A Study of Scale Economies and Price Differential of the City Gas Industry in Japan

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Abstract

The purpose of this paper is to prove price differential of the city gas industry in Japan by estimating scale economies.

There are three organizational forms in the city gas industry in Japan. In particular, the organizational forms between a firm which purchases natural gas from wholesalers and a firm which provides natural gas transformed into LNG by using its own facility are quite different. They are respectively trying to pursue their efficiency in a competitive manner. However, the results turned out to be quite different. In this paper, I estimate scale economies in two types of suppliers and factor analysis on the price of their suppliers, and then, I consider the influence which the differential of two organizational forms gave to gas price.

In conclusion, the affects of scale economy of the firm which purchases natural gas from wholesalers is larger than that of the firm which supplies natural gas transformed into LNG by using its own equipment. In addition, I found that the prices of larger scale utilities were constant or at least not rising. This means that the city gas price is decided under the influence of scale economies.

I have also found that price differential will become increasingly larger in the future. If the city gas industry is considered a universal service, we need to reduce this price differential. However, if this industry is considered a local service in a particular district, some utilities would lose in the competition, then stop supplying, and finally leave the market. Hence, we need to make a new policy as a next step after the reform of liberalization since 1995 by considering whether this industry is universal or not.

Keywords: city gas industry, price differential, scale economies, pipeline, vaporizing facility

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1. Introduction

In Japan, the natural gas (including petroleum gas) industry is classified into three business forms, which are City gas utilities, Community gas utilities, and LP gas utilities. These utilities supply natural gas or petroleum gas to customers through pipelines. City gas utilities tend to be operating in large cities throughout Japan. Community gas utilities supply gas to customers in smaller areas compared to city gas utilities by using simple facilities and pipelines. These utilities generally operate in the suburbs close to large cities. LP gas utilities supply gas to customers in areas where the two kinds of utilities mentioned above cannot supply gas. LP gas utilities tend to operate in rural areas. The purpose of this paper is to prove price differential of the city gas industry by estimating scale economies. And moreover, I verify that the price differential is caused by deregulation in the city gas industry.

The city gas industry has been deregulated gradually since 1995. In the reform of 1995, the government introduced the institution that customers who demand more than 2,000,000m^3 could purchase gas from suppliers outside of their area's supplier. The government also instituted a slight adjustment to the energy price. In the reform of 1999, the institution which customers could purchase gas from other suppliers was extended from more than 2,000,000 m^3 to more than 1,000,000 m^3, consignment supply[2] was legislated and formally instituted. The government deregulated the retail sales price. In the reform of 2003, by legal institution the gas pipeline service company (Doukan Jigyosya) was established, and the range of liberalization was extended from more than 1,000,000 m^3 to more than 500,000 m^3. Finally, the range of liberalization was enlarged to more than 100,000 m^3 in 2007. The purpose of the deregulation above is to decrease the gas price by means of introduction of competitive principle.[3]

To evaluate the effect of the deregulation, I classified city gas utilities as three organizational forms based on the groups of yardstick regulation.[4]

1. "Big supplier[5]" (Utilities which provide gas to customers of more than 150,000)

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[2] It means that every company can use the pipelines which a particular company owns. This institution is called "Open Access".

[3] The consignment supply is gradually increasing by this deregulation. The whole amount of consignment supply including wholesale and retail is 96,482,658,000MJ. The ratio of consignment supply out of the whole amount of total sales(1,562,551,643,000MJ) is 6.17% in 2008.

[4] There are seven classifications in yardstick regulation. The seven are as follows.

(1) More than 150,000 customers
(2) Purchase from wholesalers
(3) Hold facilities(LNG-satellite, LNG-air)
(4) Use a lot of materials(LNG, LPG, Naphtha etc.)
(5) Public utility(Municipal utility) and purchase from wholesalers
(6) Public utility(Municipal utility) and hold facilities(LNG-satellite, LPG-air)
(7) Public utility(Municipal utility) and use some types of material(LNG, LPG, Naphtha etc.)

In this paper, (1) is defined as big supplier, (2) and (5) are defined as pipeline supplier, and (3), (4), (6), and (7) are defined as manufacturing supplier. The utilities of big supplier are Tokyo-gas, Osaka-gas, Toho-gas, Saibu-gas, Hokkaido-gas, Keiyo-gas, Hokuriku-gas, Shizuoka-gas, Hiroshima-gas, and Nihon-gas respectively.

