The impact of accrual accounting on the cost efficiency of municipally controlled enterprises: Evidence from the Japanese municipal sewerage system

Ogawa, Akinobu and Kondoh, Haruo

Niigata University, Seinan-Gakuin University

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Akinobu Ogawa, Haruo Kondoh

Niigata University, Seinan-Gakuin University

Corresponding author: Akinobu Ogawa

Abstract

In recent decades, the global trend has been moving toward the adoption of accrual accounting in the public sector. However, quantitative analysis regarding its fiscal effects is still in its infancy. Thus, this study examines the impact of accrual accounting on municipally controlled enterprises, with specific focus on the Japanese municipal sewage system. For this purpose, it employs a combination of instrumental variables as well as stochastic frontier analysis to quantitatively determine the fiscal effects from the perspective of cost efficiency. Based on the results, the transition from cash- to accrual-based accounting has led to improvements in overall cost efficiency. These findings also provide new quantitative evidence for future discussions on fiscal discipline, which is a key area in the field of public economics.

Keywords: Public accounting, Accrual accounting, Cost efficiency, Stochastic frontier analysis with instrumental variables

JEL Classification: H83; H72

1. Introduction

Under the New Public Management movement, the global trend has been moving toward the adoption of accrual accounting in the public sector (Lapsley, 2009). For example, the European Commission (EC) issued the European Public Sector Accounting Standards (EPSAS) in 2013 (based on the International Public Sector Accounting Standards (IPSAS)), which required member states to adopt accrual accounting. Similarly, in the United States, the Governmental Accounting Standards Board (GASB) issued the GASB Statement No. 34 in 1999, which has been adopted by various state governments. According to the EC (2024), a survey conducted by the International Federation of Accountants and The Chartered Institute of Public Finance and Accountancy found that 83 out of 165 countries planned to introduce accrual accounting by 2025 and that more local governments were actively adopting this accounting approach than central governments. The report also divided the EPSAS into two phases: 1) To increase the fiscal transparency of member countries' public finances; and 2) To increase comparability.

The accounting literature has also indicated that the introduction of accrual accounting can increase fiscal transparency and prevent resource waste in the public sector (Parker and Gurhrie, 1990; Pallot, 1992, 1994; Lapsley, 1999; Likierman, 2000; Lapsley and Oldfield, 2001; Brito and Jorge, 2021).[1] Meanwhile, the International Monetary Fund and the World Bank have supported the switch to accrual accounting in emerging countries (Adhikari and Gårseth Nesbakk, 2016; Adhikari and Jayasinghe, 2017; Harun et al. 2012). However, some emerging countries have not introduced accrual accounting (Salato et al. 2024).[2] In this

[1] Specifically, they stated that the introduction of accrual accounting can increase the transparency of public finances, improve accountability, enable efficient financial management, and make it possible to manage assets and liabilities from a medium- to long-term perspective.

[2] For example, there are concerns that the introduction of accrual accounting can lead to a decline in the quality of public services, due to the prioritization of financial efficiency, the overwhelming cost of

regard, it has been pointed out that not only in emerging countries, but also in Europe, the cost of introducing accrual accounting is relatively high (Christofzik, 2019; Dorn et al. 2021; Bessho and Hirota, 2023).

Several research studies that measured the impact of introducing accrual accounting on local public finances exist. For instance, van der Hoek (2005) examined the central government in the Netherlands, Kuhlmann et al. (2008) analyzed regional governments in Germany, Paulsson (2006) focused on the Swedish central government, Christiaens and Van Peteghem (2007) evaluated Belgian local governments, and Carilin (2005) assessed Australian state governments. However, since these studies are primarily based on questionnaires and case studies, it is difficult to determine whether the introduction of accrual accounting leads to cost efficiency or whether the motivation to introduce such accounting leads to cost efficiency (Bessho and Hirota, 2023). More recently, previous studies have examined the effects of introducing accrual accounting through econometric analysis (Lampe et al., 2015; Christofzik, 2019; Raffer, 2020; Dorn et al., 2021). Specifically, Lampe et al. (2015) investigated from the perspective of cost efficiency, while Christofzik (2019), Dorn et al. (2021), and Bessho and Hirota (2023) focused on expenditures.

However, the empirical results in these studies have been inconsistent. For example, Lampe et al. (2015) indicated that the introduction of accrual accounting can increase cost efficiency, whereas Christofzik (2019), Dorn et al. (2021), and Bessho and Hirota (2023), found no major effect on expenditures. In this case, Christofzik (2019) and Dorn et al. (2021) argued that sufficient information is already provided with cash-based accounting and that political decision-makers generally lack the skills to fully utilize new information from accrual accounting.

introducing it in smaller municipalities, and the possibility that accrual accounting data might not be fully utilized (Lapsley et al. 2009).

In the present study, we focus on the cost efficiency of municipally controlled enterprises based on two reasons. First, despite the global trend toward the adoption of accrual accounting in the public sector, only a few studies have quantified its fiscal effects, including those in Europe (e.g., Lampe et al. 2015; Christofzik, 2019; Dorn et al. 2021) and Japan (e.g., Bessho and Hirota, 2023). Meanwhile, although Christofzik (2019) and Bessho and Hirota (2023) analyzed the effects of local governments preparing consolidated financial statements, neither study directly captured the impact of introducing accrual accounting by public enterprises. Second, there has been little mention of the effects of introducing accrual accounting to special accounts, especially for public services with a strong corporate character. Thus, there is still a lack of quantitative evidence on the fiscal effects of introducing accrual accounting in the public sector.

Under the Japanese local government finance system, local governments operate various projects such as waterworks, sewage systems, bus and subway transportation, and port services. However, the nature of introducing accrual accounting differs according to the project.[3] For example, municipal enterprises, such as waterworks and bus and subway transportation, were originally required by national law to use accrual accounting. However, in 2015, the national government started requiring accrual accounting for municipal sewage enterprises, which was a complete switch from the cash-based accounting system. In this regard, since it is possible to compare the results of this analysis with those of local governments in Germany, the present study provides new empirical results that capture the fiscal effects of introducing accrual accounting in the public sector in Japan.

This study also contributes to the debate on fiscal discipline in the fields of public economics and public choice theory. In this regard, although fiscal spending in democracies

[3] When local governments in Japan operate waterworks, sewage systems, transportation, electricity, gas, ports, markets, etc., they are required by law to manage them by using an accounting system that differs from the normal budget system. Moreover, the law stipulates that the accrual accounting method should be applied to some of these aspects (e.g., waterworks).

is frequently excessive (e.g., Alesina et al. 1998; Persson and Tabellini, 2000), many studies have found that the establishment of fiscal rules has a positive impact on fiscal sustainability (Poterba, 1994; Eichengreen and Bayoumi, 1994; von Hagen and Harden, 1995; Debrun et al. 2008). However, it has also been shown that the positive effects of such rules mainly depend on fiscal transparency (Alt and Lassen, 2006; Benito and Bastida, 2009). This is because governments tend to avoid fiscal rules by applying "creative accounting" (von Hagen 1991; Milesi-Ferretti, 2004). Hence, if the introduction of accrual accounting improves fiscal transparency, then it may decrease the incentives of government decision-makers for fiscal manipulation, positively impacting government budgeting and cost efficiency (Dorn et al. 2021).

