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Abstract
The Japanese government initiated a series of regulatory reforms in the mid-1990s. The Japanese urban gas industry consists of various sized private and non-private firms. Numerous previous studies find that deregulation leads to productivity improvements. We extend the literature by analyzing deregulation, privatization, and other aspects of a regulated industry using unique firm level data. This study measures productivity to evaluate the effect of the deregulation reform. Using data from 205 firms from 1993 to 2004, we find that the deregulation effect differs depending on firm size. Competitive pressure contributes to advanced productivity. The deregulation of gas sales to commercial customers is the most important factor for advancing productivity.

Keywords: Productivity analysis, Deregulation reform, Gas industry, Proportional distance function, Natural gas

1 Introduction

Substantial reforms deregulating the energy market have occurred since the early 1980s in the USA and European countries. The Japanese government also initiated regulatory reforms in the mid-1990s. This deregulation was motivated by the consensus view that deregulation was a key factor for advancing productivity in the industry. Numerous previous studies analyze the effects of deregulation on productivity, including analyses on the energy industry (see Price and Weyman-Jones, 1996; Kleit and Terrell, 2001; Nakano and Managi, 2008).

The present study contributes to the literature on deregulation and productivity in two ways. Previous studies do not separate the effect of each enforcement policy included in the deregulation. Generally, the deregulation of the energy industry includes several policies. The most important channel is the creation of a competitive market, i.e., new entrants are permitted in the energy market. In theory, firms have a strong incentive to increase production efficiency under high competitive pressure. Deregulation of the wholesale market is expected to encourage efforts to achieve productivity gains. If the wholesale market is competitive, energy firms can keep the capital cost of energy production low.

Another potential limitation in the literature is the small sample size used to measure production efficiency. Nearly all prior studies use a limited number of samples that make it difficult to analyze the complex effects of deregulation policies. Productivity measurement techniques, such as Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA), require a large sample of observations to obtain robust estimates of the production frontier. However, relatively small numbers of companies tend to operate in the energy market because of the presence of a natural monopoly in many countries. Thus, nearly all studies are forced to measure productivity using a small sample. In addition, regulated markets do not experience dynamic change, such as corporate mergers and business collusion.

In contrast to these limitations in the literature, the Japanese urban gas industry has unique characteristics. It includes both private and non-private firms of various sizes. This characteristic helps us analyze the effects of deregulation on a regulated industry in detail. For example, corporate mergers and privatization occurred in conjunction with the deregulation of the Japanese urban gas industry. Consequently, an analysis of the Japanese gas industry has the potential to contribute to the discussion of deregulation and other important market reforms such as privatization and corporate mergers. In addition, we analyze the deregulation effect based on a firm's scale, taking into account large differences in firm size.

In this study, we employ a proportional distance function to measure a firm's productivity. In addition, we analyze the factors that influence each firm's productivity change using a dynamic generalized method of moments (GMM) estimation. Based on these results, we discuss the effect of deregulation and other possibilities for the change in productivity in the urban gas industry.

2 Background

2.1 Previous Studies

The effects of deregulation have been an important policy topic over the last few decades. Numerous researchers have analyzed the effect of deregulation on the advancement of productivity. DEA is one of the principal tools used to measure the productivity of a regulated industry (Megginson and Netter, 2001). For example, numerous previous studies focus on the electricity industry. Nakano and Managi (2008) measured the Luenberger productivity of the Japanese electricity industry. They find that productivity increased following the deregulation reforms. Pombo and Taborda (2006) focus on the deregulation of the electricity distribution sector in Columbia. They divide production inefficiency into policy inefficiency and managerial inefficiency. They find that inefficiency in the post-reform period is dramatically lower than in the pre-reform period.

Several previous studies also analyze the deregulation of the gas industry. For example, Price and Weyman-Jones (1996) measure Malmquist productivity in UK gas firms using DEA. They compare the productivity trends pre- and post- privatization. They find that the UK gas industry privatization program contributes to an increase in productivity. Farrsi et al. (2007) apply SFA to estimate the inefficiency of the Swiss gas distribution sector. They note the importance of environmental and output characteristics. In particular, they find that increased customer density decreases costs.

Carrington et al. (2002) measure the production efficiency of US and Australian gas distributers using DEA and a parametric frontier model. They focus on the effect of a cost benchmarking program on production efficiency. They find that a benchmarking program can support efficient decision making among gas distributers.

2.2 Regulatory reforms in the Japanese urban gas industry

The Japanese energy industry has undergone deregulation since the 1990s. The most dramatic reform is the admission of new entrants to the retail market. Regulatory reform in the Japanese urban gas industry began in 1995 with the amendment of the gas industry law. Due to these reforms, new firms can enter the market for major customers that consume over 2 million m^3. The second major deregulation reform was implemented in 1999, expanding the range of entry to the retail market. Firms can now enter the market for customers that consume over 1 million m^3.

The other major reform is the consolidation of the competitive wholesale market. The amount of wholesale gas trading reached approximately 20% of all retail sales. Good performance in the wholesale market is important for firm production efficiency. In addition, many small gas firms cannot directly purchase LNG—the primary source of gas—because Japanese urban gas firms need to purchase LNG from overseas. The direct acquisition of LNG requires a large investment. Thus, small firms in Japan purchase LNG from large gas firms or other energy firms. Prior to the secondary reforms, wholesale contracts between gas firms required the approval of the Ministry of Economics, Trade and Industry. However, such permission was no longer required following the second deregulation reform, which is why the wholesale market is crucial for the Japanese urban gas market. These reforms are considered to be important. For example, Borenstein et al. (2002) find a significant amount of dead weight loss due to market power in California's electricity market.

