Graduate School of
Business Administration

KOBE UNIVERSITY

ROKKO KOBE JAPAN

2016-2

Factors Affecting Inefficiency Level:Stochastic Frontier Analysis of Public Utility Firms in Japan

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Discussion Paper Series

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Stochastic Frontier Analysis of Public Utility Firms in Japan

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January 8th, 2016

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[Abstract]: The main purpose of this study is to investigate what types of internal and external factors affect technical inefficiency in public utility firms. We consider governance structure and business diversification strategy as internal factors and governmental intervention and competition as external factors. By using 1106 observations comprised of Japanese public utility firms from 1989 to 2002, we estimate the stochastic frontier production function. The main findings are as follows: (i) The governance factor has an important effect on a firm's inefficiency. As ownership by foreign shareholders and investment funds increase, the technical inefficiency of a public utility firm decreases. (ii) A business diversification strategy increases inefficiency, though the magnitude of increase is relatively small. (iii) Governmental intervention does not have a clear effect on inefficiency. (iv) The monopoly level shows a quite clear effect on a firm's inefficiency. Overall, our empirical results suggest that internal factors such as governance structure and ownership by foreign shareholders and investment funds, and external factors such as monopoly level are factors especially important to the reduction of technical inefficiency in public utilities.

[Key Words]: Stochastic Frontier Analysis, Governance, Diversification Strategy, Regulation, Competition, Public Utility Firms

[JEL Classification Number]: M11, M21, L14, L51

1. Introduction

In studies of inefficiency in public utility firms, external factors such as governmental intervention, including regulations and competition, are typically examined as important determinants (e.g. Berg and Jeong (1991), Antel et al. (1995), Pantalone and Platt (1997), Schneider (2003), Fenn et al. (2008), Ter-Martirosyan and Kwoka (2010)). However, recent developments among private firms indicate that internal corporate management could induce effective management. For example, corporate governance and business diversification strategy have been shown to be important factors in firms' cost efficiency (e.g. Berger and Hannan (1998), Fries and Taci (2005), Jeng and Lai (2005), Zelenyuk and Zheka (2006) and Berger et al. (2009)). Thus, not only external but also internal factors can play an important role in improving efficiency. Nevertheless, these internal factors are rarely investigated in research on the efficiency of public utility firms.

By using a stochastic frontier production model, this study aims to identify what types of internal and external factors affect public utility firms' technical inefficiency. We consider governance structure and business diversification strategy as internal factors, and governmental intervention in the form of regulation and industry structuring through competition as external factors.

This study makes several contributions to the literature. First, this is the only study so far to consider together the four important factors mentioned above (i.e. governance structure, business diversification strategy, governmental intervention, and industry structure) and to investigate which are effective in reducing the technical inefficiency of public utility firms. Recently public utility firms are under great pressure from governance forces such as foreign shareholders. By considering both internal and external factors in the analysis, we can identify which internal or external factors are important to the reduction of inefficiency among public utility firms.

Second, we apply to our technical inefficiency analysis of public utility firms the factors considered important in private firms' performance analysis. Since the reduction of inefficiency is one process for improving a firm's performance, we can distinguish the effects of these internal management factors on inefficiency from their effects on performance. For example, while studies on corporate governance in private firms examine performance by looking at profitability and corporate value as factors impacted by governance structure, we investigate to what degree the governance structure improves production efficiency, by looking closely at previous research (e.g. Berger and Hannan (1998), Fries and Taci (2005), Jeng and Lai (2005), Zelenyuk and Zheka (2006) and Berger et al. (2009)). Similarly, we include a variable for the strategic behavior of a firm. Many public utility firms operate in more than two industries. In this study, the effect of a diversified strategy (i.e. a multi-segment strategy) is investigated.

Third, this study uses the quantity rather than the quality variable of governmental intervention. In previous studies (e.g. Berg and Jeong (1991), Antel et al. (1995), Ai and Sappington (2002), Schneider (2003), Fabrizio et al. (2007), Ter-Martirosyan and Kwoka (2010)), regulation, one form of governmental intervention, is commonly represented as a dummy variable, whether regulation is applied or not, or whether it has been enacted or not. On the other hand, in this study, we use "the degree of regulation" as a quantity variable. Similarly, we try to obtain more general results for the effect of governmental intervention. Heretofore, analysis has focused either only on specific types of regulation: environmental regulation (e.g. Nowell and Shogren (1994)), incentive regulation (e.g. Berg and Jeong (1991), Vogelsang (2002), Mizutani et al. (2009), Ter-Martirosyan and Kwoka (2010)), and price regulation (e.g. Cabral and Riordan (1989), Bös and Peters (1995), Vogelsang (2002)); or on specific industries: the energy industry (e.g. Nelson and Wohar (1983) and Majumdar and Marcus (2001)), rail (e.g. Mizutani et al. (2009)), and postal service (e.g. Mizutani and Uranishi (2003)). It cannot be assumed that, when the focus shifts to general regulation or to other industries, the results will be the same as in the specific cases listed here.