The remainder of this study is organized as follows. Section 2 discusses the local public finance system and public enterprises in Japan, while Section 3 introduces our theoretical setting and hypotheses. Section 4 describes our empirical framework and data, and includes the results of the analysis. Finally, Section 5 interprets the results, presents the conclusions, and makes recommendations for future policies and research.

2. Institutional background

2.1. Japanese Local Government and Public Enterprises

Japan is a highly unified country with a three-tiered government structure, including the national government at the top, followed by 47 prefectures (regional) and 792 cities and 926 towns and villages (municipal), as of January 2025. In most cases, public services are provided by the cities, towns, and villages (municipalities). However, the range of authority delegated to the cities differs from that to the towns and villages, with the former having more authority than the latter. Meanwhile, in FY2022, the local government expenditures totaled 117 trillion yen, which was 56% of the expenditures of the national and local

governments.[4] Conversely, local taxes only amounted to 44 trillion yen, which was 36.6% of the tax revenues of the national and local governments. Due to this fiscal imbalance, it was supplemented by vertical fiscal transfers from the national government. In this case, the main fiscal transfers included the Local Allocation Tax Grant (19 trillion yen) and National Government Disbursements (27 trillion yen). It should be noted that vertical fiscal transfers also occurred between the prefectures and municipalities.

In Japan, some public enterprises are established and controlled by local governments. These enterprises are divided into those to which the Local Public Enterprise Act (LPEA)[5] applies and those to which the Local Finance Act (LFA)[6] applies. When the LFA is applied, finances are required to be separated from the general account. When the LPEA is applied, not only must finances be separated from the general account, but they must also be based on accrual accounting. The LPEA also includes certain provisions that (if fully applied) allow the executive managing directors of organizations to formulate their own budgets, increasing the independence of the organizations. Additionally, the LPEA covers public services such as transportation (ship traffic), electricity (other than power generation), simple water supply,[7] markets, slaughterhouses, public sewage, tourism facilities, port facilities, parking lots, and residential land development.

Table 1 summarizes the relationship between public enterprises and the aforementioned acts. Some of these services are almost solely provided by local public enterprises, while others are offered by both local public and private enterprises. For instance, 99.6% of the total population is covered by local public enterprises for water supply, whereas only 10.3% and 19.4% of the population are covered by local public enterprises for railroads

[4] From the "White Paper on Local Public Finance, 2024" by the Ministry of Internal Affairs and Communications in Japan.
[5] This law came into effect in 1952.
[6] This law came into effect in 1947.
[7] The Water Supply Act, which came into effect in 1957, refers to the water supply for a population of 101 to 5,000 people.

and buses, respectively.[8] As for the public sewage system, it is almost entirely operated by local governments, covering 90.4% of the total population. In contrast, the scale of public sewage is 5 trillion yen[9] (or 29% of all public enterprises), which is larger than the 4 trillion yen for water supply. Meanwhile, construction investment is 1.7 trillion yen (or 40% of all public enterprises), which is larger than the 1.4 trillion yen for water supply. Regarding corporate bond issuance, it totals 1.1 trillion yen (or 47% of all public enterprises), which exceeds the 0.5 trillion yen for water supply. Moreover, the outstanding balance of corporate bonds is 20 trillion yen, accounting for 57% of all public enterprises.[10]

2.2. Public Accounting of Local Public Enterprises

Due to the existence of vertical fiscal transfers, both prefectures and municipalities are influenced by national ministries and agencies, especially the Ministry of Internal Affairs and Communications (MIC), which determines the distribution of the Local Allocation Tax Grant. Additionally, municipalities are affected by both the national and prefectural governments. This is also true for public accounting in which the national government's policy has had a significant impact on whether to introduce accrual accounting in local governments.

In Japan, local governments are required to prepare financial statements based on accrual accounting, which is in line with the Key Policy for Administrative Reform introduced by the Koizumi Cabinet in 2005. Since 2015, each local government (both prefectures and municipalities) has prepared and published financial statements based on this accounting approach. For more information on the preparation of accrual-based financial statements by local governments, see Bessho and Hirota (2023). As mentioned earlier, these

[8] From the "Local Public Enterprise Yearbook, 2022" by the Ministry of Internal Affairs and Communications in Japan.
[9] 1 JPY is almost equivalent to 0.0067 USD (as of February 2025).
[10] From the "Local Public Enterprise Yearbook, 2022" by the Ministry of Internal Affairs and Communications in Japan.

financial statements are supplementary, since local governments generally manage their budgets through cash-based accounting.

2.3 Introduction of Accruals in Public Sewage Services in Japan

Since the LFA applies to public sewage services, their accounts are separated from the general accounts of local governments, but are based on cash accounting. In other words, although they are outside of the scope of the LPEA, their scale is relatively larger than other public enterprises. Meanwhile, due to the decreasing population and its financial consequences, there is an increasing need for new information based on accrual accounting such as the future costs of maintaining and updating public sewage facilities.[11] Thus, the MIC has been requesting local governments to intermittently apply the LPEA to public sewage services since 1998 (e.g., the "Request in the Notice of Strengthening of Management Base" in 1998 and the "Report of the Study Group on the Accounting System for Local Public Enterprises" in 2009). However, since a certain amount of money is required to prepare a fixed asset ledger, the application of the LPEA to public sewage services (i.e., the transition to accrual accounting) has not been widespread. Consequently, in January 2015, the MIC issued requirement notices to each local government (e.g., the "Promotion of the Application of Public Enterprise Accounting" and the "Notes on the Promotion of the Application of Public Enterprise Accounting"). Specifically, these notices stated that public sewage and simple water supply should be considered as "priority projects" and that municipalities with a population of 30,000 or more should shift from cash-based accounting to accrual accounting from FY2015 to FY2019. As for the municipalities with a population of less than 30,000, they were advised to do "as much as possible." The MIC also stated the following regarding the significance of introducing accrual accounting to these public enterprises: 1) Formulation of appropriate management policies and plans based on profit and

[11] From MIC (2014), "Research Group on the Application of the Local Public Enterprise Act Report."

loss statements and stock-related information; 2) Comparison of management conditions between public enterprises; 3) Increased management efficiency and improved services through enhanced management autonomy; 4) Improved governance by both the residents and the local Diet; and 5) Development of human resources with a sufficient understanding of corporate accounting and management.[12]

As a result of these notices, 653 public sewage enterprises shifted to accrual accounting from FY2014 to FY2022 (see Fig. 1). Among them, 500 were managed by municipalities with a population of 30,000 or more, while 153 were managed by municipalities with a population of less than 30,000 (see Fig. 2). Fig. 1 presents the number of sewage public enterprises that have shifted to accrual accounting by population. Moreover, we can distinguish between the impact of introducing accrual accounting and the effect of both introducing accrual accounting and changing the organizational structure to enhance management autonomy. In this regard, if some of the LPEA's financial provisions are applied (partial application), then it is the former. If all of the LPEA's provisions are applied (full application), then it is the latter. Although the MIC's notices stated that the full application was preferable, it was ultimately up to the municipality to decide whether to implement full or partial application.