In addition, many studies note the effect of yardstick price regulation in the retail market. Under yardstick regulation, the price each firm charges for urban gas is partly determined by comparing its performance with that of other firms. Companies with larger costs suffer losses, whereas those with smaller costs generate profits. Therefore, this system is expected to promote cost-cutting competition. Yardstick regulation was introduced in the Japanese urban gas industry following the second deregulation reform in 1999.

However, the effects of deregulation are not clearly revealed in the market. Generally, one of the effects of deregulation is a decrease in the retail price (Winston, 1993). Figure 1 plots the rate of the increase in retail urban gas prices in Japan and the prices of imported LNG and oil. One reason we present the trend in the oil price is that the import price of LNG is linked to the import price of oil. In addition, increases in the oil price result in increased shipping costs for LNG. Thus, the oil price is important for the LNG pricing decision in Japan. The retail price of gas is constant over the entire period, although fuel import prices fluctuated. Moreover, the retail urban gas price is constant after 2000, although the LNG import price is increasing. Thus, deregulation may change the performance of each urban gas firm.

2.3 Supply chain in the Japanese urban gas industry

The Japanese urban gas supply chain is unlike those in the European and US markets. European gas distributers directly purchase natural gas from another region or country using a pipeline. However, Japan is surrounded by the ocean. Additionally, there are few gas fields in Japan. Total LNG imports account for approximately 99% of the total amount of gas consumed.

Therefore, Japanese gas firms purchase their natural gas from abroad in the form of LNG that is transported via ships. After importing, each firm converts the LNG into gas[1]. Finally, gas firms distribute the gas to customers using circular pipes. Many urban gas firms began using LNG in the 1990s because the Ministry of Economy, Trade and Industry encouraged the use of LNG for urban gas (Integrated Gas Family 21 plan). Two primary reasons explain this phenomenon. The first reason is the long run effect regarding the efficient usage of gas pipelines. The heat content of LNG is higher than LPG (Liquefied petroleum gas)[2]. Thus, using LNG increases the transport capacity of a gas pipeline. Second, LNG is a low carbon energy source. Thus, shifting from using LPG to LNG as fuel can decrease CO_2 emissions. Generally, natural gas generates lower carbon emissions than other fuel fossils. Regarding life cycle assessments, previous studies indicate than LNG is the low carbon energy sources in Japan (see Okamura et al., 2007).[3]

3 The model

3.1 Productivity indicator

As a first step, this study applies the Luenberger productivity indicator consisting of a proportional distance function, which is a special case of the shortage function. Our problem can be formulated as follows:

Let $x=(x^1,\dots x^M)\in R_+^M$ and $y=(y^1,\dots y^M)\in R_+^N$ be the vectors of inputs and outputs, respectively. The technology set, which is defined by (1), consists of all feasible input vectors, x_t and output vectors, y_t, at time t and satisfies certain axioms, which are sufficient to define meaningful proportional distance functions:

$$T(t)\equiv\{(x_t,y_t):x_t \text{ can produce } y_t\} \qquad (1)$$

The proportional distance function is defined as follows:

$$d_{T(t)}(x_t,y_t)=\max\{\delta;(x_t,(1+\delta)y_t)\in T(t)\} \qquad (2)$$

where δ is the maximal proportional amount that y_t can be expanded given the technology $T(t)$. This formulation produces an output-oriented distance function. DEA is used to estimate the proportional distance

[1] In the case of Tokyo Gas Co., Ltd., which is the largest urban gas firm in Japan, 89.6% of urban gas is methane. The other components consist of ethane (5.62%), propane (3.43), and butane (1.35%). Other firms are somewhat similar to case of Tokyo Gas. Japanese urban gas includes several LPG for the adjustment of heat quality.

[2] Currently, Japanese urban gas firms use the high calorie gas is classified as 13A (46.04655MJ - 43.14MJ per 1m³). Gas firms purchase LNG from Middle East and Asia. However, the imported gases have some differences in terms of components and heat quality. Ultimately, the gas firms elected to combine the gases (vaporized LNG and LPG) to adjust heat quality.

[3] Several urban gas firms used LPG as the primary component of urban gas until the 1990's. Currently, LNG has several advantages for Japanese urban gas firms. The practice of importing LNG in Japan began in 1969. Japanese urban gas firms require substantial investments to transition from LPG to LNG. These costs include those due to the change in heat quality and investments in facilities among others. The process of shifting the primary component from LPG to LNG was completed in 2010.

function under variable returns to scale (VRS) by solving the following optimization problem (Managi, 2007):

$$d_{T(t)}(x_t, y_t) = \max_{\delta,\lambda} \delta$$
$$s.t. \quad Y_t\lambda \geq (1+\delta)\, y_i^t$$
$$X_t\lambda \leq x_i^t$$
$$N1'\lambda = 1$$
$$\lambda \geq 0, \qquad (3)$$

where δ is the measure of inefficiency for company *i* in year *t*. *N1'* is a row vector with all components equal to 1, λ is an N×1 vector of weights, Y_t and X_t are the vectors of outputs y_t and x_t. To estimate productivity changes over time, several proportional distance functions are used for the input-output vector for period *t+1* and technology in period *t*. These functions are also estimated using DEA below.