By stochastic frontier production analysis using 1106 observations comprised of Japanese public utility firms from 1989 to 2002, we conclude that ownership by foreign shareholders, top management, and investment funds, and the monopoly level of an industry, are the important factors in reducing a firm's technical inefficiency. In contrast, ownership by the government and individual shareholders, and business diversification, increase technical inefficiency. Governmental intervention does not have a significant effect on inefficiency.

This paper consists of five parts after the introduction. In section 2, we summarize previous studies, focusing especially on the relationship between efficiency and the four factors mentioned above. In section 3, the empirical model is specified. Section 4 presents an explanation of the data and the definitions of variables used in this study. In section 5, the empirical results are summarized. Section 6 contains concluding remarks.

2. Previous Studies

In this section, we will summarize previous studies concerning the relationship between the four important factors (i.e. governance structure, business diversification, governmental intervention, and industry structure) and firms' inefficiency.

2.1 Governance Structure

Previous studies in the area of private firms show that governance structure affects a firm's inefficiency significantly through the discipline of corporate management. For example, Berger and Hannan (1998), Fries and Taci (2005), Jeng and Lai (2005), Zelenyuk and Zheka (2006) and Berger et al. (2009) evaluate to what degree governance structure improves cost efficiency.

As for the measures of governance structure, there are (i) insider ownership (e.g. Berger and Hannan (1998)), (ii) foreign ownership (e.g. Fries and Taci (2005), Zelenyuk and Zheka (2006), Berger et al. (2009)), (iii) large shareholders (e.g. Berger and Hannan (1998) and Berger et al. (2009)) and (iv) governmental or public ownership (e.g. Berger et al. (2009)).

These measures of governance structure are commonly defined as either the ratio or dummy variable. For example, some studies (e.g. Berger and Hannan (1998), Fries and Taci (2005), Zelenyuk and Zheka (2006)) take the ratio of these governance measures to total shares or total assets. On the other hand, some studies (e.g. Berger and Hannan (1998) and Weistain and Yafeh (1998)) treat the governance measure as a dummy variable. Furthermore, in addition to these methods, some studies analyze the effect of the governance structure by comparing results obtained from different observations according to type of governance structure (e.g. Berger et al. (2009) and Jeng and Lai (2005)).

Finally, we will summarize the empirical results of our study of governance structure's effect on efficiency as follows. First, foreign ownership improves efficiency, as Zelenyuk and Zheka (2006) and Berger et al. (2009) show. Second, the existence of large shareholders has differing results. Berger and Hannan (1998) obtain the result that large shareholders decrease efficiency. On the other hand, a more recent study by Berger et al. (2009) produced the opposite result that large shareholders increase cost efficiency. Furthermore, Berger et al. (2009) also obtain a result contradictory to what is commonly perceived as the effect of governmental ownership. According to their results, governmental ownership increases efficiency. As for insider ownership, an increase in the manager's ownership tends to decrease efficiency but the effect is not statistically significant.

2.2 Diversification Strategy

There are few previous studies analyzing to what extent a business diversification strategy affects the inefficiency of public utility firms. Business diversification could propel the costs of a firm in two different directions. If there exist economies of scope among diversified businesses, the more diversified firms have smaller costs than otherwise. On the other hand, more diversified firms might have bigger costs if they are promoting excess investment and cross-subsidies among diversified divisions.

Some previous empirical studies investigate the relationship between business diversification and the cost efficiency of a firm (e.g. Ferrier et al. (1993), Rajan et al. (2000), Jeng and Lai (2005)). These studies focus on industries such as banking (e.g. Ferrier et al. (1993), Rajan et al. (2000)) and insurance (e.g. Jeng and Lai (2005)) and conclude that diversification causes cost inefficiency through the promotion of excess investing and cross-subsidizing. On the other hand, in the Italian bus industry, there exist economies of scope (e.g. Ottoz and Di Giacomo (2012)). Although his study is a productivity analysis of Italian manufacturing firms, Vannoni (2000) concludes that the degree of diversification is not significantly related to productivity.

2.3 Governmental Intervention

Studies have been done to determine the degree to which governmental intervention affects a firm's inefficiency. The most common approach is to use a cost of production function such as the translog cost function (e.g. Berg and Jeong (1991), Antel et al. (1995), Pantalone and Platt (1997), Schneider (2003), Ter-Martirosyan and Kwoka (2010)). Some studies analyze the cost efficiency change due to regulatory reform, one of the forms of governmental intervention, by using the stochastic cost frontier function (e.g. Kleit and Tecrell (2001) Mizutani et al. (2009)). Also, theoretical studies have been done which construct the relationship between governmental intervention and the costs of a firm (e.g. Cabral and Riordan (1989), Bös and Peters (1995), Vogelsang (2002)).