[Insert Fig. 1 here]

3. Theoretical concept and hypotheses

According to Christofzik (2019), Raffer (2020), Dorn et al. (2021), and Bessho and Hirota (2023), accrual accounting has a significant impact on local expenditures. In this regard, many studies have found that the introduction of accrual accounting can increase fiscal transparency (Micaleff, 1994; Boxall, 1998) and resource allocation efficiency (Ball, 1994;

[12] Ibid.

Likierman, 2000), making it easier to grasp the costs of public service provision for both policymakers and residents (Evans, 1997; Webster, 1998). This relationship between enhanced fiscal transparency and public sector efficiency can be best explained by the standard principal-agent setting (cf. Migué and Bélanger, 1974; Niskanen, 1975; Borge et al. 2008). In other words, the residents (the principals) demand efficient management of the local public sector. However, since there is information asymmetry between the bureaucrats in the local public sector and the residents regarding the costs of providing local public services, the former can pursue their own personal goals of maximizing their budgets. In order to overcome this principal-agent problem, it is important to eliminate such information asymmetry and increase the monitoring of agents (Alchian and Demsetz, 1972; Jensen and Meckling, 1976; Holmström, 1979; Laffont and Tirole, 1986). In this regard, the MIC included the following two aspects regarding the significance of introducing accrual accounting: 1) Formulation of appropriate management policies and plans based on profit and loss statements and stock-related information; and 4) Improved governance by both the residents and the local Diet. Meanwhile, in the case of local public enterprises that consist of a single administrative project, residents can easily understand the relationship between the financial benefits and burdens. Thus, the impact of introducing accrual accounting may be more obvious than for general accounts.[13] Based on these findings, we present the following hypothesis:

H1: *The introduction of accrual accounting will increase the cost efficiency of sewage public enterprises*.

Furthermore, as Geys et al. (2010) quantitatively showed, the impact of increased fiscal transparency and improved monitoring by residents on public sector efficiency mainly

[13] The LFA states that the reason why public enterprise accounts should be separated from general accounts is that "each administrative project should be managed by clarifying its business performance and financial position."

depends on the degree of fiscal autonomy. In this case, if this degree is low, then it is easy to rely on external subsidies, i.e., this situation deviates from the principle of "fiscal equivalence" (Olson, 1969). Since there is also a disparity between the financial benefits and burdens borne by the residents, their incentive to monitor the local government is undermined. However, having an independent executive managing director in a public enterprise (who is required to manage fiscal resources independently from the municipality) can make it difficult to rely on external subsidies. In other words, the full application of the LPEA (which promotes organizational independence) may increase the positive impact of introducing accrual accounting. Hence, we present the following hypothesis:

H2: *The full application of the LPEA will be more cost efficient*.

4. Empirical analysis

4.1. Identification Strategy

In order to determine the fiscal effects of introducing accrual accounting, it is important to address the issue of endogeneity. For instance, local governments under pressure to improve fiscal efficiency may be more willing to introduce this accounting approach. In this regard, Christofzik (2019) and Dorn et al. (2021) utilized the variations in the timing of introducing accrual accounting among counties in Bavaria (Germany), while Raffer (2020) applied multiple matching techniques based on the data from municipalities in Baden-Württemberg (Germany) to distinguish the impact of the treatment from other confounding factors. In related research, Bessho and Hirota (2023) used the differences in the degree of enforcement between municipalities with a population of 30,000 or more and those with a population of less than 30,000. In their study, a dummy variable was created that took a value of 1 if the population exceeded 30,000 in 2007. It was also used as the instrumental variable.

As mentioned earlier, the MIC issued notices requiring the introduction of accrual accounting to sewage public enterprises. However, the degree of enforcement differed,

depending on population size, i.e., between municipalities with a population of 30,000 or more and those with a population of less than 30,000. Thus, following Bessho and Hirota (2023), we create a dummy variable for the population in 2015 and use it as an instrumental variable for addressing the endogeneity issue.

Based on Fig. 2, which presents the percentage of accrual accounting adoption by population size, the majority of the municipalities with a population of 30,000 or more shifted to accrual accounting by 2020, whereas many municipalities with a population of less than 30,000 did not make such a transition. In other words, although the population size is exogenous for each municipality, it has a significant influence on whether to introduce accrual accounting. Hence, this study uses population size as an instrumental variable in order to identify the financial impact of introducing accrual accounting.

[Insert Fig. 2 here]

4.2. Empirical Framework

Following Lampe et al. (2015), we use stochastic frontier analysis (SFA) to determine the effects of introducing accrual accounting in terms of cost efficiency.[14] SFA is an analytical method established by Aigner et al. (1977) and Meeusen and van den Broeck (1977), and subsequently expanded by Battese and Coeli (1995) to panel data. In this method, the inefficiency of the decision-maker is represented by the deviation from the cost function (frontier), representing the minimum theoretically feasible cost and output. We also measure cost efficiency by using Japanese municipality data. As shown in the following equation, we assume a Cobb-Douglas cost function that includes cost efficiency:

[14] In addition to Lampe et al. (2015), numerous studies have measured the cost efficiency of the local public sector by using SFA (Vanden Eeckhaut et al. 1993; De Borger et al. 1994; De Borger and Kerstens, 1996; Geys and Moesen, 2009a; Geys and Moesen, 2009b; Geys et al. 2010; Kalb, 2010; Kalb et al. 2012).

$$lnC_{it} = \beta_0 + \sum_{r=1}^{s} \beta_{1r} lny_{r,it} + \beta_2 lnw_{it} + v_{it} + u_{it} \quad (1)$$

where C_{it} is the cost of each decision-maker (i.e., each local government or sewage public enterprise), w_{it} is the factor price of production, and y_{it} is the output. As for the estimated parameters, they are β_1 and β_2, while the subscript i denotes the local government or sewage public enterprise (as decision-makers) and t represents the year. Additionally, v_{it} is a normal error term following a normal distribution $N(0,\sigma_v^2)$ and u_{it} is a random error term representing cost inefficiency that follows a truncated normal distribution $N(z_i\delta, \sigma_u^2)$. In Battese and Coeli (1995), the error term representing inefficiency u_{it} is explained by the number of variables z_{it}. In this case, the determinants of inefficiency are identified by using the maximum likelihood method in Equation 2, in which $\delta_j,\ j = (1, \cdots, J)$ are the estimated parameters and ε_{it} follows a truncated normal distribution $N(0, \sigma_u^2)$:

$$u_{it} = \sum_{j=1}^{J} \delta_j z_{j,it} + \varepsilon_{it} \quad (2)$$

However, if the model faces an endogeneity issue, then the estimated parameters in the maximum likelihood method will be inconsistent. Hence, the standard response is employing instrumental variables. For example, Karakaplan and Kutlu (2017) combined SFA with panel data and instrumental variables to overcome this endogeneity problem. In the present study, we assume that adopting accrual accounting is not exogeneous. Thus, we use a dummy variable indicating whether the population is either over or under 30,000 as the instrumental variable. As mentioned earlier, although population size is exogenous for local governments and sewage public enterprises, it has a significant impact on whether to introduce accrual accounting.

4.3. Data and Definitions of the Variables

In line with the present study, Tadatomo (1997) and Kawamura et al. (2009) measured the cost efficiency of sewage public enterprises in Japan by using SFA. However, in our case, the variables were selected with reference to Kawamura et al. (2009), while the data was obtained from the MIC, which is published on an annual basis.