The Luenberger productivity indicator is defined as (4), with several proportional distance functions:

$$TFPC = \frac{1}{2}\{[d_{T(t)}(x_t, y_t) - d_{T(t)}(x_{t+1}, y_{t+1})]$$
$$+[d_{T(t+1)}(x_t, y_t) - d_{T(t+1)}(x_{t+1}, y_{t+1})]\} \qquad (4)$$

Following Chambers et al. (1996), this indicator is divided into two components as follows:

$$TFPC = \{[d_{T(t)}(x_t, y_t) - d_{T(t+1)}(x_{t+1}, y_{t+1})]\}$$
$$+\frac{1}{2}\{[d_{T(t+1)}(x_{t+1}, y_{t+1}) - d_{T(t)}(x_{t+1}, y_{t+1})]$$
$$+[d_{T(t+1)}(x_t, y_t) - d_{T(t)}(x_t, y_t)]\}. \qquad (5)$$

where the first difference represents Efficiency Change (EC) and the second arithmetic mean represents Technological Change (TC):

$$EC = \{[d_{T(t)}(x_t, y_t) - d_{T(t+1)}(x_{t+1}, y_{t+1})]\}. \qquad (6)$$

$$TC = \frac{1}{2}\{[d_{T(t+1)}(x_{t+1}, y_{t+1}) - d_{T(t)}(x_{t+1}, y_{t+1})]$$
$$+[d_{T(t+1)}(x_t, y_t) - d_{T(t)}(x_t, y_t)]\}. \qquad (7)$$

Therefore, a positive change in Total Factor Productivity Change (TFPC) is measured as a decrease in inefficiency and an outward shift of the frontier (TC). In short, the decomposition of TFPC is defined as (8):

$$TFPC = EC + TC \qquad (8)$$

3.2 Econometric models

In the second stage, we analyze the determinants of productivity change. That is, productivity measures are estimated in the first stage (e.g., (4)) and regressed on explanatory variables in the second stage. However, this type of two-stage approach should be treated with caution. Following Simar and Wilson (2007), productivity measures estimated by DEA are serially correlated. These authors argue that a bootstrapping method should be used.

However, the use of panel data and dynamic specifications make this problem more complex. Alternatively, to eliminate the serial correlation problem, Zhengfei and Oude Lansink (2006) suggest the use of dynamic panel analysis by applying System GMM to analyze the TFP measures estimated by DEA. Therefore, this article uses a System GMM model to analyze productivity change, in addition to an Ordinary Least Squares (OLS) model. We estimate the following equation:

$$\begin{aligned}
&\mathrm{PROCH}_{i,t} = c + \alpha_1 \mathrm{PROCH}_{i,t-1} + \alpha_2 \mathrm{PROCH}_{i,t-2} + \beta_1 \mathrm{CUSDEN}_{i,t} \\
&+\beta_2 (\mathrm{Large}\times\mathrm{Buy})_{i,t} + \beta_3 (\mathrm{Middle}\times\mathrm{Buy})_{i,t} + \beta_4 (\mathrm{Small}\times\mathrm{Buy})_{i,t} \\
&+\beta_5 (\mathrm{Large}\times\mathrm{Comp})_{i,t} + \beta_6 (\mathrm{Middle}\times\mathrm{Comp})_{i,t} \\
&+\beta_7 (\mathrm{Small}\times\mathrm{Comp})_{i,t} + \beta_8 (\mathrm{der}\times\mathrm{year}\times\mathrm{Large})_{i,t} \\
&+\beta_9 (\mathrm{der}\times\mathrm{year}\times\mathrm{Middle})_{i,t} + \beta_{10} (\mathrm{der}\times\mathrm{year}\times\mathrm{Small})_{i,t} \\
&+\beta_{11} (\mathrm{Large}\times\mathrm{Merge})_{i,t} + \beta_{12} (\mathrm{Middle}\times\mathrm{Merge})_{i,t} \\
&+\beta_{13} (\mathrm{Small}\times\mathrm{Merge})_{i,t} + \beta_{14} \mathrm{Private}_{i,t} + \beta_{15} \mathrm{yeardum}_t \\
&+\varepsilon_{i,t} \qquad (9)
\end{aligned}$$

where "PROCH" is the annual productivity change (such as TFP, TC or EC), measured by the Luenberger productivity indicator, for firm *i* at time *t*. The "CUSDEN" variable refers to an increase in the rate of customer density, which is the number of customers per distribution of gas pipe (km). The "CUSDEN" variable captures a geographical characteristic that affects each firm's productivity.

In this model, we use the cross terms of the firms' scale group dummies and other variables. As discussed below, the results of the productivity analysis indicate the different trends for each scale group. Scale efficiency effects might contribute to these results. Thus, we include the cross terms to analyze these differences.

In this study, we divide the firms into three groups: "Large", "Middle", and "Small". The "Large" group includes the top four firms in the urban gas industry. Combined, their gas sales account for 80% of all urban gas sales in Japan. The "Middle" group is composed of firms that have total capital in excess of ten billion Japanese Yen and 300 employees. Other small firms are placed in the "Small" group. The variable "Buy" denotes the increase in the amount of gas purchased from other gas firms. In other words, this variable indicates the extent to which gas sales depend on the wholesale market.

