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Abstract

This study examines whether the Japanese scheme of nontransferable water rights results in technical inefficiency. Using data on 1,263 Japanese retail water suppliers for 2008, their technical efficiency is measured employing data envelopment analysis. Next, a bootstrapped truncated regression model is specified to examine the determinants of technical efficiency. The estimation results reveal that the nontransferability of water rights leads to technical inefficiency of retail water suppliers. Furthermore, the costs of this efficiency amount to about 462 billion yen. This result suggests the government should reallocate water rights flexibly in order to ensure efficiency.

Keywords: bootstrapped truncated regression, data envelopment analysis, technical efficiency, water rights
JEL Classification: Q25, L51, L95

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1 Introduction

Water rights, the rights of users to use water from a water resource, determine water allocation, sometimes resulting in overuse of land and suboptimal adoption of water conservation. Caswell and Zilberman (1985, 1986), for example, examine the choice of irrigation technologies in California and suggest that the adoption of inefficient technologies is caused by a water rights regime which prevents water from being allocated according to the marginal willingness to pay for water.

In Japan, water rights are not transferable across retail water suppliers. The government sets strict guidelines on the daily and annual amounts of water that retail suppliers need to supply and regulates the purpose for which they can supply water. Moreover, the government prohibits water users with water rights from not exercising their water rights, rescinding water rights when they are not used. In addition, the government has not established a water trading scheme among retail water suppliers, so that suppliers cannot buy and sell water access entitlements. Furthermore, because of the difficulties of water resources development, suppliers rarely obtain new water rights. This rigid regime provides them with an incentive to retain water rights.

Studies suggest that this lack of transferable water rights likely results in considerable inefficiency. Rosegrant and Binswanger (1994), as well as Fisher (1995), applying the Coase theorem and focusing on developing countries, for example suggest that transferable water rights could improve efficiency and sustainability of water use. Other studies on the issue of water rights include those by Peterson et al. (2004), who examine the benefits of water trade in Australia, and Grafton et al. (2011), who compare the gains from water trade in Australia and the western United States. While these studies produce interesting results on the efficiency of water resource usage, none of these studies consider the efficiency of water suppliers.

There are, however, a number of studies on the relationship between the regulatory scheme and the efficiency of water suppliers, but they do not allow the formulation of stylized facts.[1] Aubert and Reynaud (2005), for instance, focusing on the state of Wisconsin in the United States, find that rigorous regulation results in more efficient water suppliers. On the other hand, Byrnes et al. (2010), focusing on husbanding water policies in New South Wales and Victoria, suggest that rigorous regulation results in less efficient water suppliers.

In the Japanese context, there appear to be a few published studies on the water supply industry. Nakayama (2002), for example, measures the economic efficiency of retail water suppliers, while Mizutani and Urakami (2001) and Kuwahara (2008) examine economies of scale in the industry. However, these studies provide little analysis on the determinants of efficiency and do not focus on the regulatory regime and the efficiency of Japanese water suppliers.

The purpose of this study is to examine whether the Japanese regulatory scheme with nontransferable water rights causes technical inefficiency, based on the two-stage procedure proposed by Simar and Wilson (2000, 2007). First, using data on 1,263 Japanese retail water suppliers for 2008, data envelopment analysis (DEA) is employed to obtain an index of technical efficiency. Second, a bootstrapped truncated regression model is specified in order to examine the determinants of the DEA efficiency index. The estimation reveals that the scheme of nontransferable rights leads to technical inefficiency of retail water suppliers. Furthermore, the costs of this inefficiency amount to about 462 billion yen when compared with a counterfactual scenario in which water rights are reallocated in order to raise the efficiency of the water supply industry.

This result suggests that the government should reallocate water rights flex-

[1]Most studies on the efficiency of water suppliers focus on the effect of different ownership types and therefore are not directly relevant to this paper.

ibly in order to ensure efficiency. It could do so by allowing water suppliers to trade in water rights. The underlying rationale would be the Coase theorem, which states that bargaining will lead to an efficient outcome regardless of the initial allocation of property rights. The reallocation of water rights through the introduction of a trading scheme could improve water suppliers' technical efficiency and achieve Pareto efficiency.

This paper is organized as follow. Section 2 provides a brief overview of the Japanese retail water supply industry. Section 3 then outlines the methodology used for the analysis, explaining how technical efficiency is measured using DEA and presenting the regression model to examine the determinants of efficiency. Next, Section 4 describes the dataset and presents the estimation results, while Section 5 assesses the technical inefficiency caused by the nontransferable water rights scheme. Section 6 concludes.

