln Output	8.41	1.24	4.39	14.29
Efficiency Score	0.54	0.13	0.15	1
[All Years]				
Output	12,578.52	55,710.86	75	1,624,602
Ln Output	8.41	1.23	4.32	14.3
Efficiency Score	0.54	0.13	0.09	1