Nakano and Managi (2008) use the percentage of home generation to capture the competitive pressure in the electricity industry. In this model, we add the increase in gas sales of new entrant firms to capture competitive pressure ("Comp"). The aggregate sales of new entrants vary over time but not across firms.[4]

The "der" represents dummy variables for the full regulatory reform period (dummy variables between 1995 - 2004). The parameter "year" is the time trend (value of year). The interaction terms between "der", "year" and scale group dummies capture the remaining deregulation effect, which is the exclusive effect of the policy to reform the competitive environment and the wholesale market. "Merge" is a dummy variable used to capture a merger or acquisition[5]. The "yeardum" variables are dummy variables for each year. "Private" is a dummy variable that captures a change in ownership from the local government to the private sector.

3.3 Data

In this first step, productivity change is computed using data from 1993 to 2004. Mergers reduced the number of firms over time, and 205 firms operated in the market in 2004. A sample of 205 firms is used to measure efficiency in each year. Therefore, the number of observations is 2460 for the 12 years of this study. To calculate productivity, three inputs and one output are used. The output is the amount of gas sales (kcal). Inputs are the number of employees working in each firm (head-count), gas generating equipment (kcal per day), and length of circular pipe (km).

Data on gas sales are obtained from the *Gas Business Report* published by the Japan Gas Association. The number of employees, gas generating equipment and length of circular pipe are obtained from the *Gas Business Yearbook* published by the Japan Gas Association. In this study, our data are based on the Japanese fiscal year, running from April to March.

The econometric analysis in the second step is conducted using the productivity indicator.

[4] There are several reasons that we use aggregate sales data. First, gas trading does not entail comparatively difficult technological problems when new entrants enter the urban gas market. In addition, there are potentially new entrants that use the same technology to treat gases (i.e., LP gas firms). Second, gas firms can use tanker trucks to transport LNG. Thus, if customers are distant from gas firms, the firms can sell the gas to them. New entrants from other regions become potential sources of pressure in each region and, therefore, we use aggregate data.

[5] We discuss the measurement of business mergers in Appendix 1.

Independent variables include the increasing in the rate of customer density and percentage of gas bought from other firms. The amount of gas bought from other gas firms is the indicator of the extent to which each firm uses the wholesale market. In addition, we include the dummy variables to consider the effects of privatization and mergers. The dummy variable for privatization and mergers is created from information from the *Gas Business Year Book*. Descriptive statistics of each variable are presented in Table 1A. The number of "Merger" and "Privatization" events is presented in Table 1B[6].

4 Results

4.1 Measurement of productivity

We present the productivity results obtained by DEA. Descriptive statistics on productivity values are presented in Table 1C. Figure 2A (averaged by the number of firms) and Figure 2B (averaged by output values) show the average productivity change each year. Throughout nearly all of our study periods, average TFPC tends to not change substantially in Figure 2A except in 1995 and 1996. Drastic productivity changes occur in 1995 and 1996. These changes in TFPC are caused by EC. Apparently, the presence of a single outlier influences the results.[7] When we omit the outlier, the TFPC averages in 1995 and 1996 are not extreme and become 0.106 in 1995 and -0.008, respectively. Thus, the productivity values do not exhibit substantial changes until 2000. We observe a different trend after 2001 in Figure 2A.[8]. TFPC decreases slightly after 2001. TC increases over this time period, while EC exhibits a decreasing trend.

Note that the values in Figure 2A are dominated by results from small firms, presumably because productivity changes were averaged across the 205 firms. For the analysis of overall productivity in the urban gas industry, we also need to consider the gas sales volume of each firm (i.e., size). Thus, we present the average of arithmetic weighted productivity change[9] in Figure 2B. The arithmetic weighted productivity change tends to increase beginning in 1999. Figure 2B shows the substantial increase in TFPC after the second wave of deregulation. Here, TC is a factor that increases the TFPC in most years, whereas EC decreases TFPC after 2000. Comparing Figure 2A to Figure 2B, advances in TFPC occur in relatively large firms.

[6] For a detailed explanation on how we create the "Merger" dummy variable, see Appendix 1.

[7] Measuring efficiency using DEA occasionally leads to outliers. In 1995, only one firm's EC (Izumi Gas) is calculated, -316.67. Thus this value pulls up the averages of EC and TFPC. The averages of TFPC and EC in1996 represent a rebound from the results in 1995.

[8] In addition, the results of our econometric analysis in section 4 support this point. Our estimation result for the 1995 year dummy exhibits a positive coefficient (35.262) that is statistically significant for TFPC even if the outlier is included in the regression. Thus this drastic change in TFPC does not rely on year effects.

[9] Arithmetic weighted productivity change based on the output scale of each company.

$$\left(\frac{y_i}{\sum_i^{205} y_i} \times PROCH \times 100\right)$$

Figure 3 shows the average productivity change based on each scale group. Each scale group has a different TFPC trend. "Large" scale firms do not achieve any apparent productivity advancement until 2000. However, the TFPC values of "Large" scale firms increase after 2001. "Middle" scale firms experience limited productivity advancements until 1998. After the second deregulation effort, the "Middle" scale group was able to achieve a substantial increase in productivity. Thus, deregulation reforms have the potential to increase the TFPC of "Large" and "Middle" scale firms. However, "Small" scale firms exhibit a different TFPC trend. Small scale firms were able to achieve substantial productivity advances in 1995 and 1999. However, the TFPC of "Small" scale group decreased after 2000. These results indicate that the effect of deregulation on productivity may differ in each firm's scale. Figures 4 and 5 show the trends in average efficiency change (EC) and technological change (TC) based on scale group.