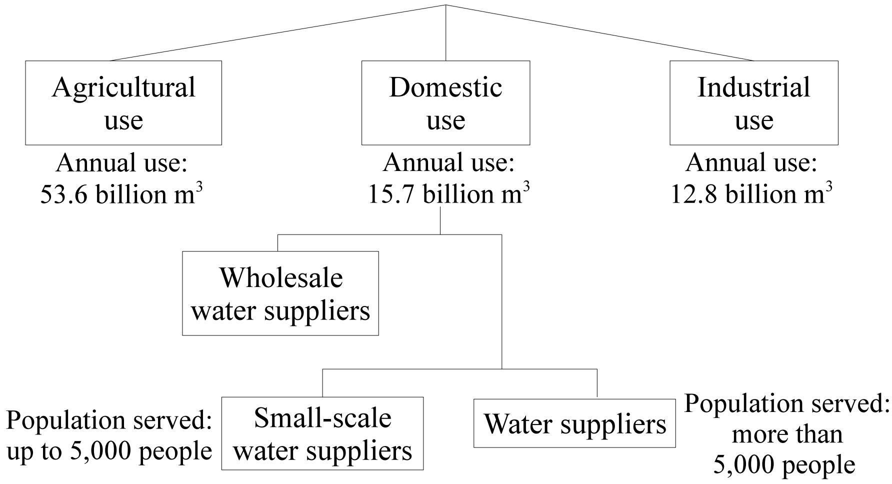
2 Industry Background

2.1 Types of water utilities

Water suppliers provide their services for certain purposes. Figure 1 depicts the range of services provided by water suppliers. Water use in Japan divides broadly into three categories: agricultural use, industrial use, and domestic use, respectively accounting for 53.6 billion m^3, 12.8 billion m^3, and 15.7 billion m^3 in 2008. Water for domestic use is supplied and distributed by wholesale and retail water suppliers. Wholesale water suppliers sell their cleaned water not to individual households but to retail water suppliers.[2] Retail water suppliers can be distinguished in terms of the size of the population they serve. Suppliers serving a population of up to 5,000 persons are classified as small-scale water

[2]There are 78 wholesale water suppliers which are owned by prefectures and multi-municipalities and are subject to the Local Public Enterprise Act.

Figure 1: The structure of Japan's water supply industry, 2008



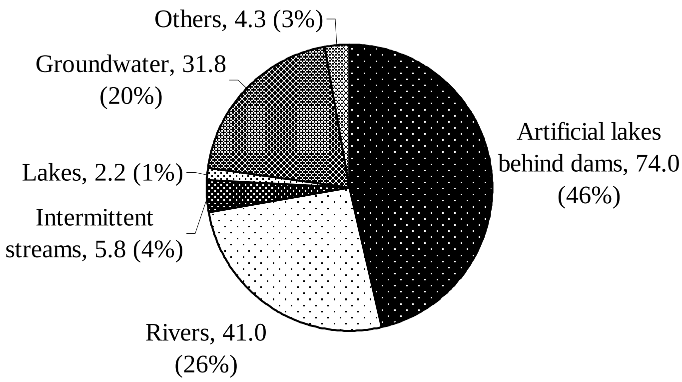
Data source: *Water Resources in Japan*, 2008.

suppliers and are not subject to the Local Public Enterprise Act. On the other hand, suppliers serving a population of more than 5,000 persons are subject to the Local Public Enterprise Act. This study focuses on retail water suppliers serving a population of more than 5,000 people, which are simply referred to as water suppliers hereafter.

2.2 Nontransferable water rights

Water supplies fundamentally rely upon water rights. Water rights are defined in the River Act as the rights of users to use water from a water resource owned and administered by the Ministry of Land, Infrastructure, Transport and Tourism or a prefectural government. The Ministry and prefectural governments administer surface water sources, including artificial lakes behind dams, rivers, intermittent streams, and lakes. However, groundwater is owned by the owner of the land under which the water is stored and not subject to the water rights granted

Figure 2: Distribution of water withdrawals by type of source, 2008



Unit: Hundred million m^3
Date source: Japan Water Works Association.

by the government.[3] Figure 2 shows the distribution of withdrawals by type of source in Japan. Due to the mountainous topography of Japan, about half of the water for domestic use is from artificial lakes behind dams. About 80% of water for domestic use relies on water sources subject to water rights. Therefore, water rights have a serious influence on the stable supply of water.