[5] Due to the intention of emphasis of supply sector, I have used the word of "supplier" instead of the word of "utility" in this paper.

2. “Pipeline supplier” (Utilities which purchases natural gas from wholesalers through pipelines)
3. “Manufacturing supplier” (Utilities which provide gas by using vaporizing facilities)

Within the three kinds of gas utilities, the big supplier is the leader in the region, and holds a huge manufacturing facility. This big supplier provides gas not only customers in its own area but also city gas suppliers in the vicinity. The pipeline supplier, which is shown on the right side of Figure 1, constructs trunk pipelines to other suppliers in the vicinity, and then purchases natural gas from the suppliers, and provides the gas to customers in his area. The manufacturing supplier, which is shown on the left side of Figure 1, purchases LNG, then vaporizes the LNG into natural gas by its own facility, and provides this gas to customers in its own area. The manufacturing supplier has to possess vaporizing facilities because this supplier cannot tie pipelines between itself and other suppliers.[6]

I researched the approved prices (Ninka kakaku) in the household sector. The prices are approved by government, and they are shown in Table 1. These prices are the average value of approval prices respectively.

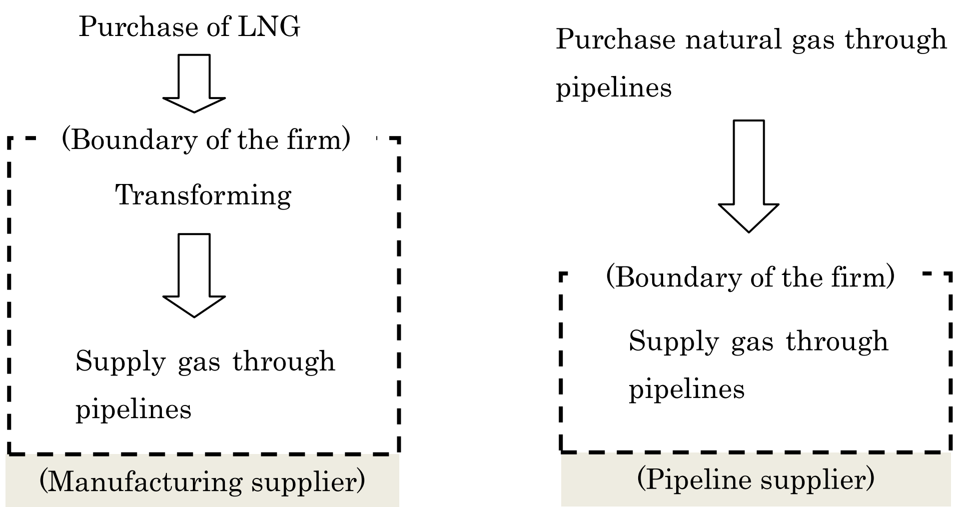

Figure 1 Organizational forms

[6] Because the city gas supplier is assigned the supply area by the government, it is basically a monopoly against household customers. Meanwhile, the government does not regulate the means of purchase of raw materials. Hence, some suppliers purchase LNG, and then transform LNG into natural gas by using vaporizing facilities. The other suppliers purchase natural gas from wholesalers through pipelines.

Table 1 The approval prices of the three types of suppliers (Unit: yen)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
(Big supplier)	115.6	118.6	132.7	141.4	141.1	139.3	144.90	150.8	157.8	163.7
(Pipeline supplier)	108.3	109.6	115.9	130.0	125.8	131.6	132.3	135.3	140.7	147.4
(Manufacturing supplier)	151.4	155.4	161.8	162.1	173.5	194.1	205.2	211.1	225.2	238.2