4.2 Econometric analysis

To confirm the effect of deregulation, we conducted an econometric analysis. Table 2 presents the results of the OLS and two step system GMM estimations. As discussed, the OLS results suffer from the serial correlation problem, and our OLS estimation results do not show statistically significant results between productivity changes and most independent variables. These results imply that an OLS model does not provide good fit. The system GMM method is a suitable means of analyzing productivity change (Zhengfei and Oude Lansink, 2006; Nakano and Managi, 2008). Thus, we focus on the system GMM estimation results.

In all model estimations, the Sargan test of over-identifying restrictions implies that the instruments used in the GMM estimation are valid. In most results (except those of TC), the lagged dependent variables are negative and significant, indicating that further productivity improvement following higher prior growth seems to be more difficult. In addition, "CUSDEN" exhibits positive coefficients in all models. Increasing customer density leads to the efficient use of circular pipe.

Hardly any of the cross terms for the deregulation reform period exhibit a positive coefficient for TFPC. The "der×year×Middle" and "der×year×Small" interactions have a negative relationship with TFPC. However, the "Large×comp", "Middle×comp" and "Small × comp" variables produce a positive coefficient for TFPC. These results imply that, on average, competitive pressure encourages productivity advancement for all firms.

However, other deregulation effects, with the exception of competitive pressure and the wholesale market, decrease TFPC. In addition, the cross term of "der" and "Middle" takes a negative sign for TC. One reason for these negative signs for TFPC is the inter-energy competition between gas and electricity. Inter-energy competition became more severe during these periods (Ministry of Economy, Trade and Industry, 2003)[10]. Thus, several gas firms lost the customers to competitors (i.e., electricity firms). The cross terms of "Merger" and "Middle" take positive coefficients for TFPC and EC.

However, the cross terms of "Merger" and other scale dummies do not take statistically significant signs. Many previous studies seek to observe a relationship between mergers and productivity (e.g., Odeck, 2008; Haynes and Thompson, 1999). Several studies show that mergers improve productivity. However, mergers do not consistently provide benefits for firms. In fact, 43% of all merged firms worldwide reported lower profits than comparable non-merged firms during the period from 1981 to 1998 (Gulger, 2003). Banal-Estañol and Seldeslachts (2009) note that informational asymmetries arising from the pre-merger period and cooperation and coordination problems in recently merged firms are important factors for whether mergers succeed. Our results reveal that the "Middle" scale firms can engage in successful mergers with other firms. In our study, "Middle" scale firms tend to merge with nearby small firms. Thus, "Middle" firms obtain sufficient information to complete a beneficial merger.

However, nearly all cross terms for "Buy" and the scale dummies do not show positive effects. The cross terms of "Buy" and "Small" only show a negative sign. If the wholesale market functions well, increasing gas purchases from other firms contributes to the efficient management of the gas firms. Thus, our results show that the wholesale market must be improved to enhance productivity.

In general, privatization leads to productivity advancement (Megginson and Netter, 2002). However, "Private" exhibits a negative association with all productivity measures. Several previous studies reveal that privatization encourages increases in service prices (e.g., Andres et al., 2006). If the price of output is increased, demand is reduced. Thus, privatization may reduce the outputs of each gas firm.

In our study, privatization occurs among smaller, local firms. The primary motivation for the privatization of Japanese urban gas firms is unprofitability. This phenomenon is particularly the case if a local area faces several problems that firms cannot overcome (e.g., population outflows, highly aged society, etc.). In these cases, firms do not have the managerial flexibility to improve productivity. Therefore, if privatization occurs, such firms cannot easily increase their productivity, at least in the short run.

Based on our estimation results, we calculate the elasticities of the cross terms that exhibit a positive relationship with TFPC. In particular, we focus on the effects of "Comp" and "Merge". Our estimation results indicate that competitive pressure has positive effects on all urban gas firms, regardless of scale. The elasticities of "Large×Comp", "Middle×Comp" and "Small×Comp" are 0.043, 0.010 and 0.109, respectively.

10 One of the reasons for the decrease in urban gas demand is the the increase in the number of residents exclusively using electricity during our estimation periods (see METI, 2009). Until the 1990's, nearly all Japanese retail customers consumed both electricity and urban gas. As a result of diffusion of all electrification residents beginning in the 1990's as a strategy for marketing an image of safety for their system, electricity companies succeed in taking business from urban gas firms.

Conversely, Merge does not exhibit a positive effect on all urban gas firms. Our estimation results indicate that "Middle×Merge" has a positive effect on TFPC. The elasticity of "Middle×Merge" is calculated as 0.022. However, Merge does not show a positive effect for other scale groups. There are only 7 Middle firms. Therefore, the effect of mergers on advancing TFPC is limited.

5 Discussion and Conclusion

The literature reflects a substantial discussion on deregulation, privatization, and mergers. Most studies show that deregulation and privatization increase productivity. In this paper, we measured Luenberger productivity in the Japanese urban gas industry and obtained variation across firm size. In addition, our study reveals the effects of deregulation reforms using system GMM estimations. We obtain two important results.

First, the effects of deregulation and other important structural changes (i.e., merger) differ with respect to firm size. Although scale efficiency effects may be important in certain industries, our results suggest that productivity is not only improved for large firms but also for middle firms. The results indicate that competitive pressure encourages increases in productivity for all firm size groups. However, mergers only increase productivity for middle scale firms.