(1) Cost Functions

The sewage treatment cost (i.e., the treatment cost per unit of water volume subject to fee revenue) in the maintenance cost of the sewage (i.e., the cost that can be covered by the fee revenue) is applied as the cost function. As the output, the water volume subject to fee revenue is employed (*SEWAGE*), while the salary of local government employees (*WAGE*) is used as the production factor price. As the control variables, we consider the number of years since the start of service (*YEAR*). This is based on the idea that the longer the years of shared use, the more likely it is possible to operate at a lower cost. We also apply the population density in the service area (*DEN*), which is based on the notion that the smaller the population density, the longer the sewer pipes are needed and the more costly they become. Moreover, we use nonplant (*PLANT*) as a dummy variable, which takes the value of 1 when there is a terminal sewage plant.[15] This is because public enterprises that have a terminal sewage plant tend to have higher costs. Finally, we use diversion tube (*DIVER*) as a dummy variable, which takes the value of 1 when there is a diversion system in which rainwater and sewage flow in separate tubes, or 0 otherwise (i.e., when there is a combined system in which rainwater and sewage flow in one tube, or when there are both combined and separated tubes). In this case, the higher the number of tubes, the greater the costs.

(2) Cost Inefficiency Terms

[15] This treatment facility, located at the end of the sewer pipe, detoxifies sewage. Specifically, microorganisms break down the organic matter in the precipitated sludge.

The following three variables are added as explanatory variables for cost inefficiency. First, there is the LPEA application dummy (*ACCRUAL*), which is equal to 1 when the LPEA is applied and accrual accounting is introduced. To measure the effect of the full application of the LPEA, we apply a dummy (*FULL*) that takes a value of 1 when all the provisions of the law are applied. Second, there is the connection rate (*CONNECT*), which is the population with flush toilets connected to the sewage system divided by the population in the service area. In this case, if the connection rate is high, then it indicates that the sewage system is being utilized as expected by the municipality. However, if the connection rate is low, it means that the sewage system is not being used as expected by the municipality, resulting in overcapacity and lower cost efficiency. Third, there is the ratio of transfers from other accounts (*TRANSFER*) to total revenues. In this regard, Kawamura et al. (2009) showed that when such transfers increase, cost efficiency declines, due to soft budget constraints.[16] Additionally (as mentioned earlier), in order to account for the possibility that the dummy variables *ACCRUAL* or *FULL* are endogenous, we use a population dummy (*POPD*) as an instrumental variable, which takes the value of 1 if the population is more than 30,000, as of January 2015.

Based on these variables, the estimating equations are as follows:

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[16] For more information on soft budget constraints, see Kornai et al. (2003). The following is a summary of previous research on the consequences of public enterprises facing soft budget constraints. By using panel data from Italian state-owned manufacturing enterprises, Bertero and Rondi (2000) found that when budget constraints are "hard," the productivity of state-owned enterprises increases and employment decreases. Similarly, Segal (1998) theoretically demonstrated that in the case of a monopolistic company that is in the public interest (but has a deficit), if it is expected that the government will provide subsidies, then it will be a soft budget constraint.

$$lnC_{it} = \beta_0 + \beta_1 SEWAGE_{it} + \beta_2 lnWAGE_{it} + \beta_3 lnYEAR_{it} + \beta_4 lnDEN_{it} + \beta_5 PLANT_{it} + \beta_6 lnDIVER_{it} + v_{it} + u_{it} \quad (3)$$

$$u_{it} = \delta_1 ACCRUAL\ (FULL)_{it} + \delta_2 CONNECT_{it} + \delta_3 TRANSFER_{it} + \varepsilon_{it} \quad (4)$$

In Equation (3), C_{it} is the cost of sewage treatment, $SEWAGE_{it}$ is the amount of sewage that is covered by fee revenue, $WAGE_{it}$ is the salary of local government employees, $YEAR_{it}$ is the number of years in service, DEN_{it} is the population density in the service area, $PLANT_{it}$ is a dummy for a nonplant, $DIVER_{it}$ is a dummy for a diversion tube, and $\beta_n,\ n = (1, \cdots 6)$. are the estimated parameters. In Equation (4), $ACCRUAL_{it}$ is a dummy for low or accrual accounting adoption, $FULL_{it}$ is a dummy for the full adoption of the law, $CONNECT_{it}$ is the connection rate, $TRANSFER_{it}$ is the transfer rate from other accounts, and $\delta_{n,}\ n = (1, \cdots, 3)$ are the estimated parameters. As for the error terms and subscripts, they are the same as those in Equations (1) and (2). In this case, if the explanatory variables in Equation (4) result in cost inefficiency, then δ_n takes a positive value. Moreover, if our hypothesis is supported, then the coefficient for *ACCRUAL* will be negative (H1), while the coefficient for *FULL* will also be negative, but larger than that for *ACCRUAL* (in absolute value) (H2).

It is important to note that only sewage public enterprises established and managed by a single municipality are included in our analysis.[17] The data also covers a nine-year period from 2014 to 2022. Furthermore, 783 municipalities with populations between 10,000 and 100,000 were included in the sample to ensure a similar sample size to the threshold population of 30,000. The descriptive statistics for the variables are summarized in Table 2.

4.4. Estimation Results

Based on the estimation results in Table 3, Model EX is the model without instrumental variables and Model EN is the model with instrumental variables. In this case, the eta

[17] In some local governments in Japan, there are cases in which multiple local governments have established a single sewage public enterprise. However, there are only 15 such public enterprises, as of 2022.

endogeneity test shows that *ACCRUAL* is endogenous and supports Model EN, which takes endogeneity into account. Additionally, the estimation results for the determinants of inefficiency in Model EN show that *ACCRUAL* and *CONNECT* are negatively significant, whereas *TRANSFER* is positively significant. Since inefficiency is expressed as a positive value, a positive coefficient implies a decrease in cost efficiency, while a negative coefficient suggests an increase in such efficiency. Thus, it is clear that the introduction of accrual accounting through the LPEA and a high connection rate increases cost efficiency, while a high transfer rate from other accounts decreases such efficiency. As for the coefficients of each variable in the cost function, *SEWAGE* is negative. Since the dependent variable is the water volume subject to fee revenue (*SEWAGE*), the fact that the coefficient for *SEWAGE* is significantly negative indicates that there is an economy of scale. Meanwhile, *DEN* is also negatively significant. Regarding the positive significance of *WAGE* and *PLANT* as well as the negative significance of *YEAR*, they are also similar to the results of Kawamura et al. (2009). Based on these findings, H1 is supported.

According to the estimation results in Table 4, the eta endogeneity test indicates that *FULL* is endogenous and supports Model EN, which takes endogeneity into account. Moreover, the estimation results for the determinants of inefficiency in Model EN show that *FULL* is negatively significant and improves cost efficiency, as in the case of *ACCRUAL*. Regarding the coefficients for the other variables in the cost function and cost inefficiency terms, they are similar to those used in *ACCRUAL*. Upon comparing the coefficients for *ACCRUAL* in Table 3 and *FULL* in Table 4, the coefficient for *FULL* is larger (in absolute value). However, since the difference is insignificant, H2 is not supported.