However, the Japanese water rights regime provides little flexibility, encouraging water suppliers to retain water rights. The government strictly allocates water resources to set the annual total and daily usage for a predetermined purpose, assigning exclusive usage for 10 years. Although water rights are usually renewed, they can be rescinded if water suppliers do not exercise their water rights.[4] In addition, there is no water trading scheme enabling retail water suppliers to buy and sell water access entitlements. Furthermore, because of the difficulty of water resources development, water suppliers rarely obtain new

[3]However, the daily or annual withdrawal of groundwater is often limited by an ordinance in order to prevent land subsidence and saltwater intrusion.

[4]Unusual weather conditions sometimes prevent water rights holders from exercising their rights. The government takes the impact of weather conditions into account. If water suppliers do not exercise their water rights when weather conditions are clearly irrelevant, their water rights can be rescinded.

water rights. This rigid regime provides suppliers with an incentive to retain water rights.

2.3 Vertical structure

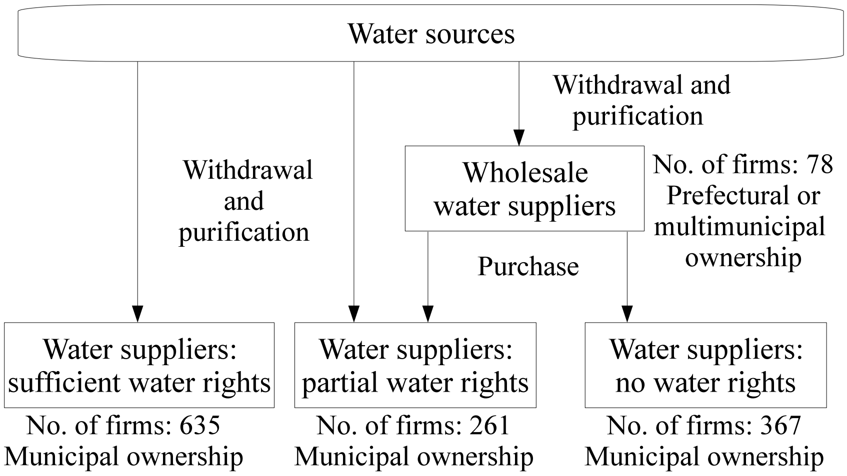
Furthermore, this rigid water rights regime gives rise to vertical integration in the water utilities industry. Figure 3 provides a graphic representation of the three types of retail water suppliers that can be found in Japan: those with sufficient water rights, those with partial water rights, and those with no water rights. In 2008, 635 retail water suppliers fell into the first category with sufficient water rights to meet the demand they face. Such suppliers are vertically integrated, i.e., they extract and purify water and then supply this as drinking-water to households. 261 retail water suppliers fell into the second category with insufficient water rights to meet the demand they face and, as a result, were partially vertically integrated. Similar to the first type of water suppliers, they extract and purify water and supply this as drinking-water to households. In addition, however, they also need to purchase water from wholesale suppliers in order to meet the demand they face. Finally, there were 367 water suppliers with no water rights, meaning that they had to purchase water from wholesale water suppliers to supply individual households.

2.4 Other regulations: Prices and service areas

Both the prices water suppliers charge and the area they serve are regulated. Water prices are stipulated by the Local Public Enterprise Act and are based on the full-cost pricing rule.[5] Furthermore, water prices are specified in an ordinance concerning water supply. If water suppliers want to change their

[5]Most water suppliers are owned by municipalities that have their own sewage systems. However, the Local Public Enterprise Act requires that the accounts for providing water supply need to be separate from the accounts of other activities such as the provision of sewage.

Figure 3: Three types of retail water suppliers



Data source: *Local Public Enterprise Yearbook*, 2008.

prices, they need to gain the consent of the local assembly to amend ordinances concerning water supply, and give notice to the Ministry of Health, Labor and Welfare. Therefore, this leads to regulated water price setting. In addition, the Water Supply Act stipulates that regionally monopolistic water suppliers may only provide water within their predetermined service areas and need to obtain permission from the Ministry of Health, Labour and Welfare before changing their service area.