Second, deregulation reforms contribute to improved productivity. The deregulation of gas sales for commercial scale customers plays the most important role in advancing productivity because competitive pressure increases overall productivity in the Japanese urban gas industry. However, the deregulation of the Japanese urban gas industry must be improved if additional productivity increases are to be achieved. Our estimation results demonstrate that the deregulation of the wholesale market does not affect changes in productivity. Thus, policy makers need to improve the structure of the wholesale market.

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Appendix 1 Construction of corporate merger

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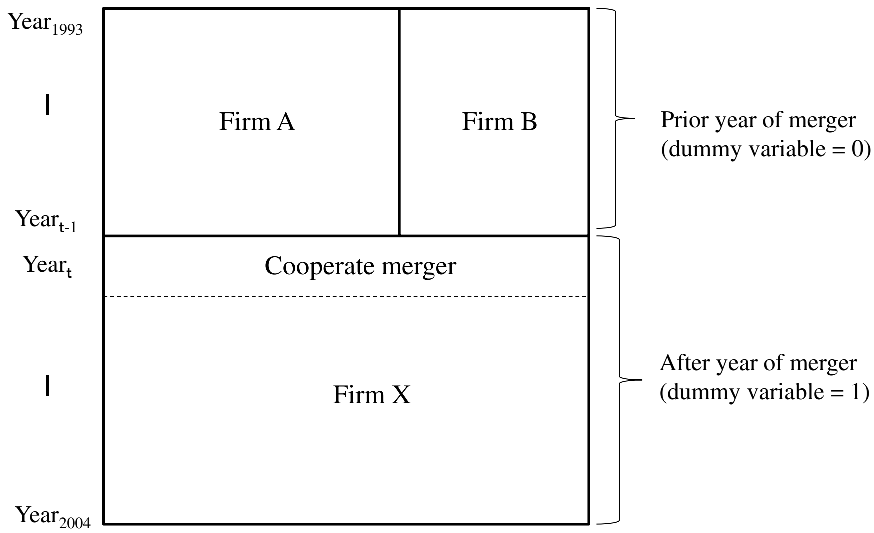

DEA requires a full panel data set to measure the production efficiency of firm. However, there are several firms that merged with other firms in our sample period. Thus we construct the dataset to consider such mergers as follows. For example, there are two firms, A and B. When firm A merges with firm B in year_t, the merged firm is denoted firm X. Prior to the merger, we treat firms A and B as one firm. In short, we use the summation of these firms' data as firm X prior to year_t.

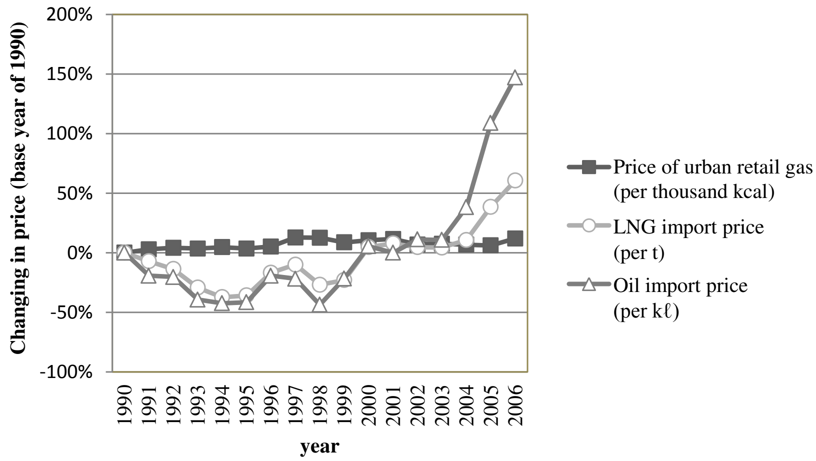

Figure 1 Increase in urban retail gas and fossil fuel (LNG and oil) import price

Note: Price of urban retail gas is average of major three urban gas firm's retail price where the price of Japanese yen is used. Each price refer to the institute of Energy Economics, Japan (2008).Each price are deflated by Consumer price index (IMF, 2012).

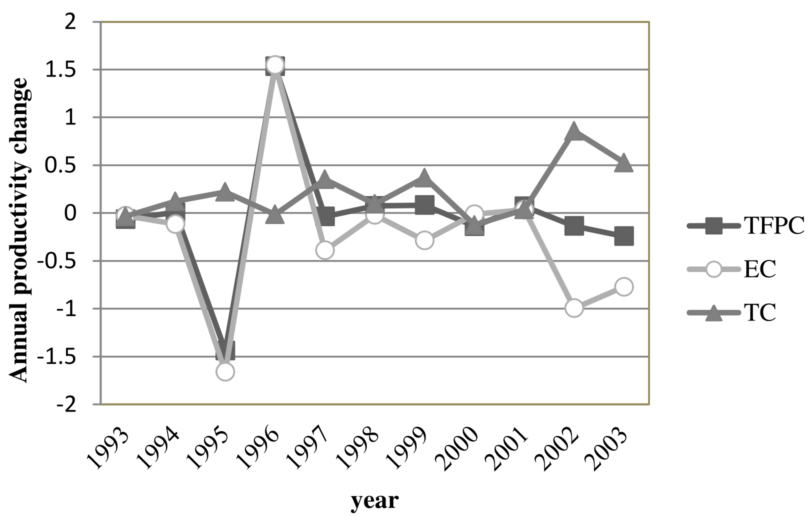

Figure 2A The average of productivity change in each year

(Average of all firms)