Second, in most previous studies, the measure of governmental intervention is used as a dummy variable, whether or not there is regulation (e.g. Berg and Jeong (1991), Antel et al. (1995), Ai and Sappington (2002), Schneider (2003), Fabrizio et al. (2007), Ter-Martirosyan and Kwoka (2010)). Other measures of governmental intervention vary by individual study, with, for example, the revenue ratio of a hospital under regulation defined as a proxy variable for regulation in Antel et al. (1995). There are almost no studies in which the degree of governmental intervention is measured as a directly obtained continuous variable.

Third, most previous studies focus on some specific governmental interventions: environmental regulation (e.g. Nowell and Shogren (1994)), incentive regulation (e.g. Berg and Jeong (1991), Vogelsang (2002), Mizutani et al. (2009), Ter-Martirosyan and Kwoka (2010)), and price regulation (e.g. Cabral and Riordan (1989), Bös and Peters (1995), Vogelsang (2002)). There are few studies on how governmental intervention itself in general affects the efficiency of individual firms.

Fourth, previous studies have produced conflicting results, with many studies supporting the idea that governmental intervention reduces inefficiency (e.g. Cabral and Riordan (1989), Kleit and Tecrell (2001), Ai and Sappington (2002), Ter-Martirosyan and Kwoka (2010), Nakamura (2010) and Buranabunyut and Peoples (2012), and other studies showing that governmental intervention increases productivity (e.g. Dufour et al. (1998), Berman and Bui (2001), Majumdar and Marcus (2001), Alpay et al. (2002) and Knittel (2002)). On the other hand, some studies show that governmental interventions increase the costs of firms (e.g. Gollop and Roberts (1983), Berg et al. (2005) and Fabrizio et al. (2007)), while others suggest that governmental intervention decreases firms' productivity (e.g. Christainsen and Haveman (1981), Gollop and Roberts (1983), Gray (1987), Majumdar and Marcus (2001) and Nicoletti et al. (2003)).

In addition to these results, some studies show that governmental intervention does not affect inefficiency. For example, studies such as Antel et al. (1995), Berg and Jeong (1991) and Bös and Peters (1995) conclude that the cost effect of regulation is not significant. Furthermore, there are two studies, Pantalone and Platt (1997) and Meyer and Leland (1980), which have different results. Pantalone and Platt (1997) conclude that effect on costs by regulation varies according to the difference in ability to respond to environmental change. Although Gutierrez' study (2003) is not a cost but a productivity study, Gutierrez concludes that regulatory governance has a positive effect on sector performance and efficiency.

2.4 Competition

First, competition among firms certainly affects firms' inefficiency. Most previous studies take cost efficiency as dependent variables: for example, Berger and Hannan (1998), Sari (2003) and Fenn et al. (2008). As a definition of competition, the Herfindahl-Hirschman index (e.g. Berger and Hannan (1998), Sari (2003)) and a concentration ratio of the top 5 firms (e.g. Fenn et al. (2008)) are often used. Most studies conclude that competition can improve cost efficiency.

According to Fenn et al. (2008), competitive pressures impose the threat of bankruptcy on firm managers and thus work as an incentive to cut inefficiency. Moreover, firm owners can judge the performance of their company by comparing it to rival firms when the industry is competitive, which results in appropriate pressure on the firm. On the other hand, Nakamura (2010) shows that competition sometimes worsens internal efficiency, since competitive pressures can drive firm managers to reduce necessary investment and costs. Sari (2003) integrates these conflicting results by pointing out that the relationship between cost inefficiency and competition is U-shaped, indicating that while a certain degree of competition improves cost efficiency, too much competition creates the opposite effect.

3. Empirical Model

As we mentioned before, the main purpose of this study is to investigate what types of factors most affect a firm's technical inefficiency. For the empirical analysis, we use the stochastic frontier production model[1], which is frequently used because it can identify the level of inefficiency of each individual firm. In order to examine the effects of various factors on inefficiency, we consider four types of factors: governance structure, diversification structure, government intervention, and competition, the former two types being internal factors and the latter two external factors relative to a firm. Next, we will explain the stochastic frontier production model and then discuss the determinants of inefficiency of public utility firms to construct the model.

Figure 1 shows the stochastic frontier production model and technical inefficiency. In this figure, technical inefficiency is shown as υ. The set of the most efficient levels that firms can achieve is shown as the production frontier. When a firm has no inefficiency, the firm's observed output level is located on the production frontier line. In this figure, firm A is considered the efficient firm. However, as firm B is located below the production frontier, the firm is considered as inefficient, as situation A shows.