3 Methodology

To examine whether the nontransferability of water rights results in technical inefficiency, a two-stage procedure is employed. In the first stage, water suppliers' technical efficiency is calculated by constructing a DEA efficiency index, while in the second stage, a bootstrapped truncated regression model is estimated to examine the determinants of the DEA efficiency index.

3.1 Data envelopment analysis

The DEA method derives a piecewise linear production frontier conditional on observed data, to evaluate technical efficiency. Following the definition of technical efficiency suggested by Farell (1957), Charnes et al. (1978) developed the DEA method to use a linear programming approach. While this approach assumes constant returns to scale between inputs and outputs, Banker et al. (1984) propose an alternative model which relaxes this assumption and allows variable returns to scale. The model, which will be referred to as the Banker, Charnes and Cooper (BCC) model, will be used to measure technical efficiency here. Technical efficiency is defined as the solution of the following linear-programming problem:

$$
\begin{aligned}
\min \ \theta \ \ s.t. \ \ & -y_i + y'\lambda \geq 0 \\
& \theta x_i' - X'\lambda \geq 0 \\
& e'\lambda = 1 \\
& \lambda \geq 0,
\end{aligned} \tag{1}
$$

where y is the output vector, y_i is the output of firm i, X is the input matrix, x_i is the input vector of firm i, and e is the unit vector. The solution of this linear-programming problem results in an index value of technical efficiency.

3.2 Regression analysis of the determinants of efficiency

The calculated efficiency index is regressed on water withdrawals associated with water rights, using the bootstrapped procedure proposed by Simar and Wilson (2000, 2007). Thus, the following bootstrapped truncated regression model is specified:

$$\hat{\theta}_i = Z_i\beta + \varepsilon_i, \tag{2}$$

where $\hat{\theta}$ is the technical efficiency obtained from equation (1), Z is a vector of water withdrawals and other control variables, and $\varepsilon \sim N(0, \sigma^2)$ such that $\varepsilon \geq 1 - Z_i\beta$.

Many studies estimating a model such as equation (2) employ the Tobit estimator. However, Simar and Wilson (2007) have shown that the Tobit estimator is inappropriate, because the error term is correlated with Z and the technical efficiency obtained from equation (1) binds both sides of equation (2) by unity. They therefore suggest using a bootstrapped truncated regression and propose an estimation algorithm. This study adopts their procedure and uses their algorithm.[6]

4 Empirical Analysis

4.1 Data

The data used for the analysis are mainly obtained from the *Local Public Enterprise Yearbook 2008* (Chiho Koei Kigyo Nenkan 2008) published by the Ministry of Internal Affairs and Communications. The *Yearbook* contains data on the financial and managerial accounts of 1,317 water suppliers (including one that was not operating). After deleting observations with missing or implausible values, the resulting dataset consists of cross-sectional data of 1,263 observations.

Nikkei NEEDS was used to obtain information on the municipal area. In this study, the municipal area is used as the service area of a water supplier,

[6]Studies that employ a methodology similar to the one used here include Zelenyuk and Zheka (2006) and Barros and Peypoch (2008, 2009).

Table 1: Basic statistics and definition of variables

Variable	Mean	S.D.	Definition
y	15.25	1.19	Logarithm of water supplied per year
K	19.62	1.21	Logarithm of tangible fixed assets
L	2.49	1.17	Logarithm of the number of employees
WP	7.61	7.71	Logarithm of water purchase per year
WR	7.57	7.67	Logarithm of water withdrawals associated with water rights
RAP	81.79	8.30	Ratio of annual average water distribution to peak water distribution
Pop	7.63	19.52	Population supplied (million)
$Dens$	10.19	1.57	Logarithm of population density
Age	51.77	18.47	Years since establishment
DCD	0.58	0.49	Dummy variable that takes a value of one if any deficits that a water supplier incurs are covered by a local government and zero otherwise
CRD	0.00	0.06	Dummy variable that takes a value of one if a water supplier's current liabilities exceed its current assets and zero otherwise
IRD	0.31	0.46	Dummy variable that takes a value of one if the redemption cost of the municipal bonds issued by a water supplier is less than the depreciation cost, otherwise zero
$Price$	1.47	0.52	Average water price per 10m^3 (thousand ¥)

Data sources: Nikkei NEEDS and *Local Public Enterprise Yearbook*, 2008.

because most water utilities are owned by municipalities, so that service areas typically are approximately equal to municipal areas.