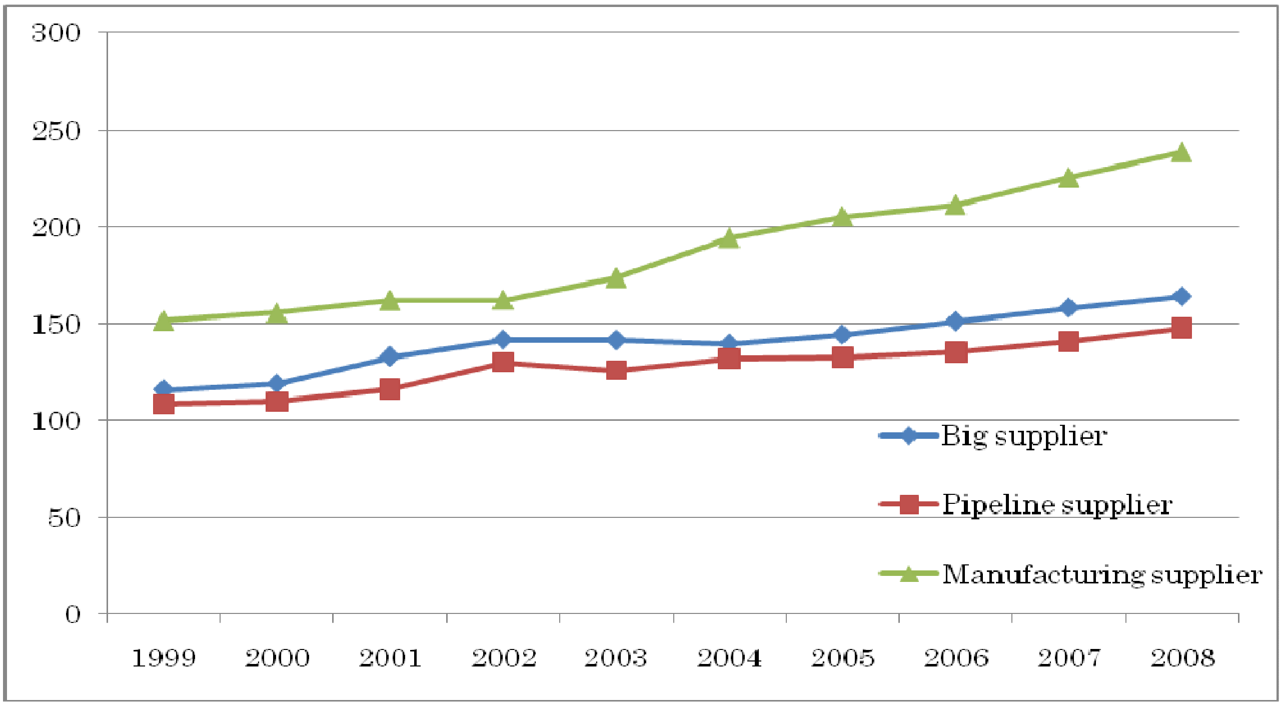

Figure 2 The approval prices of the three types of suppliers (Vertical axis: price, Unit: yen)

The price differential between big suppliers and pipeline suppliers is not obvious. However, it seems that the price differential between big supplier and manufacturing supplier definitely exists, and the price differential between pipeline suppliers and manufacturing suppliers also significantly exists.[7] The approval price of city gas suppliers is basically decided by the cost price method which adds up the whole cost to produce natural gas, therefore we can interpret this price differential as cost differential between those suppliers. The price of pipeline suppliers is the lowest out of the three types of suppliers because some pipeline suppliers can purchase domestic natural gas. The domestic natural gas is cheaper than imported LNG. The reason is that the transportation cost of domestic natural gas is cheaper compared to that of imported LNG, and moreover, domestic natural gas is unaffected by the fluctuation of the exchange rate.

Although deregulation enables a lot of suppliers to make consignment supply, the effects of

[7] The average price included the suppliers which are practicing calorie conversion. The number of suppliers which are changing gas calorie is approximately 30, and the number of suppliers which amortize pipelines' facilities costs is approximately 30 at the end of 2009 fiscal year. While many pipeline suppliers practiced calorie conversion at the beginning of 2000s, many manufacturing suppliers practiced calorie conversion at the end of 2000s. Therefore, the influence of calorie conversion could have appeared in this figure.

deregulation penetrates into the management of big suppliers and pipeline suppliers more strongly than that of manufacturing suppliers. Hence, the effects of deregulation might be different among these suppliers.

2. The purpose of this paper

In this section, I deal with pipeline suppliers and manufacturing suppliers. And I consider what influence the difference of management forms gives their costs. I have three steps for methodology. First, I estimate the scale economies of two forms by supposing cost functions. Next, to verify whether the scale of each supplier gives gas price some influence, I practice the factor analysis by putting the gas price as the dependent variable. Finally, based on my estimation results, I consider the price differential between pipeline suppliers and manufacturing suppliers.

3. Related literature

There is a little related literature in this industry.