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Figure 1

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In this study, we assume a two-input production function, with Q as observed production level, K as capital and L as labor of a firm. The public utility firm's production function is shown

[1] Because our data for the cost function did not have sufficient credibility when estimated, we specify the production function here rather than the cost function. For example, some of the estimated coefficients were not reasonable in light of economic theory, and the magnitudes of the key variables were not stable. This may have occurred because, as our sample includes multiple public utility industries for multiple years, we estimated for the key variables certain data that were unavailable directly from published information.

as equation (1). The function $f(K, L)$ is the production frontier, and thus equation (1) shows that the observed level of production is equal to the production frontier.

$$Q=f(K, L) \tag{1}$$

On the other hand, when a firm has inefficiency (υ), the observed level of output is less than the level of the production frontier by υ. Therefore, the firm's production function is shown as equation (2).

$$Q=f(K, L) - \upsilon \tag{2}$$

The inefficiency level, υ, is affected by four factors mentioned earlier. The inefficiency is assumed as Equation (3). Equation (3) shows that inefficiency υ follows the truncated normal distribution N_t and has the structure of $\boldsymbol{A'X}$ as the mean and σ^2 as the variance. $\boldsymbol{X}$ is the vector of factors influencing inefficiency and $\boldsymbol{A}$ is the parameter vector of $\boldsymbol{X}$. These factors, $\boldsymbol{X}$**,** are four. In this study, equations (2) and (3) are estimated simultaneously with the maximum likelihood method.

$$\upsilon \sim N_t(\boldsymbol{A'X}, \sigma^2) \tag{3}$$

Next, we explain the factors influencing the technical inefficiency hereafter to specify $\boldsymbol{X}$. As many public utility firms are privately owned, governance by significant actors is important. Proper governance structure, including private ownership and monitoring, might reduce the inefficiency of a firm. Furthermore, many firms have diversified their business. If there exist economies in business diversification, a more diversified firm can attain a higher efficiency level than others. On the other hand, a diversification strategy might generate extra costs through unnecessary investment and cross-subsidies. As public utility firms are in general regulated and limited in terms of competition, too much intervention by the government in the form of regulation might lead to the over-costing of a firm. Thus, we included these four important factors (i.e. governance structure, diversification strategy, governmental intervention, and competition) as the determinants of production inefficiency.

It is worth noting that governance structure and diversification strategy are factors over which a firm can exercise a degree of control. Each individual firm can change its internal environment. If a firm can gain cost advantages from business diversification, then the firm has incentive to diversify. At the same time, it can be easily seen that governance structure affects a firm's cost structure, in that a firm with strict management discipline adopting proper governance structure would generate less cost than a firm with loose management. On the other hand, variables such as governmental intervention and competition reflect the situation of the external environment in which each firm is involved. These are factors the firm cannot change, as set by the government or as the industry was created by the market.

In addition to these four factors, we included various factors as control variables. For macro-level differences among industries, an industry's characteristics variables are included as control variables (*IND*). Some industries might be declining while others are growing. For the progress in technology that can affect the production frontier, technology trend (*T*) is included in addition to two input factors, capital (*K*) and labor (*L*). Thus, considering the above discussion, we specified our basic model as the following system of equations.

$$Q=f(K, L, T)-\upsilon$$
$$\upsilon\sim N_t(\mathbf{A'X},\sigma^2)$$
$$\upsilon=g(GS, STR, GOV, ICMP, IND) \qquad (4)$$

where *Q*: observed level of output,
K: capital input,
L: labor input
T: technology,
υ: technical inefficiency,
GS: governance structure,
STR: diversification strategy,
GOV: governmental intervention,
ICMP: competition,
IND: characteristics of industry as a control variable.

Based on the above basic model, we specify the variables included in four factors. As for the governance structure, we consider the following variables: stock ratio held by the top 10 shareholders (GS_{TOP}), stock ratio held by foreign shareholders (GS_{FRN}), stock ratio held by top management (GS_{MANAG}), stock ratio held by government and public organizations (GS_{PUB}), stock ratio held by investment funds (GS_{FUND}), and stock ratio held by individuals (GS_{INDIV}). As for the strategy variable, we define the number of industries in which each firm is involved (STR_{DIV}). As for governmental intervention, we take the degree of regulation (GOV_{REG}). This variable is a quantity variable showing the magnitude of regulation. As for the competition factor, we consider the Herfindahl-Hirschman index ($ICMP_{HHI}$). This is the inverse variable of competition, since this index shows the extent of monopoly in an industry. Thus, when $ICMP_{HHI}$ is higher, this means that the industry is highly monopolistic. Finally, as for control variables for industries in which each firm is involved, we consider the industry's profitability (IND_{PRF}). The empirical function in this study is the Cobb-Douglas production function assuming two inputs and one output[2].