A summary of the definitions of variables and their basic statistics is provided in Table 1.

4.2 Estimation results: Data envelopment analysis

The DEA model in this study includes one output and five inputs. The output variable is defined as the logarithm of supplied water per year. As for input variables, the logarithm of tangible fixed assets,[7] the logarithm of the number of employees, the logarithm of water purchased per year, the logarithm of water withdrawals associated with water rights, and the ratio of annual average water distribution to peak water distribution (RAP) are chosen. Since whether a water supplier has water rights or not determines whether it is vertically integrated, withdrawals associated with water rights are essential inputs. The ratio of annual average water distribution to peak water distribution is intended to capture fluctuations in demand. Water suppliers pay attention to fluctuations in demand where their service areas include a resort area. The variable is an important input variable.

The DEA result shows that 19 water suppliers are technically efficient. The average value of the technical efficiency index is 0.9188, while the standard deviation is 0.0314 and the minimum value 0.8196. The results for the specification excluding RAP, the ratio of annual average water distribution to peak water distribution, are qualitatively identical: there are 14 technically efficient water suppliers and the average value of the technical efficiency index is 0.9156, with a standard deviation of 0.0311 and a minimum value of 0.8186.

The DEA efficiency index may be higher than the one obtained by Nakayama (2002). The average of DEA technical efficiency index in Nakayama (2002) is 0.58. He uses data on 594 municipal water suppliers for 1999. As for input variables, he summarizes inputs other than capital and labor in one index. However, it is not appropriate to include water purchases and withdrawals in one index, thereby ignoring that some water suppliers are vertically integrated while others are not. Hence, This may explain the difference in the DEA index estimated by between Nakayama (2002) and this study.

[7]Tangible assets include specific assets for water withdrawals, but the greatest part of tangible fixed assets consists of water pipes, i.e., assets that are not specific to water withdrawals.

4.3 Estimation results: Determinants of efficiency

To examine whether the Japanese regulatory scheme with nontransferable water rights causes technical inefficiency, the bootstrapped truncated regression is applied to separate external environmental influences from the net technical inefficiency caused by nontransferable water rights. Two types of inefficiency can be distinguished. The first type of inefficiency arises when water suppliers have sufficient water rights to meet demand but are slow to adopt new water conservation technologies. Since water rights strictly determine water withdrawals, the water supplier can be slow to adopt new water conservation technologies if the amount of water withdrawals per population served is relatively large. The second type of inefficiency arises due to excess capital when water suppliers have insufficient water rights to meet demand, meaning that even if they are near a water source, they need to purchase water from a wholesaler. This may result in an excessive water pipeline infrastructure. These two scenarios suggest that the relationship between technical inefficiency and water withdrawals is probably not a simple linear one.

The estimated specification is as follows:

$$\begin{aligned}\hat{\theta}_i &= \alpha_1 + \alpha_1 X_i + \alpha_2 X_i^2 + \alpha_3 Dens_i + \alpha_4 Age_i \\ &\quad + \alpha_5 DCD_i + \alpha_6 CRD_i + \alpha_7 IRD_i + \varepsilon_i, \qquad (3)\end{aligned}$$

where $\hat{\theta}$ is the DEA technical efficiency score, X is water withdrawals associated with water rights per population served, and X^2 is the squared value of this variable to capture any possible nonlinear relationship between technical efficiency and water withdrawals. $Dens$ is the logarithm of the population density, while Age is the number of years since the establishment of a water supplier and DCD is a dummy variable that takes a value of one if any deficits that a water supplier

Table 2: Estimation results of the bootstrapped truncated regression

Variable	(3.1)	(3.2)	(3.3)
Const.	0.8994***	0.8981***	0.9100***
	(0.0008)	(0.0008)	(0.0010)
X	0.0175***	0.0194***	0.0214***
	(0.0002)	(0.0002)	(0.0002)
X^2	−0.0055***	−0.0062***	−0.0068***
	(0.0000)	(0.0000)	(0.0001)
$Dens$	0.0041***	0.0038***	0.0020***
	(0.0001)	(0.0001)	(0.0001)
Age	−0.0002***	−0.0002***	
	(0.0000)	(0.0000)	
DCD	−0.0103***	−0.0090***	−0.0080***
	(0.0002)	(0.0002)	(0.0003)
CRD	−0.1032***	−0.0984***	−0.1289***
	(0.0019)	(0.0019)	(0.0023)
IRD	−0.0093***	−0.0068***	−0.0087***
	(0.0002)	(0.0002)	(0.0003)