4.5. Robustness Check

For the robustness check, we add prefecture-year fixed effects to Equation (3) and simultaneously estimate it with Equation (4). The reasons are as follows. First, we control for

regional shocks such as business cycles and changes in national policies. Second, Japanese municipalities are influenced by their upper level of government (i.e., the prefectures), since they usually consult with the prefectures during the implementation of policies introduced by the national government. For example, when introducing accrual accounting to the sewage public enterprises, the MIC required that the prefectures should help the municipalities make a smooth transition in the "Notes on the Promotion of the Application of Public Enterprise Accounting" in January 2015. For these reasons, we estimate the model with prefecture-year fixed effects and find that *ACCRUAL* and *FULL* are negatively significant in both Model EX and Model EN (see Tables 5 and 6).

We also determine whether the introduction of accrual accounting alone can improve cost efficiency by using a sample of municipalities that only applied the LPEA's financial provisions and those that did not apply such provisions (see Table 7). As a result, the dummy variable *PARTIAL*, which indicates that only the financial provisions of the LPEA were applied, is negatively significant in both Model EX and Model EN. Moreover, given that the initial costs of sewage systems within several years of their opening can be high (Kawamura et al., 2009), we analyze the effect of partially applying the financial provisions of the LPEA in the sample of public enterprises that opened before 2009. We find that *PARTIAL* is also negatively significant in both Model EX and Model EN. Therefore, our finding that the introduction of accrual accounting through the LPEA improves cost efficiency is robust.

5. Discussion and conclusion

This study examined the financial impact of accrual accounting on municipally controlled enterprises, with specific focus on the Japanese municipal sewage system. Previous studies, such as Bessho and Hirota (2023), have highlighted the impact of introducing accrual accounting on local government expenditures. They implied that it is highly possible that such actions are purely symbolic. Conversely, the introduction of accrual accounting in

Japanese sewage public enterprises is indeed a complete switch from cash accounting, Lampe et al. (2015) showed that such a change increase both cost efficiency and fiscal transparency. Thus, to determine the fiscal effects of introducing accrual accounting from the perspective of cost efficiency, we conducted a quantitative analysis by using a combination of SFA, panel data, and instrumental variables. For example, the MIC issued notices requiring the introduction of accrual accounting to sewage public enterprises. However, the degree of enforcement differed, depending on population size, i.e., between municipalities with a population of 30,000 or more and those with a population of less than 30,000. Thus, following Bessho and Hirota (2023), we created a dummy variable for the population in 2015 and used it as an instrumental variable for addressing the endogeneity issue.

The results of our analysis are as follows. First, in line with Lampe et al. (2015), we found that the switch from cash-based accounting to accrual accounting increased cost efficiency. In the case of introducing accrual accounting to Japanese sewage public enterprises, it was important to determine whether this change was only regarding accounting standards or involved organizational and managerial changes. Hence, we also investigated if the switch in accounting standards, along with organizational and managerial changes, enhanced cost efficiency. However, no clear difference was found.

As mentioned earlier, the introduction of accrual accounting differs between Japanese local governments and public enterprises such as sewage. In this case, although the impact on public finance most likely differs, another possible factor is that since capital investment accounts for a significant proportion of sewage public enterprises, their dependence on liabilities is also higher. From an accounting perspective, the switch to accrual accounting enables a clearer view of assets and liabilities, which can lead to greater efficiency and accountability. Therefore, in the case of sewage public enterprises (especially those with a

high dependence on liabilities), the effect of switching to accrual accounting may be significant.

Overall, these results provide new quantitative evidence for the debate on fiscal discipline. To clarify, greater fiscal transparency can lead to greater cost efficiency in the public sector. The extent to which the introduction of accrual accounting contributes to greater fiscal transparency also depends on whether the public sector actually makes the transition to accrual accounting, including the management of budgets and settlements. However, whether fiscal transparency leads to cost efficiency also depends on how much assets and liabilities the public sector holds. In the case of Japanese sewage public enterprises, which clearly include a large number of assets and liabilities, the benefits of introducing accrual accounting are believed to be significant. This is an important evidence for European countries that have adopted accrual accounting for their local public enterprises and for emerging countries that are trying to do so. Of course, introducing accrual accounting for public enterprises will incur immediate costs. Ultimately, however, it will eventually improve the cost efficiency of the public sector in general, for example, by being able to reduce subsidies from the general account to public enterprises.

Declaration of interests

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Author contributions:

Akinobu San: Conceptualization, Methodology, Data curation, Writing- Original draft preparation. Haruo Kondoh: Supervision, Writing- Reviewing and Editing.

References

Adhikari, P., Gårseth-Nesbakk, L., 2016. Implementing public sector accruals in OECD Member States: Major issues and challenges. Acc. Forum. 40, 125–142. https://doi.org/10.1016/j.accfor.2016.02.001.

Adhikari, P., Jayasinghe, K., 2017. 'Agents-in-focus' and "agents-in-context": The strong structuration analysis of central government accounting practices and reforms in Nepal. Acc. Forum. 41, 96–115. https://doi.org/10.1016/j.accfor.2017.01.001.

Aigner, D.J., Lovell, C.A.K., Schmidt, P., 1977. Formulation and estimation of stochastic frontier production models. J. Econ. 6, 21–37. https://doi.org/10.1016/0304-4076(77)90052-5.

Alchian, A.A., Demsetz, H., 1972. Production, information costs and economic organisation. Am. Econ. Rev. 62, 777–795.

Alesina, A., Perotti, R., Tavares, J., 1998. The political economy of fiscal adjustments. Brook. Pap. Econ. Act. 1, 197–266.

Alt, J.E., Lassen, D.D., 2006. Fiscal transparency, political parties, and debt in OECD countries. Eur. Econ. Rev. 50, 1403–1439. https://doi.org/10.1016/j.euroecorev.2005.04.001.

Ball, I., 1994. Reinventing government: Lessons learned from the New Zealand treasury. Gover. Account. J. 43, 19–25.

Battese, G.E., Coelli, T.J., 1995. A model for technical inefficiency effects in a stochastic frontier production function for panel data. Empirical Econ. 20, 325–332. https://doi.org/10.1007/BF01205442.

Benito, B., Bastida, F., 2009. Budget transparency, fiscal performance, and political turnout: An international approach. Public Admin. Rev. 69, 403–417. https://doi.org/10.1111/j.1540-6210.2009.01988.x.

Bertero, E., Rondi, L., 2000. Financial pressure and the behaviour of public enterprises under soft and hard budget constraints: Evidence from Italian panel data. J. Public Econ. 75, 73–98. https://doi.org/10.1016/S0047-2727(99)00057-2.

Bessho, S., Hirota, H., 2023. Do public account financial statements matter? Evidence from Japanese municipalities. Eur. J. Pol. Econ. 78, 1–18. https://doi.org/10.1016/j.ejpoleco.2023.102358.

Borge, L.E., Falch, T.F., Tovmo, P., 2008. Public sector efficiency: The roles of political and budgetary institutions, fiscal capacity, and democratic participation. Public Choice. 136, 475–495. https://doi.org/10.1007/s11127-008-9309-7.

Boxall, P., 1998. The revolution in government accounting. Aust. CPA. 68, 18–20.

Brito, J.R., Jorge, S., 2021. The institutionalization of a new accrual-based public sector accounting system: The case of Cape Verde. Int. J. Public Admin. 44, 372–389. https://doi.org/10.1080/01900692.2020.1728312.