As a result, the empirical model to be estimated is expressed as follows.

$$lnQ = \alpha_0 + \alpha_K\, lnK + \alpha_L\, lnL + \tau_T\, T - \upsilon + \varepsilon \qquad (5)$$

$$\upsilon = \beta_0 + \Sigma_m \gamma_{GSm}\, GS_m + \gamma_{DIV}\, STR_{DIV} + \gamma_{REG}\, GOV_{REG} + \gamma_{HHI}\, ICMP_{HHI} + \gamma_{PRF}\, IND_{PRF} \qquad (6)$$

where Q: revenues,

K: capital,

L: labor,

T: time trend,

υ: inefficiency term,

ε: □□□□□□□□□□

GS_m: m = *TOP* (stock ratio held by top 10 shareholders), *FRN* (stock ratio held by foreign shareholders), *MANAG* (stock ratio held by top management), *PUB* (stock ratio held by government and public organizations), *FUND* (stock ratio held by investment funds), *INDIV* (stock ratio held by individuals),

STR_{DIV}: number of segments,

GOV_{REG}: degree of regulation,

$ICMP_{HHI}$: Herfindahl-Hirschman index,

IND_{PRF}: industry's profitability.

The estimation method is the maximum likelihood (ML) method for the system of equations (5) simultaneously. We also impose restrictions in equation (5) as $\alpha_K + \alpha_L = 1$.

4. Data

4.1 Sample

As mentioned earlier, we collected observations from public utility industries in Japan. At first, we selected a total of 150 public utility firms in Japan for the 14 years from 1989 to 2002. The public utility industries in this study are electricity supply, gas supply, transportation (i.e. air,

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[2] In an analysis of a stochastic frontier production model, the Cobb-Douglas function is frequently used for feasible estimation instead of such complicated functions as the translog function (e.g. Nakamura 2010). This is because a function with many variables tends to over-absorb the inefficiency term and error term, precluding convergence by the maximum likelihood method. We also estimated the production function assuming a case with three inputs (capital, labor, and materials), but this case also lacked sufficient credibility with regard to the stability and the reasonability of the results due to the lack of data availability. Thus, we decided to use the case of the Cobb-Douglas production function, assuming two inputs.

railway, bus, and truck), telecommunications, and broadcasting. Since our data is not a balanced panel data, the total sample size is reduced to 1106 as pooling data. This reduction occurs because some variables such as diversification strategy are not available for all observations in the years from 1989 to 2002.

4.2 Definition of Variables

Table 1 shows the definition of all variables used for the estimation in this study. First, we define output (*Q*) as total sales because there are many variations if we select physical output measures. Therefore, we choose output measure as monetary values. We use two kinds of input factors: capital (*K*) defined as property, plant, and equipment, and labor (*L*) defined as number of employees. Time trend (*T*) is a proxy variable for technology progress. In this study, 1989 is defined as the starting year.

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Table 1

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As for the governance structure, we consider six kinds of measures: the stock ratio held by the top 10 shareholders (GS_{TOP}), the stock ratio held by foreign shareholders (GS_{FRN}), the stock ratio held by top management (GS_{MANAG}), the stock ratio held by government and public organizations (GS_{PUB}), the stock ratio held by investment funds (GS_{FUND}), and the stock ratio held by individuals (GS_{INDIV}).

As for the diversification strategy variable (STR_{DIV}), the number of segments is defined as the number of industries in which each firm is involved. This variable expresses the extent of diversification of the firm.

As for governmental intervention (GOV_{REG}), we choose “degree of regulation.” The degree of regulation shows to what degree each firm is subjected to regulation, or its “regulation weight,” as originally defined by the Management and Coordination Agency (*Somucho*). The original data source for regulation weight is the JIP database for 2006, issued by the Research Institute of Economy, Trade and Industry (RIETI). This measure is obtained by counting the number of existing laws and regulations in each industry, by which process we can determine quantitatively the degree of industries’ regulation. However, this measure does not include information regarding types of regulations (i.e. environment, safety, and price regulation). Finally, it is worth noting that while this measure is based on industry summaries, many firms provide various services in diversified industries. The degree of regulation referred to in this study is calculated by weighted revenues of the industries in which each firm is involved.

As for competition factors, we define $ICMP_{HHI}$ as the Herfindahl-Hirschman index. This measure is obtained on a revenues basis and again is obtained by using weights of each firm's individual industry's revenues.

As for characteristics of industry as a control variable[3], we define the industry's profitability (IND_{PRF}) as the weighted average profitability of the industries to which each firm belongs. For example, if a firm is involved in four industries, this variable is obtained by the weighted average profitability of the four industries. The weight is derived from the firm's revenues from each industry.