Notes: Specification (3.1) employs the instruments introduced in the text. Specification (3.2) uses the technical efficiency estimated excluding RAP. Specification (3.3) drops Age from the explanatory variables. ***, **, and * denote significance at the 0.01, 0.05, and 0.10 level respectively. Standard errors are in parentheses. The number of observations is 1,263. The number of replications is 2,000.

incurs are covered by a local government and zero otherwise. Next, CRD is a dummy variable that takes a value of one if a water supplier's current liabilities exceed its current assets, and zero otherwise. Finally, IRD is a dummy variable that takes a value of one if the redemption cost of the municipal bonds issued by a water supplier is less than the depreciation cost and zero otherwise. Since water suppliers generally issue municipal bonds to acquire fixed assets, IRD can be interpreted as representing the financial soundness of a water supplier..

Table 2 presents the estimation results for three different specifications. Specification (3.1) is equation (3) with the technical efficiency estimated in equation (1) as the explained variable; specification (3.2) uses the technical efficiency estimated excluding RAP; and specification (3.3) drops Age from the explanatory variables. The reason for dropping Age is that Age can be interpreted as representing the degree of aging of the infrastructure and equipment of a supplier. However, the consolidation of municipalities in recent years has led to mergers among water suppliers, and the merger between an older and a newer water supplier may make *Age* meaningless. The three different specifications yield virtually identical results. The discussion below therefore focuses mainly on the results for specification (3.1).

Looking at the results, we find that the explanatory variables concerning nontransferable water rights, X and X^2, are statistically significant at the 1% level. The sign on X is positive, while the sign on X^2 is negative, implying that the relationship between technical efficiency and water withdrawals associated with water rights is strictly concave. Furthermore, suppliers with relatively low technical efficiency as a result of nontransferable water rights can be distinguished based on the first-order condition:

$$\frac{\partial \theta}{\partial X} = \alpha_1 + 2\alpha_2 X = 0 \tag{4}$$

On the one hand, there are water suppliers for which $\alpha_1 + 2\alpha_2 X \gg 0$. These tend to be found in municipalities with lower-than-predicted population growth such as Osaka-City and Yubari-City (in Hokkaido). These municipalities have projected urban development based on their predicted population growth. Since their water suppliers have quite a strong incentive to keep their water rights, they have less incentive to adopt new water conservation technologies. On the other hand, there are water suppliers for which $\alpha_1 + 2\alpha_2 X \ll 0$. These tend to be found in relatively new municipalities such as Kadoma-City (in Osaka) and Sanda-City (in Hyogo). These municipalities have insufficient water rights to meet demand and purchase water from a wholesaler even if they are close to sources of drinking water. In order to purchase water from a wholesaler, these municipalities lay water pipes to a wholesaler. These water pipes to a wholesaler can be considered to be excessive infrastructure. The results thus support the hypothesis that nontransferable water rights cause technical inefficiency.

Looking at the estimation results for the other variables reveals the following. First, the coefficient on $Dens$ is positive and significant, indicating that water suppliers are more efficient the more densely populated the area in which they operate. Second, the coefficient on Age is negative and significant, meaning that older water suppliers are less efficient than newer ones; one possible explanation is that older supplier may be operating with older infrastructure and equipment that is less efficient. Third, the coefficient on DCD is negative and significant, suggesting that soft budget constraints result in lower technical efficiency. Finally, the coefficients on CRD and IRD are also negative and significant, implying that less efficient water suppliers suffer from serious cash flow problems and depend on externally-raised capital for reinvestment.

5 Discussion

This section explores the counterfactual scenario that water rights are transferable among water suppliers. Under this counterfactual scenario, water suppliers are assumed to choose X—water withdrawals from water rights per population served—in order to maximize their technical efficiency subject to the level of demand they face, following the first-order condition (4).[8] This improves their technical efficiency, resulting in a decrease in input for any given output level. This decrease in input is used here to assess the cost incurred due to technical inefficiency resulting from the nontransferability of water rights by multiplying the price of water with lost output, where lost output is defined as the variation in water withdrawals from water rights multiplied by the amount of water

[8]For technically efficient water suppliers, it is assumed that their water rights remain unchanged.