Carlin, T.M., 2005. Debating the impact of accrual accounting and reporting in the public sector. Financ. Acc. Manag. 21, 309–336. https://doi.org/10.1111/j.0267-4424.2005.00223.x.

Christiaens, J., Van Peteghem, V., 2007. Governmental accounting reform: Evolution of the implementation in Flemish municipalities. Financ. Acc. Manag. 23, 375–399. https://doi.org/10.1111/j.1468-0408.2007.00434.x.

Christofzik, D.I., 2019. Does accrual accounting alter fiscal policy decisions? Evidence from Germany. Eur. J. Pol. Econ. 60, 101805. https://doi.org/10.1016/j.ejpoleco.2019.07.003.

De Borger, B., Kerstens, K., 1996. Cost efficiency of Belgian local governments: A comparative analysis of FDH, DEA, and econometric approaches. Reg. Sci. Urban Econ. 26, 145–170. https://doi.org/10.1016/0166-0462(95)02127-2.

De Borger, B., Kerstens, K., Moesen, W., Vanneste, J., 1994. Explaining differences in productive efficiency: An application to Belgian municipalities. Public Choice. 80, 339–358. https://doi.org/10.1007/BF01053225.

Debrun, X., Moulin, L., Turrini, A., Ayuso-i-Casals, J., Kumar, M.S., 2008. Tied to the mast? National fiscal rules in the European Union. Econ. Policy. 23, 297–362. https://doi.org/10.1111/j.1468-0327.2008.00199.x.

Dorn, F., Gaebler, S., Roesel, F., 2021. Ineffective fiscal rules? The effect of public sector accounting standards on budgets, efficiency, and accountability. Public Choice. 186, 387–412. https://doi.org/10.1007/s11127-019-00755-8.

Eichengreen, B., Bayoumi, T., 1994. The political economy of fiscal restrictions: Implications for Europe from the United States. Eur. Econ. Rev. 38, 783–791. https://doi.org/10.1016/0014-2921(94)90114-7.

Evans, M., 1997. Information for decision taking about the allocation of resources, Public Finance. Found. Rev. 13, 1–14.

Geys, B., 2006. Looking across borders: A test of spatial policy interdependence using local government efficiency ratings. J. Urban Econ. 60, 443–462. https://doi.org/10.1016/j.jue.2006.04.002.

Geys, B., Heinemann, F., Kalb, A., 2010. Voter involvement, fiscal autonomy and public sector efficiency: Evidence from German municipalities. Eur. J. Pol. Econ. 26, 265–278. https://doi.org/10.1016/j.ejpoleco.2009.11.002.

Geys, B., Moesen, W., 2009a. Measuring local government technical (in)efficiency: An application and comparison of FDH, DEA, and econometric approaches. Public Perform. Manag. Rev. 32, 499–513. https://doi.org/10.2753/PMR1530-9576320401.

Geys, B., Moesen, W., 2009b. Exploring sources of local government technical inefficiency: Evidence from Flemish municipalities. Public Fin. Manag. 9, 1–29. https://doi.org/10.1177/152397210900900101.

Harun, H., Van Peursem, K., Eggleton, I., 2012. Institutionalization of accrual accounting in the Indonesian public sector. J. Acc. Organ. Change. 8, 257–285. https://doi.org/10.1108/18325911211258308.

Holmström, B., 1979. Moral hazard and observability. Bell J. Econ. 10, 74–91. Eom. https://doi.org/10.2307/3003320.

Jensen, M.C., Meckling, W.H., 1976. Theory of the firm: Managerial behavior, agency costs and ownership structure. J. Financ. Econ. 3, 305–360. https://doi.org/10.1016/0304-405X(76)90026-X.

Kalb, A.2009. What Determines Local Governments' Technical Efficiency? The Case of Road Maintenance. ZBW Discussion Paper Number 09047. Centre for European Economic Research, Mannheim.

Kalb, A., 2010. The impact of intergovernmental grants on cost efficiency: Theory and evidence from German municipalities. Econ. Anal. Policy. 40, 23–48. https://doi.org/10.1016/S0313-5926(10)50002-X.

Kalb, A., Geys, B., Heinemann, F., 2012. Value for money? German local government efficiency in a comparative perspective. Appl. Econ. 44, 201–218. https://doi.org/10.1080/00036846.2010.502110.

Karakaplan, M.U., Kutlu, L., 2017. Endogeneity in panel stochastic frontier models: An application to the Japanese cotton spinning industry. Appl. Econ. 49, 5935–5939. https://doi.org/10.1080/00036846.2017.1363861.

Kawamura, A., Ohira, K., Yoshida, A., 2009. The Efficiency of Public Sewage and Subsidy, Department of Social Systems and Management Discussion Paper Series 1236. University of Tsukuba, Tsukuba (in Japanese).

Kornai, J., Maskin, E., Roland, G., 2003. Understanding the soft budget constraint. J. Econ. Lit. 41, 1095–1136. https://doi.org/10.1257/002205103771799999.

Kuhlmann, S., Bogumil, J., Grohs, S., 2008. Evaluating administrative modernization in German local governments: Success or failure of the new steering model? Public Admin. Rev. 68, 851–863. https://doi.org/10.1111/j.1540-6210.2008.00927.x.

Laffont, J.-J., Tirole, J., 1986. Using cost observation to regulate firms. J. Pol. Econ. 94, 614–641. https://doi.org/10.1086/261392.

Lampe, H.W., Hilgers, D., Ihl, C., 2015. Does accrual accounting improve municipalities' efficiency? Evidence from Germany. Appl. Econ. 47, 4349–4363. https://doi.org/10.1080/00036846.2015.1030562.

Lapsley, I., 2009. New public management: The cruellest invention of the human spirit? Abacus. 45, 1–21. https://doi.org/10.1111/j.1467-6281.2009.00275.x.

Lapsley, I., Oldfield, R., 2001. Transforming the Public Sector: Management Consultants as Agents of Change, European Account.

Likierman, A., 2000. Changes to managerial decision-taking in U.K. central government. Manag. Acc. Res. 11, 253–261. https://doi.org/10.1006/mare.2000.0131.

Meeusen, W., van den Broeck, J., 1977. Efficiency estimation from Cobb–Douglas production functions with composed error. Int. Econ. Rev. 18, 435–444. https://doi.org/10.2307/2525757.

Micaleff, F., 1994. A new era in reporting by government departments. Australian Accountant. 64, 33–34.

Migué, J.-L., Bélanger, G., Niskanen, W.A., 1974. Toward a general theory of managerial discretion. Public Choice. 17, 27–47. https://doi.org/10.1007/BF01718995.

Milesi-Ferretti, G.M., 2004. Good, bad or ugly? On the effects of fiscal rules with creative accounting. J. Public Econ. 88, 377–394. https://doi.org/10.1016/S0047-2727(02)00076-2.

Niskanen, W.A., 1975. Bureaucrats and politicians. J. Law Econ. 18, 617–643. https://doi.org/10.1086/466829.

Olson, M., 1969. The principle of "fiscal equivalence": The division of responsibilities among different levels of government. Am. Econ. Rev. 59, 479–487.

Pallot, J., 1992. Elements of a theoretical framework for public sector accounting. Acc. Aud. Acc. J. 5, 38–59. https://doi.org/10.1108/09513579210008244.