5. Empirical Results

The estimation results of the system of equations shown as (5) are summarized in Table 2. We show six cases in Table 2: Case 1 as full variables included; Case 2 as competition variable excluded; Case 3 as governmental intervention excluded; Case 4 as diversification strategy and governmental intervention excluded, Case 5 as governmental intervention and industry's profitability excluded, and Case 6 as competition and industry's profitability excluded.

The results satisfy all of the required properties in the production function. First, the condition that the output is zero when all the inputs are zero, that is, $f(0, 0) = 0$, is satisfied since the constant α_0 is not significant in all cases. Second, homogeneity condition in input factors is satisfied, because we imposed restrictions on the model. Third, as for monotonicity conditions, it is necessary that the production function be a non-monotone decreasing function in input factors. Whether or not the monotonicity conditions are satisfied was evaluated by checking that the partial derivative of the production function with respect to input factors is not negative (i.e. $\partial lnQ/\partial lnK \geq 0$, $\partial lnQ/\partial lnL \geq 0$). The estimated coefficients of K and L are all positive with statistical significance, which means that monotonicity conditions are satisfied. Fourth, the concavity condition is also satisfied since the Cobb-Douglas function by nature incorporates concavity.

The results also have sufficient robustness, since key variables such as competition factor

[3] In order to control the difference among industries, industry dummy variables have frequently been used in previous studies. However, we did not include industry dummies for two reasons. First, since our sample consists of many public utility industries such as electricity supply, gas supply, transportation (i.e. air, railway, bus, and truck), telecommunications, and broadcasting, the model has too many industry dummies if included, which preclude the convergence of ML estimation. Similarly, if we estimate the model by industry instead of estimating with a whole sample including industry dummies, other trouble arises because ML estimation requires a large sample for convergence. Since our sample consists of 1106 firms in total, estimation by industry cannot be feasible in some industries due to small sample size. Second, we do not include industry dummies because we believe that industry differences can be controlled by other variables such as $ICMP_{HHI}$ and IND_{PRF}, which influence a substantial part of the industry's cost structure. Moreover, since these variables are adjusted by divisional sales ratio by firm, the effects on a firm by each industry are more properly reflected than with simple industry dummies. For example, to control the industry effect for a firm belonging to both railway and bus industries, the variables reflecting the level of business activity of the firm in each industry would be more suitable than a simple industry dummy.

show the correct sign, and the magnitudes of these variables are stable among cases. Moreover, we estimated cases with different combinations of explanatory variables in addition to those listed in Table 2. For example, we excluded the variable of corporate governance one by one for each case, then two variables, three variables, and so on. We found that the sign and the magnitude in these results were also stable. Thus, the results shown in Table 2 are robust and reasonable enough to serve as the basis for our discussion.

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Table 2
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First, governance factors are clearly important in their impact on technical inefficiency. Among six governance variables, five variables are statistically significant in all cases and their signs and magnitudes are stable. As the ratio of foreign shareholders becomes larger, the technical inefficiency of a public utility firm becomes smaller. This is consistent with Zelenyuk and Zheka (2006) and Berger et al. (2009). Foreign shareholders tend to monitor a firm's management more strictly than domestic shareholders. Similarly, as ownership by top management becomes larger, production inefficiency becomes smaller, which means that holding shares of the firms works as an incentive for top management to improve efficiency. This is consistent with previous studies arguing that stock options can be effective as an incentive for managers (e.g. Nakamura 2010). However, ownership by government and public organizations increases production inefficiency. According to Berger et al. (2005), since the goals of the government and the firm are different, agency problems occur and thus inefficiency increases. Ownership by investment funds increases production efficiency very strongly, which is also consistent with our expectation that funds have more incentives to monitor firms since they are subject to pressures to maximize the investment return for their customers. In contrast, individual shareholders tend to increase inefficiency, probably because their information on firms' management might be limited compared with organizational shareholders. The extent of the concentration of ownership, expressed as GS_{TOP}, tends to improve production inefficiency, but the coefficients in Cases 2, 5, and 6 are not significant. Thus, the effect is minor compared with the other governance variables.

Second, the fact that all empirical diversification strategy (STR_{DIV}) shows the positive sign with a statistical significance of 1% means that as a company diversifies more from its core industry to other industries, the technical inefficiency of all the firm's business increases. This result is consistent with previous studies, which were analyses of the financial industry, such as Ferrier et al. (1993), Rajan et al. (2000) and Jeng and Lai (2005). However, the magnitude of increase in technical inefficiency for diversification is relatively small.