Table 3: Estimates of the cost of technical inefficiency

	(3.1)	(3.2)	(3.3)
Avg. technical efficiency (%)	0.9697	0.9683	0.9711
Avg. ratio of improvement (%)	5.6279	5.8421	5.7789
Avg. cost of inefficiency (million ¥)	365.91	374.17	381.87
Total cost of inefficiency (billion ¥)	462.14	472.58	482.30

Note. The column labels refer to the underlying specifications shown in Table 2.

supplied.[9]

Table 3 shows estimates of the costs of the technical inefficiency caused by nontransferable water rights. The column labels refer to the underlying specifications shown in Table 2. The three specifications yield very similar results. The discussion below therefore focuses mainly on the results for column (3.1).

Under the counterfactual scenario, the average technical efficiency is 0.9697, with the standard deviation being 0.0329 and the minimum value being 0.8730, indicating that the average ratio of improvement is 5.63%. This improvement in technical efficiency enables water suppliers to decrease their input for any given output level. The average lost output is $264,775\text{m}^3$ and the average water price per 10m^3 is $1,470$ yen, so that the average cost per water supplier due to the nontransferability of water rights is 365.9 million yen. Multiplying this by the number of water suppliers included in the calculations here, which is 1,263, yields a total cost of 462.1 billion yen due to inefficiency caused by the nontransferability of water rights. This amount is equivalent to 18.5% of the total operating revenue of Japanese water suppliers.

The implication of this finding is that the technical efficiency of Japan's water supply industry could be increased if water rights were transferable. This

[9] It would be more accurate to estimate the cost incurred due to technical inefficiency by multiplying lost output not by the price of water but the marginal cost of that lost output. However, the marginal cost of lost output cannot be observed.

finding is in line with the Coase theorem and suggests that the present water rights regime in Japan prevents water being allocated according to the marginal willingness to pay for water. One possible solution therefore would be to allow water suppliers to trade in water rights.[10] Another possible solution would be for the government itself to reallocate water rights according to the marginal willingness to pay for water. In any case, the results here provide a strong case that the government should make possible the reallocation of water rights in order to raise the efficiency of the water supply industry.

6 Concluding Remarks

This study examined whether the Japanese scheme of nontransferable water rights results in technical inefficiency, employing the two-stage procedure proposed by Simar and Wilson (2000, 2007). First, using data on 1,263 retail water suppliers in Japan for 2008, data envelopment analysis (DEA) was employed to obtain an index of technical efficiency. Second, a bootstrapped truncated regression model was specified to examine the determinants of the DEA efficiency index. The analysis revealed that the nontransferability of water rights leads to technical inefficiency of retail water suppliers. Furthermore, it was shown that the costs of this inefficiency amount to about 462 billion yen when compared with a counterfactual scenario in which water rights are reallocated in order to raise the efficiency of the water supply industry. This result suggests that the government should allow greater flexibility in the reallocation of water rights—either through the introduction of a trading scheme or by reallocating water

[10] In fact, in many countries around the world, such trade in water rights is possible. Australia, Chile, China, South Africa, and the western United States all have tradable water rights regimes, and there are a number of studies that show that these improve the efficient use of water resources. Peterson et al. (2004), for example, examine the benefits of water trade in Australia, while Grafton et al. (2011) compare the gains from water trade in Australia and the western United States. Furthermore, Fisher (1995) applies the Coase theorem, showing that tradable water rights would promote efficient management of water resources in the Middle East.

rights itself based on water suppliers marginal willingness to pay—in order to increase efficiency.

This study focused strictly on the nontransferability of water rights and the implications this has for the technical efficiency of water utilities. In doing so, two important issues were not addressed. First, the regime of nontransferable water rights may result not only in technical inefficiency, but also in allocative inefficiency. If water suppliers regard water withdrawals as a fixed input, their cost functions should be similar to a short-run cost function: a constrained version of the cost function associated with variable water withdrawals. Therefore, allocative inefficiency is likely to arise unless the amount of fixed water withdrawals is equal to the amount of water withdrawals that would minimize the cost function associated with variable water withdrawals.

Second, the discussion here is restricted to transferable water rights for water for domestic use and, in addition, does not control for the climatic environment of watershed areas. The purpose of water rights regimes is to prevent the tragedy of the commons. In drought areas, not all water users have sufficient water rights. Therefore, the appropriate water rights regime needs to take into account the climatic environment and apply not only to water for domestic use but also to water for agricultural and industrial use.

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