Pallot, J., 1994. The development of accrual-based accounts for the government of New Zealand. Adv. Int. Acc. 7, 287–308.

Parker, L., Guthrie, J.1990. Public sector accounting and the challenge of managerialism, in: Forster, J., Wanna, J. (Eds.), Budgetary Management and Control: The Public Sector in Australasia. MacMillan, Melbourne, pp. 114–127.

Paulsson, G., 2006. Accrual accounting in the public sector: Experiences from the central government in Sweden. Financ. Acc. Manag. 22, 47–62. https://doi.org/10.1111/j.0267-4424.2006.00392.x.

Persson, T., Tabellini, G., 2000. Political Economics: Explaining Economic Policy. MIT Press, Cambridge.

Peter van der Hoek, M.P., 2005. From cash to accrual budgeting and accounting in the public sector: The Dutch experience. Public Budg. Finance. 25, 32–45. https://doi.org/10.1111/j.0275-1100.2005.00353.x.

Poterba, J.M., 1994. State response to fiscal crisis: The effects of budgetary institutions and politics. J. Polit. Econ. 102, 799–821. https://doi.org/10.1086/261955.

Raffer, C., 2020. Accrual accounting and the local government budget – A matching evaluation. SSRN: https://ssrn.com/abstract=3547302.

Ridder, H.-G., Bruns, H.-J., Spier, F., 2005. Analysis of public management change processes: The case of local government accounting reforms in Germany. Public Admin. 83, 443–471. https://doi.org/10.1111/j.0033-3298.2005.00457.x.

Salato, P., Gomes, P., Ferreira, C., 2023. Accrual accounting in the public sector of emerging economies: Bibliometric analysis and future research. Public Money Manag. 44, 376–388. https://doi.org/10.1080/09540962.2023.2200968.

Segal, I.R. Hya, 1998. Monopoly and soft budget constraint. RAND J. Econ. 29, 596–609. https://doi.org/10.2307/2556106.

Tadatomo, K., 1997. Efficiency and cost burden of public sewage, Fiscal Stud. 22, 56–63 (in Japanese).

Vanden Eeckhaut, P., Tulkens, H., Jamar, M.A.1993. Cost efficiency in Belgian municipalities, in: Fried, H.O., Lovell, C.A.K., Schmidt, S.S. (Eds.), The Measurement of Productive Efficiency: Techniques and Applications. Oxford University Press, New York, pp. 300–340.

von Hagen, J., 1991. A note on the empirical effectiveness of formal fiscal restraints. J. Public Econ. 44, 199–210. https://doi.org/10.1016/0047-2727(91)90025-W.

von Hagen, J., Harden, J., 1995. Budget processes and commitment to fiscal discipline, European Economic Revire. 39, 771–779.

Webster, A., 1998. Improving performance: Accrual accounting points the way ahead. Aust. CPA. 68, 24–26.

Table 1. Public Enterprises and Related Acts

Local Public Enterprises		
“Local Public Enterprise Act”	Full application	Water supply Transportation Electricity Gas
	Partial application	Hospital
“Local Finance Act”		Transportation (ship traffic) Electricity (other than power generation) Simple water supply Markets Slaughterhouses Public sewage Tourism facilities Port development (port facilities only) Parking lots Residential land development

Source: Ministry of Internal Affairs and Communications,

https://www.soumu.go.jp/main_sosiki/c-zaisei/kouei.html.

Table 2. Descriptive Statistics (783 municipalities over nine years)

Variable	Obs.	Mean	Std. dev.	Min	Max
ln Cost (JPY/㎥)[1]	7,047	4.7484	0.4645	2.0794	8.4422
ln *SEWAGE* (㎥)[1]	7,047	14.2509	1.0323	8.0971	9.0219
ln *WAGE* (1,000 JPY per capita)[2,3]	7,047	8.6412	0.0875	8.2365	9.022
ln *DEN* (people/ha)[1]	7,047	3.5010	0.4447	1.8546	5.0280
ln *YEAR*[1]	7,047	3.4519	0.3273	2.3979	4.1744
PLANT dummy[1]	7,047	0.5506	0.4975	0	1
DIVER dummy[1]	7,047	0.9384	0.2404	0	1
CONNECT rate[1]	7,047	0.8452	0.1446	0.0661	1
TRANSFER rate[1,3]	7,047	0.3892	0.2113	0	1.3234
ACCRUAL dummy[1]	7,047	0.4332	0.4956	0	1
FULL dummy[1]	7,047	0.2574	0.4372	0	1

Source: [1] Survey of the Ministry of Internal Affairs and Communication, “Public Enterprise Yearbook; [2] Survey of the Ministry of Internal Affairs and Communication, “Population Based on Basic Resident Register; [3] Survey of the Ministry of Internal Affairs and Communication, “Local Government Financial Survey.”

Table 3. Results of the Multioutput Frontier Estimation (LPEA applied)

	Model EX	Model EN	
Constant	5.654***	5.767***	(0.358)
	(0.355)		
Ln *SEWAGE*	−0.107***	−0.115***	
	(0.014)	(0.014)	
Ln *WAGE*	0.232***	0.239***	(0.038)
	(0.038)		
Ln *DEN*	−0.261***	−0.253***	
	(0.025)	(0.024)	
Ln *YEAR*	−0.343***	−0.370***	
	(0.045)	(0.044)	
PLANT	0.085***	0.093***	(0.016)
	(0.016)		
DIVER	0.033	0.025	(0.022)
	(0.023)		
Dep.var: ln(σ^2_u)			
Constant	0.342**	0.409***	
	(0.134)	(0.136)	
ACCRUAL	0.029*	−0.120**	
	(0.017)	(0.039)	
CONNECT	−1.459***	−1.368***	
	(0.144)	(0.149)	

TRANSFER	0.391***	0.192**
	(0.067)	(0.083)
Dep.var: ln(σ²_v)		
Constant	−3.957***	
	(0.018)	
Dep.var: ln(σ²_w)		
Constant		−3.960***
		(0.018)
eta1 (*ACCRUAL*)		0.057*** (0.014)
eta endogeneity test		X2 = 17.46 p = 0.000
Observations	7,047	7,047
Log Likelihood	2,333.52	−1,483.41
Mean Cost Efficiency	0.5479	0.5476
Median Cost Efficiency	0.5291	0.5261

Notes: Std. errors are shown in parentheses. Except for the variables in the inefficiency model, each variable is normalized by its sample mean and natural logs. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 4. Results of the Multioutput Frontier Estimation (LPEA fully applied)

	Model EX	Model EN	
Constant	5.660***	5.821***	(0.360)
	(0.354)		
Ln *SEWAGE*	−0.104***	−0.123***	
	(0.014)	(0.015)	
Ln *WAGE*	0.229***	0.231***	(0.038)
	(0.038)		
Ln *DEN*	−0.260***	−0.246***	
	(0.025)	(0.024)	
Ln *YEAR*	−0.352***	−0.340***	
	(0.044)	(0.044)	
PLANT	0.083***	0.088***	(0.016)
	(0.016)		
DIVER	0.030	0.031	(0.023)
	(0.022)		
Dep.var: ln(σ^2_u)			
Constant	0.322**	0.354***	
	(0.134)	(0.136)	
FULL	0.068***	−0.122**	(0.051)
	(0.020)		
CONNECT	−1.454***	−1.352***	
	(0.142)	(0.150)	
TRANSFER	0.413***	0.249***	(0.073)
	(0.060)		