Third, governmental intervention (GOV_{REG}) does not affect technical inefficiency. Although it shows the positive sign statistically in Case 1, which means that governmental intervention does increase technical inefficiency, the coefficient in the other cases is not statistically significant. These results suggest that the effect of governmental intervention is not stable but changeable according to the situation of the other factors. Thus, previous studies such as Antel et al. (1995), Berg and Jeong (1991) and Bös and Peters (1995) might reflect only one aspect of governmental intervention in a specific situation.

Fourth, compared with governmental intervention, the competition factor is quite clear. As the empirical results show, the monopoly level ($ICMP_{HHI}$) has the effect of reducing the inefficiency of a firm. The market becomes more competitive, which means that as $ICMP_{HHI}$ decreases, inefficiency increases. This is probably because public utilities are network industries with scale economy, and thus large and monopolistic firms tend to be efficient.

Last, as for characteristics of industry as a control variable, as industry's profitability (IND_{PRF}) increases, the inefficiency of a firm decreases.

In summary, our empirical results suggest that internal as well as external factors are important for cost reduction or efficiency. Both governance factors and the diversification factor are statistically significant. On the other hand, as governmental intervention does not have a clear effect, among external factors, traditionally considered the main determinants of a firm's efficiency, there are some factors whose effects on a firm's production structure are minor.

6. Conclusion

The main purpose of this study is to investigate how four factors—governance structure, business diversification strategy, governmental intervention, and competition—affect the technical inefficiency of public utility firms. Among the four factors, governance structure and business diversification strategy are considered internal factors amenable to change at the will of a firm seeking to achieve managerial efficiency. On the other hand, governmental intervention and competition are considered external factors that are beyond a firm's control. A firm must accept these factors, while striving to attain efficiency under the given conditions. Our main research question is this: among these four factors, which is the most influential?

From the empirical analysis, we found the following results.

(i) The governance factor has an important impact on firms' technical inefficiency. Empirical results show that as ownership by foreign shareholders, top management, and investment funds becomes larger, a firm's technical inefficiency decreases. The effect of investment funds is largest, followed by that of foreign shareholders. In contrast, ownership by the government and public organizations and individuals increases inefficiency significantly. The concentration rate of shareholding structure tends to decrease inefficiency, though the effect is relatively minor.

(ii) As a company diversifies more from its core industry into other industries, the inefficiency of all a firm's business increases. Our results are consistent with previous studies such as Ferrier et al. (1993), Rajan et al. (2000) and Jeng and Lai (2005). However, the magnitude of increase in efficiency for diversification is relatively small.

(iii) Governmental intervention does not have a clear effect on inefficiency. The effect depends on other variables included in the model, which suggests that the effects of governmental intervention suggested in previous studies such as Antel et al. (1995), Berg and Jeong (1991) and Bös and Peters (1995) might reflect one aspect of the effects in a specific situation.

(iv) Compared with governmental intervention, the competition factor shows a quite clear effect in technical inefficiency. As the industry tends to be monopolistic, the production efficiency increases, probably because of the scale economy of public utility industries. This result is consistent with theory and supports previous literature.

(v) Another important finding is that as an industry's profitability increases, the inefficiency of a firm decreases.

Overall, we can conclude that certain governance factors, that is, ownership by foreign shareholders and investment funds, and the monopoly level of an industry are the important factors in reducing a firm's technical inefficiency, and that, contrary to traditional expectations, governmental intervention as an external factor does not have a significant effect on inefficiency.

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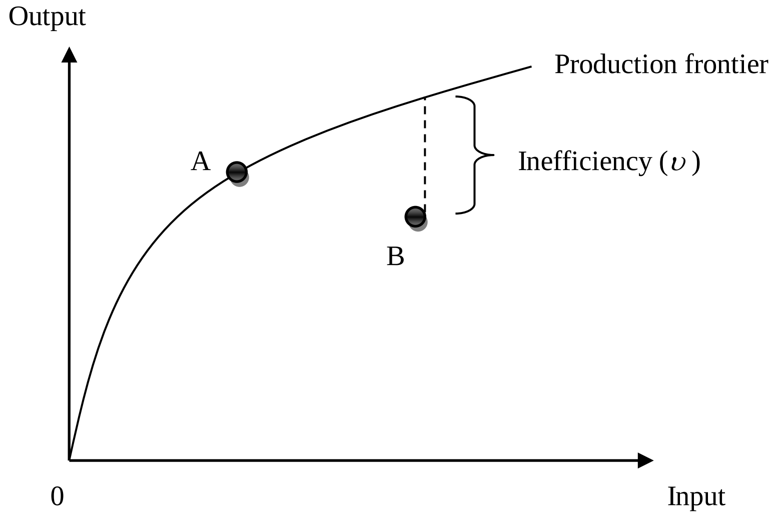