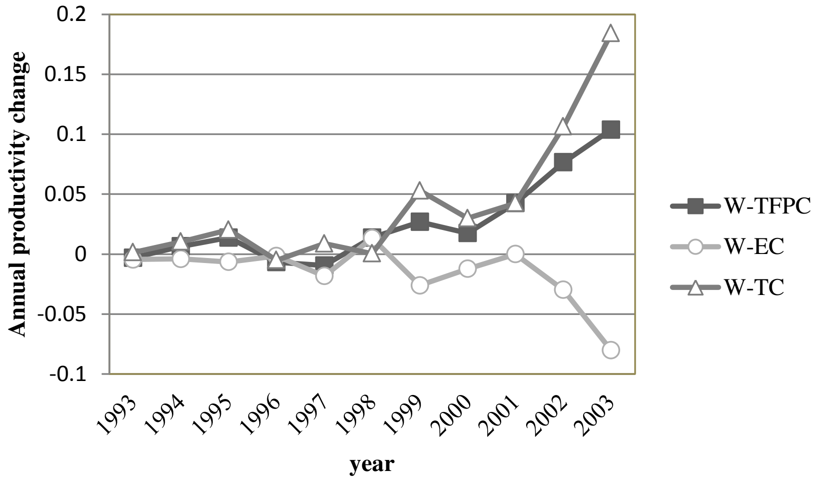

Figure 2B The average of productivity change in each year

(Arithmetic weighted mean)