Dep.var: ln(σ²_v)		
Constant	−3.958*** (0.018)	
Dep.var: ln(σ²_w)		
Constant		−3.961*** (0.018)
eta1 (*FULL*)		0.069*** (0.017)
eta endogeneity test		X2 = 17.21 p = 0.000
Observations	7,047	7,047
Log Likelihood	2,337.72	−1,207.39
Mean Cost Efficiency	0.5485	0.5469
Median Cost Efficiency	0.5299	0.5283

Notes: Std. errors are shown in parentheses. Except for the variables in the inefficiency model, each variable is normalized by its sample mean and natural logs. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 5. Results of the Multioutput Frontier Estimation (FE, LPEA applied)

	Model EX	Model EN

Constant	6.304*** (0.372)	6.350***	(0.373)
Ln *SEWAGE*	−0.262*** (0.016)	−0.264*** (0.016)	
Ln *WAGE*	0.146*** (0.039)	0.144***	(0.039)
Ln *DEN*	−0.029 (0.025)	−0.027	(0.025)
Ln *YEAR*	0.011 (0.047)	0.007	(0.047)
PLANT	0.051*** (0.016)	0.054*** (0.016)	
DIVER	0.088*** (0.022)	0.086***	(0.021)
pref.-year dummy	yes	yes	
Dep.var: $\ln(\sigma^2\_u)$			
Constant	0.122 (0.161)	0.129	(0.162)
ACCRUAL	−0.137*** (0.023)	−0.179*** (0.038)	
CONNECT	−1.473*** (0.178)	−1.438*** (0.181)	
TRANSFER	0.301*** (0.075)	0.258** (0.081)	

Dep.var: ln(σ²_v)		
Constant	−4.153*** (0.018)	
Dep.var: ln(σ²_w)		
Constant		−4.153*** (0.018)
eta1 (*ACCRUAL*)		0.016 (0.011)
eta endogeneity test		X2 = 1.97 p = 0.160
Observations	7,047	7,047
Log Likelihood	3,066.15	884.85
Mean Cost Efficiency	0.6397	0.6392
Median Cost Efficiency	0.6224	0.6211

Notes: Std. errors are shown in parentheses. Except for the variables in the inefficiency model, each variable is normalized by its sample mean and natural logs. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 6. Results of the Multioutput Frontier Estimation (FE, LPEA fully applied)

	Model EX	Model EN

Constant	6.174*** (0.374)	6.274***	(0.377)
Ln *SEWAGE*	−0.262*** (0.016)	−0.267*** (0.016)	
Ln *WAGE*	0.152*** (0.039)	0.150***	(0.039)
Ln *DEN*	−0.031 (0.025)	−0.031	(0.025)
Ln *YEAR*	0.036 (0.050)	0.033	(0.049)
PLANT	0.047*** (0.016)	0.048*** (0.016)	
DIVER	0.100*** (0.022)	0.099***	(0.022)
pref.-year dummy	yes	yes	
Dep.var: ln(σ^2_u)			
Constant	0.105 (0.160)	0.108	(0.162)
FULL	−0.065*** (0.024)	−0.149***	(0.044)
CONNECT	−1.577*** (0.176)	−1.526*** (0.180)	
TRANSFER	0.450*** (0.070)	0.391***	(0.075)

Dep.var: ln(σ^2_v)		
Constant	−4.147***	
	(0.018)	
Dep.var: ln(σ^2_w)		
Constant		−4.149***
		(0.018)
eta1 (*FULL*)		0.028*
		(0.012)
eta endogeneity test		X2 = 5.36 p = 0.021
Observations	7,047	7,047
Log Likelihood	3,051.47	303.37
Mean Cost Efficiency	0.6398	0.6388
Median Cost Efficiency	0.6211	0.6207

Notes: Std. errors are shown in parentheses. Except for the variables in the inefficiency model, each variable is normalized by its sample mean and natural logs. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 7. Results of the Multioutput Frontier Estimation (FE, LPEA partial applied)

	Model EX	Model EN

Constant	6.379*** (0.454)	6.359***	(0.455)
Ln *SEWAGE*	−0.250*** (0.020)	−0.251*** (0.020)	
Ln *WAGE*	0.096** (0.049)	0.098**	(0.049)
Ln *DEN*	0.002 (0.034)	−0.001	(0.035)
Ln *YEAR*	0.020 (0.055)	0.026	(0.056)
PLANT	0.068*** (0.020)	0.064*** (0.020)	
DIVER	0.071*** (0.023)	0.072***	(0.023)
pref.-year dummy	yes	yes	
Dep.var: ln(σ^2_u)			
Constant	0.126 (0.183)	0.118	(0.183)
PARTIAL	−0.128*** (0.031)	−0.088*	(0.053)
CONNECT	−1.575*** (0.202)	−1.589*** (0.202)	
TRANSFER	0.495*** (0.098)	0.522***	(0.102)

Dep.var: ln(σ^2_v)		
Constant	−4.140***	
	(0.021)	
Dep.var: ln(σ^2_w)		
Constant		−4.141***
		(0.021)
eta1 (*PARTIAL*)		−0.015
		(0.016)
eta endogeneity test		X2 = 0.83 p = 0.363
Observations	5,233	5,233
Log Likelihood	2,073.51	1,115.87
Mean Cost Efficiency	0.6292	0.6289
Median Cost Efficiency	0.6169	0.6154

Notes: Std. errors are shown in parentheses. Except for the variables in the inefficiency model, each variable is normalized by its sample mean and natural logs. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 8. Results of the Multioutput Frontier Estimation (FE, LPEA partial applied, not new)

	Model EX	Model EN

Constant	6.483*** (0.450)	6.480*** (0.450)
Ln *SEWAGE*	−0.232*** (0.019)	−0.232*** (0.019)
Ln *WAGE*	0.074 (0.048)	0.075 (0.048)
Ln *DEN*	0.001 (0.034)	0.000 (0.034)
Ln *YEAR*	−0.030 (0.056)	−0.030 (0.057)
PLANT	0.069*** (0.019)	0.068*** (0.020)
DIVER	0.073** (0.023)	0.073** (0.023)
pref.-year dummy	yes	yes
Dep.var: ln(σ^2_u)		
Constant	−0.594*** (0.217)	−0.599*** (0.218)
PARTIAL	−0.157*** (0.031)	−0.139*** (0.053)
CONNECT	−0.744*** (0.237)	−0.749*** (0.237)
TRANSFER	0.514*** (0.101)	0.526*** (0.105)
Dep.var: ln(σ^2_v)		

Constant	−4.197*** (0.022)	
Dep.var: ln(σ²_w)		
Constant		−4.197*** (0.022)
eta1 (*PARTIAL*)		−0.007 (0.016)
eta endogeneity test		X2 = 0.18 p = 0.671
Observations	5,106	5,106
Log Likelihood	2,155.97	1,238.90
Mean Cost Efficiency	0.6342	0.6341
Median Cost Efficiency	0.6223	0.6217

Notes: Std. errors are shown in parentheses. Except for the variables in the inefficiency model, each variable is normalized by its sample mean and natural logs. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.