First, Aivazian et al. (1987) estimates scale economies by using translog cost function and data from 1953 to 1979. According to this literature, there are scale economies in the U.S. natural gas transmission industry, and they found that the growth rate of productivity depended on scale economy.

In Japan, there is little literature in price differential among city gas suppliers. Kaino (2008) researched the factor of this price differential, and the productivity of labor and capital influenced this differential as the results.

Takenaka and Urano (1994) estimated scale economies using Translog cost function. And they verified that there are scale economies in the city gas industry. Kinugasa (2002) also estimated scale economies using Translog cost function. Although the purpose of his paper is to consider the Averch-Johnson effect, he found this industry existed scale economies.

4. Empirical analysis

Here, I verified scale economies of the two types of suppliers, which are pipeline suppliers and manufacturing suppliers, by estimating cost functions.

In order to test scale economies (returns to scale), a general model of energy companies cost with two outputs and three inputs types is specified as follows.

$$C = (p_i, Q, Z) \ ,$$

where C, long term total cost; Q, output; Z, additional output; p_i, factor price of i^{th} input (i=k

(Capital), l (Labor), m (Energy)).

The most widely used functional form is the translog function, which is flexible in the sense that it provides a second order approximation to an unknown function at any given point. The translog function is specified in the following form:

$$\ln TC = \alpha_0 + \sum_{i=k,l,m} \alpha_i \ln p_i + \alpha_q \ln Q + \alpha_z \ln Z + \frac{1}{2} \sum_{i=k,l,m} \sum_{j=k,l,m} \beta_{ij} \ln p_i \ln p_j + \frac{1}{2} \beta_{qq} (\ln Q)^2 + \frac{1}{2} \beta_{zz} (\ln Z)^2$$
$$+ \frac{1}{2} \sum_{i=k,l,m} \gamma_{qi} \ln p_i \ln Q + \frac{1}{2} \sum_{i=k,l,m} \gamma z_i \ln p_i \ln Z.$$

In order to estimate more accurately, I impose the restriction on input factor prices such that

$$\sum_{i=k,l,m} \alpha i = 1 \qquad \sum_{i=k,l,m} \beta ij = \sum_{i=k,l,m} \gamma qi = \sum_{i=k,l,m} \gamma zi = 0 .$$

Furthermore, I apply Shephard's Lemma on the total cost function. Then I obtain the input share equations as follows:

$$SHLi = \frac{\partial \ln TC}{\partial \ln pi} = \frac{\partial TC}{\partial pi} \cdot \frac{pi}{TC} = \frac{Xi \cdot pi}{TC} = \alpha i + \sum_{i=k,l,m} \beta ij \ln pj + \gamma qi \ln Q + \gamma zi \ln Z ,$$

where *SHLi*, input *i*'s share of variable costs.

As for the estimation technique, I apply the SUR (seemingly unrelated regression) by Zellner (1962) for the total cost function and the input share equations. And moreover, it is worth noting that I normalize the observation on each variable by dividing by its sample mean, before making the natural logarithmic transformation.

I could use the pooled data from 2002 until 2007 excluded big 10 suppliers[8]. The observations of pipeline suppliers are 447, and the observations of manufacturing suppliers are 811. I excluded the data which I cannot obtain exactly. The detail of data is following.

(Data)

Source: Annual report of city gas distribution utilities (Gas Jigyou Nenpo), Corporate goods price index(The Bank of Japan), GDP Data Base (Cabinet Office, Government of Japan)

Total cost: Energy cost + Labor cost + Capital cost

Energy costs(m): The amount of LNG×LNG-price + The amount of LPG×LPG-price + (The

[8] The big 10 suppliers are Tokyo-gas, Osaka-gas, Toho-gas, Saibu-gas, Hokkaido-gas, Keiyo-gas, Hokuriku-gas, Shizuoka-gas, Hiroshima-gas, and Nihon-gas.

amount of natural gas + volatile oil + others gas + wholesalers) × natural gas-price (Corporate goods price index 2000 base)

Labor costs(l): The number of employee × The wage of each prefecture(more than 30people × 12(GDP deflator 2000 base)

Capital costs(k): Depreciation expense + (The real assets × Government bonds(10years)) (Corporate goods price index 2000 base)

Energy price(P_m): Energy costs/the amount of sales

Labor price(P_l): The wage of each prefecture (more than 30people)

Capital price(P_k): Capital price index × (depreciation expense/real assets + the rate of government bonds(10years)

Sales(Q): The whole amount of sales for a year (1000MJ)

Additional revenue(Z): The incidental business earning and miscellaneous revenue of sales

Public dummy(d_1): The public utility(1), The private utility(0)

LNG dummy(d_2): Supply only natural gas(1), otherwise(0)

The descriptive statistics are shown in Table2 and 3. Then, the average costs of the two types of suppliers are also shown in Figure4 and 5. The vertical axis is average cost (unit yen), and the horizontal axis is the whole amount of sales for each supplier (unit 1000MJ).