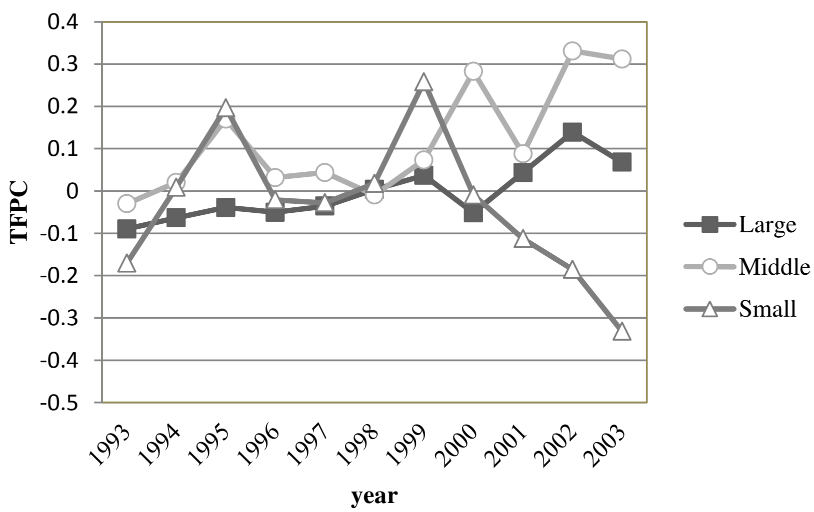

Figure 3 Productivity change (TFPC) by scale group

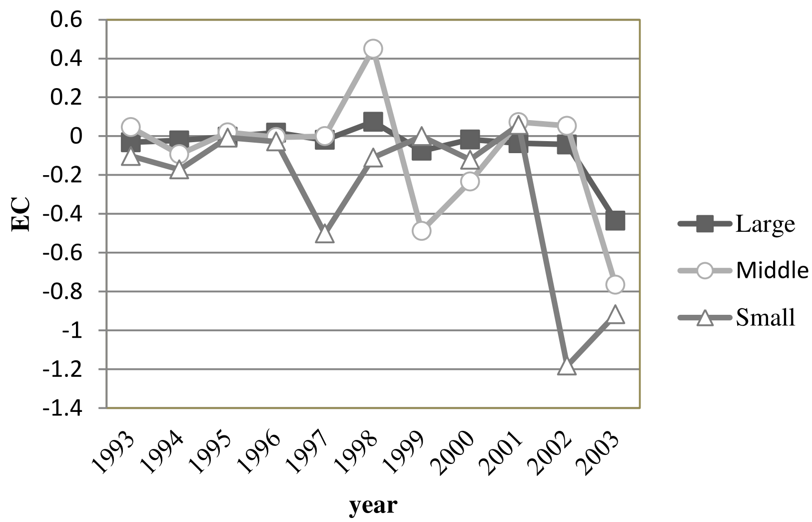

Figure 4 Efficiency change (EC) by scale group

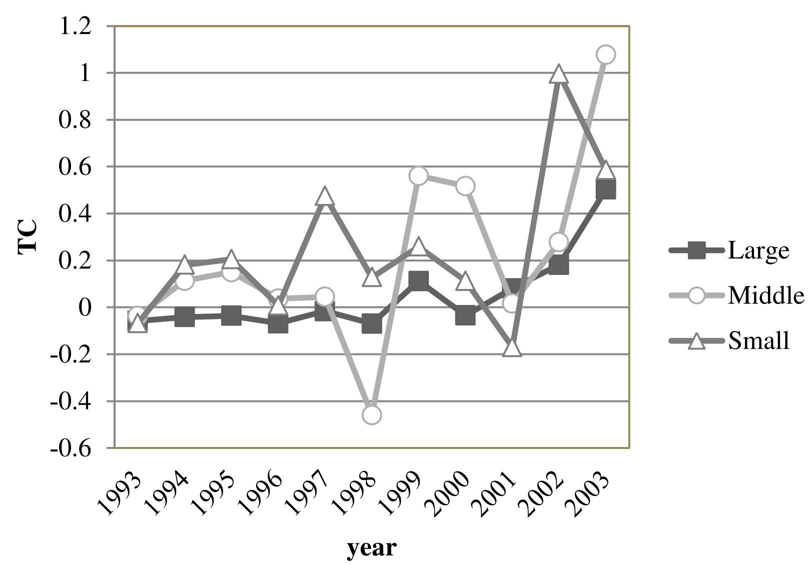

Figure 5 Technological change (TC) by scale group

Table 1A Descriptive statistics for productivity measurement

	Output	Input		
	Amount of gas sales (kcal)	The number of employees (head-count)	Gas generating equipmen (kcal per day)	Length of circular pipe (km)
Average	1,130,518	203	2,747,725,670	1,043,896
Median	61,406	30	98,490	171,174
Min	122	3	1,386	5,932
Max	114,259,481	13,010	13,733,110,368	55,385,445
Variance	6.43655E+13	1164219.955	3.0182E+19	2.36746E+13
Standard deviation	8022814.124	1078.990	5493816000	4865658.920

Table 1B Scale group, Merge and Privatization

Scale group	The number of firms	Structure change	The number of times
Large	4	Merger	18
Middle	7	Privatization	7
Small	194		

Table 1C Descriptive statistics for determinants of productivity analysis

Variables	TFPC	TC	EC	CUSDEN	Buy	Comp
Average	-0.027	0.219	-0.246	0.013	0.041	0.004
Median	0.013	0.134	-0.066	-0.004	0.000	0.000
Min	-316.671	-14.627	-323.155	-0.902	-112.707	-0.002
Max	316.104	6.508	314.275	9.422	112.707	0.021
Variance	90.003	0.658	91.560	0.134	23.754	0.000
Standard deviation	9.487	0.811	9.569	0.366	4.874	0.007

Table 2 OLS and System GMM estimation result

	TFPC		TC		EC	
	OLS	GMM	OLS	GMM	OLS	GMM
$PROCH_{t-1}$	-0.639***	-0.463***	-0.216***	-0.104	-0.640***	0.499***
	(-28.94)	(-30.63)	(-8.76)	(-0.96)	(-28.95)	(-60.93)
$PROCH_{t-2}$	-0.321***	-0.027***	-0.050*	-0.679***	-0.3212***	-0.113***
	(-14.52)	(-2.73)	(-1.88)	(-6.49)	(-14.49)	(-9.30)
CUSDEN	2.276***	74.579***	-0.000	56.269***	2.251***	64.339***
	(4.39)	(12.80)	(-0.01)	(8.67)	(4.31)	(16.55)
Large × Buy	-17.198	-7688.731	-7.272	-3667.078	-9.277	1053.834
	(-0.12)	(-1.20)	(-0.54)	(-0.38)	(-0.06)	(0.32)
Middle × Buy	-1.072	17.878	-0.012	-79.466	-1.010	27.082
	(-0.30)	(0.42)	(-0.04)	(-0.64)	(-0.09)	(0.44)
Small × Buy	-0.002	0.344	0.001	0.250	-0.004	-1.156***
	(-0.06)	(0.82)	(0.28)	(0.75)	(-0.09)	(-2.96)
Large × Comp	7.240	3214.895*	-30.148	-1697.440	29.515	3165.136
	(0.03)	(1.93)	(-1.36)	(-1.35)	(0.12)	(0.66)
Middle × Comp	36.686	7804.907***	-43.488**	1056.050	75.707	1590.329*
	(0.19)	(2.86)	(-2.43)	(-1.35)	(0.39)	(4.68)
Small × Comp	18.336	721.348**	-5.833	304.985	19.345	405.499
	(0.22)	(2.47)	(-0.76)	(0.65)	(0.23)	(0.94)
der × year × Large	-0.000	-0.070	0.000	-0.005	-0.000	0.022
	(-0.23)	(-1.34)	(0.36)	(-0.30)	(-0.22)	(0.51)
der × year × Middle	-0.001	-0.078**	0.000	-0.048**	-0.001	-0.019
	(-0.32)	(-2.57)	(0.90)	(-2.26)	(-0.37)	(-0.87)
der × year × Small	-0.001	-0.078**	0.000	-15.863	-0.001	-16.678
	(-0.28)	(-2.57)	(1.09)	(-1.06)	(-0.37)	(-0.83)
Large × Merge	0.766	-37.814	-0.105	-8.372	0.811	-203.698
	(0.19)	(-0.52)	(-0.27)	(-0.07)	(0.20)	(-1.16)
Middle × Merge	0.696	192.484***	0.168	119.102**	0.428	-17.342
	(0.27)	(2.69)	(0.71)	(2.27)	(0.17)	(-0.43)
Small × Merge	0.042	36.367	0.113	11.122	0.204	-8.954

	(0.02)	(0.59)	(-0.63)	(0.31)	(0.11)	(-0.31)
Private	-0.207	-0.634*	-0.703***	-11.1345***	-1.098	-5.641***
	(-1.03)	(-0.34)	(-3.72))	(-3.90)	(-0.54)	(-2.88)
c	0.604	-12.846**	-0.197	0.878	0.322	-4.588*
	(0.21)	(-2.33)	(-0.71))	(0.04)	(0.11)	(-1.83)
R_2	0.318	-	0.144	-	0.320	-
AR(1)	-	-2.24**	-	-2.06**	-	--2.22**
AR(2)	-	-0.63	-	1.12	-	2.05**
Observation	2255	1845	2255	1845	2255	1845

Values in parentheses are t-values. *Significant at the 10% level, **significant at the 5% level, ***significant at the 1% level.