Figure 1 Stochastic Frontier Production Function and Technical Inefficiency

Table 1 Summary Statistics

Variable	Definition	Mean	Standard Deviation	Min	Max
Q	Sales (million yen)	290,830	628,621	1,926	7,000,000
K	Property, plant, and equipment (million yen)	351,976	1,052,506	20	12,000,000
L	Number of employees (people)	9,511	23,907	34	283,294
T	Time trend	9.653	3.810	2.000	15.000
GS_{TOP}	Concentration ratio of 4 firms	0.427	0.159	0.000	0.928
GS_{FRN}	Stock ratio held by foreign shareholders	0.039	0.049	0.000	0.269
GS_{MANAG}	Stock ratio held by top management	0.026	0.055	0.000	0.418
GS_{PUB}	Stock ratio held by government and public organizations	0.008	0.052	0.000	0.655
GS_{FUND}	Stock ratio held by investment funds	0.008	0.011	0.000	0.100
GS_{INDIV}	Stock ratio held by individuals	0.289	0.150	0.000	0.884
STR_{DIV}	Number of industries in which a firm is involved	3.722	1.405	2.000	11.000
GOV_{REG}	Regulation index	0.546	0.343	0.000	1.000
$ICMP_{HHI}$	Herfindahl-Hirschman index	0.388	0.250	0.004	1.000
IND_{PRF}	Industry’s profitability	0.880	0.382	0.244	2.536

(Note) The number of observations is 1106.

Table 2 Regression Results: Coefficients and Standard Error

Case	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Dependent variable	log(*Q*)	log(*Q*)	log(*Q*)	log(*Q*)	log(*Q*)	log(*Q*)
Capital (log(*K*))	0.468*** (0.015)	0.463*** (0.015)	0.465*** (0.015)	0.475*** (0.015)	0.409*** (0.014)	0.408*** (0.014)
Labor (log(*L*))	0.532*** (0.015)	0.537*** (0.015)	0.535*** (0.015)	0.525*** (0.015)	0.591*** (0.014)	0.592*** (0.014)
Time trend (*T*)	-0.006 (0.004)	-0.005 (0.004)	-0.008** (0.004)	-0.009** (0.004)	0.006* (0.004)	0.007* (0.004)
Constant	2.949 (21.774)	2.918 (13.094)	3.024 (26.083)	3.060 (31.543)	3.181 (67.030)	3.243 (99.318)
Dependent variable	υ	υ	υ	υ	υ	υ
Concentration ratio of 4 firms (GS_{TOP})	-0.153* (0.089)	-0.147 (0.090)	-0.152* (0.089)	-0.159* (0.090)	-0.147 (0.093)	-0.143 (0.093)
Stock ratio held by foreign shareholders (GS_{FRN})	-1.798*** (0.285)	-1.856*** (0.287)	-1.755*** (0.285)	-1.838*** (0.285)	-1.719*** (0.295)	-1.779*** (0.296)
Stock ratio held by top management (GS_{MANAG})	-0.867*** (0.287)	-0.842*** (0.290)	-0.893*** (0.288)	-0.931*** (0.289)	-1.418*** (0.292)	-1.379*** (0.293)
Stock ratio held by government and public organizations (GS_{PUB})	0.913*** (0.244)	0.933*** (0.246)	0.892*** (0.245)	0.855*** (0.246)	1.035*** (0.253)	1.055*** (0.254)
Stock ratio held by investment funds (GS_{FUND})	-3.646*** (1.186)	-3.803*** (1.194)	-3.901*** (1.184)	-3.968*** (1.190)	-3.939*** (1.227)	-3.971*** (1.236)
Stock ratio held by individuals (GS_{INDIV})	0.570*** (0.109)	0.592*** (0.110)	0.585*** (0.109)	0.609*** (0.109)	0.957*** (0.105)	0.961*** (0.105)
Number of industries in which a firm is involved (STR_{DIV})	0.032*** (0.009)	0.030*** (0.009)	0.031*** (0.009)	-	0.038*** (0.010)	0.037*** (0.010)
Regulation index (GOV_{REG})	0.115** (0.046)	0.017 (0.040)	-	-	-	-0.036 (0.041)
Herfindahl-Hirschman index ($ICMP_{HHI}$)	-0.246*** (0.060)	-	-0.170*** (0.051)	-0.163*** (0.051)	-0.162*** (0.053)	-
Industry's profitability (IND_{PRF})	-0.308*** (0.033)	-0.293*** (0.033)	-0.292*** (0.032)	-0.302*** (0.032)	-	-
Constant	0.789 (21.775)	0.710 (13.094)	0.874 (26.083)	1.038 (31.543)	0.906 (67.030)	0.931 (99.318)
Wald chi2	1037.230	1007.430	1027.790	1095.930	887.470	875.130
Log likelihood	-595.091	-603.589	-598.181	-603.637	-637.401	-641.640

(Note): Numbers in parentheses are standard error.

[2016.1.8 1214]