Table 2 Descriptive statistics (Manufacturing supplier)

	Total Cost	Quantity	Additional	Capital	Labor	Energy
Unit	1000yen	1000MJ	1000yen	1000yen	1000yen	1000yen
Average	1210911	797563	6006794	0.104	361621	0.562
S.D.	2385999	1728790	58652831	0.043	33183	0.136
Min	35830	13046	3415	0.010	295294	0.235
Max	16351723	12386950	949019845	0.939	520876	1.100

S.D.: Standard deviation

Table 3 Descriptive statistics (Pipeline supplier)

	Total Cost	Quantity	Additional	Capital	Labor	Energy
Unit	1000yen	1000MJ	1000yen	1000yen	1000yen	1000yen
Average	1253951	1271306	2208073	0.107	381071	0.586
S.D.	84762	122440	743318	0.002	1842	0.012
Min	13106	2038	183113057	0.013	309899	0.179
Max	14470261	28015405	987008633	0.319	532773	1.223

S.D.: Standard deviation

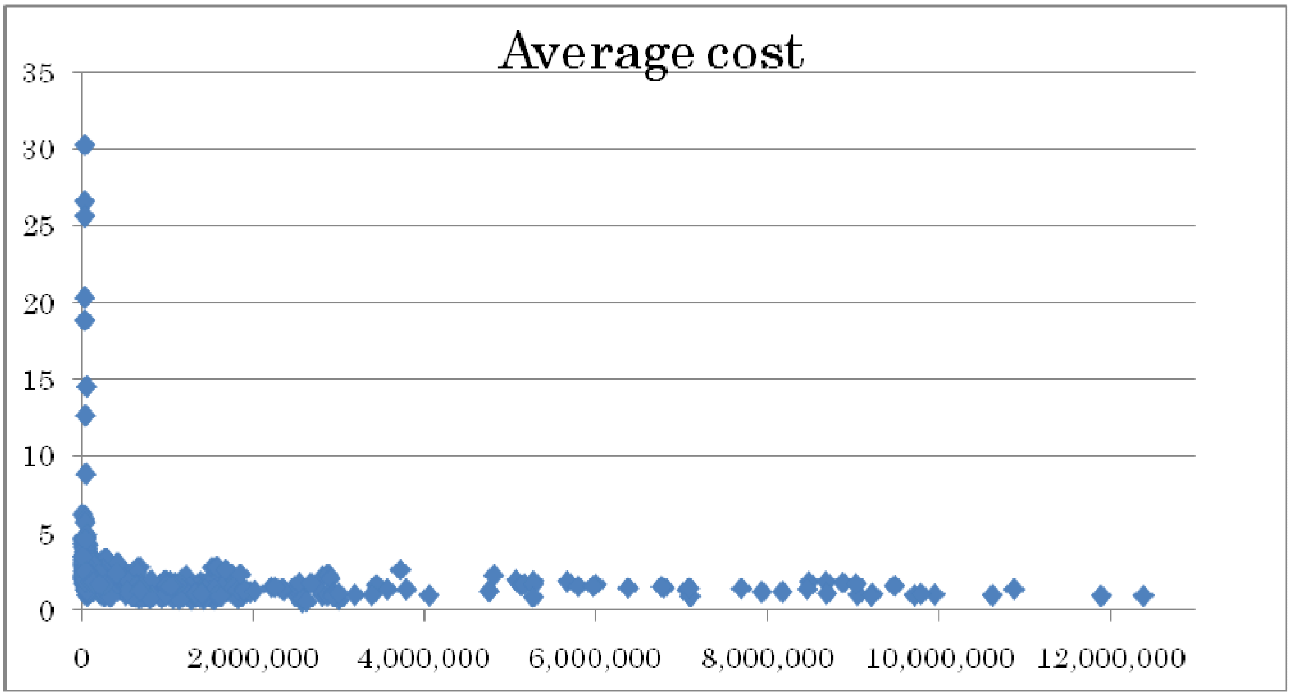

Figure 4 Average costs of manufacturing suppliers

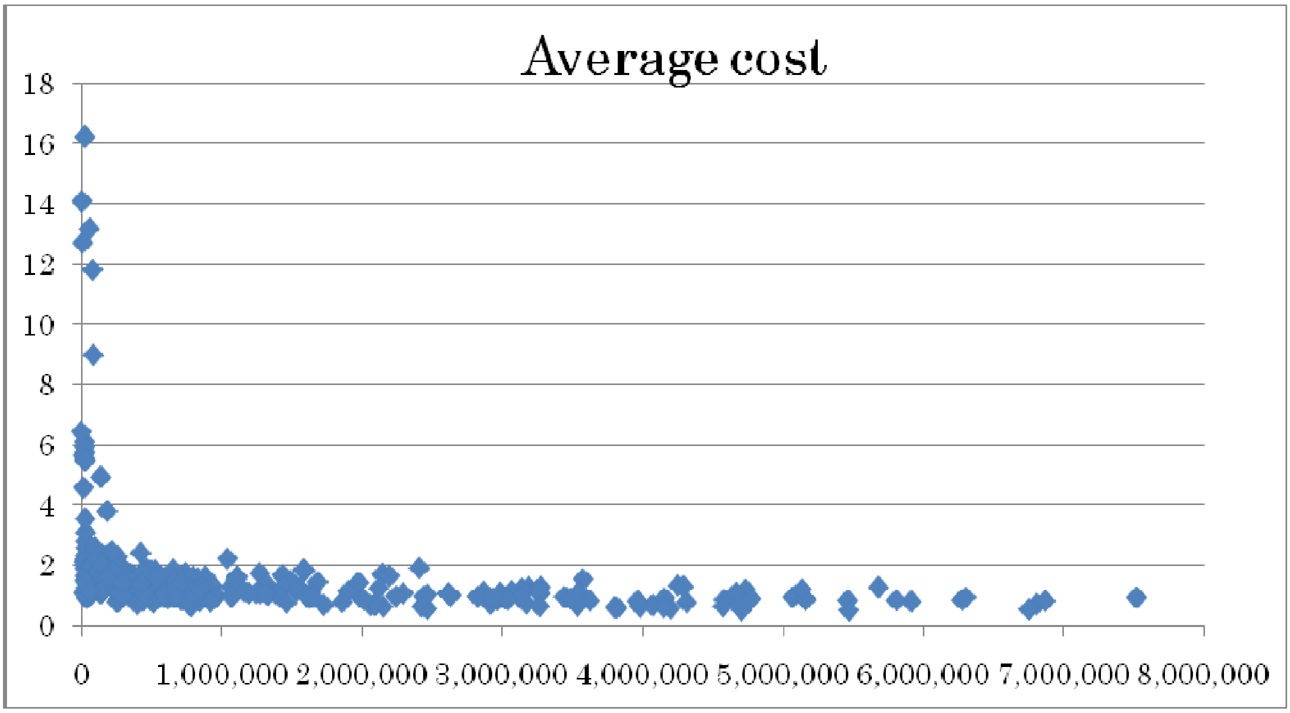

Figure 5 Average costs of pipeline suppliers

5. Estimation results

Although the value of R-square of labor cost function is a little small, the performance of my estimation results is robust.

Table 4 Estimation results

Variable	manufacturing	pipeline	Variable	manufacturing	pipeline
constan	0.421(11.34***)	0.330(15.80***)	ek	-0.069(-22.65***)	-0.051(-7.90***)
e(energy	0.338(132.46***)	0.464(59.28***)	lk	-0.075(-24.67***)	0.024(2.25**)
l(labor)	0.332(133.47***)	0.161(20.95***)	qe	-0.0001(-0.07)	0.091(26.96***)
k(capital	0.331(67.91***)	0.375(37.77***)	ql	0.001(0.57)	-0.038(-10.82***)
q(quantity	0.729(68.35***)	0.680(65.71***)	qk	-0.001(-0.25)	-0.053(-7.90***)
f(additional	0.206(13.39***)	0.146(12.35***)	qf	-0.007(-1.33)	-0.066(-19.60***)
ee	0.131(102.03***)	0.129(27.18***)	fe	0.00005(0.06)	-0.031(-10.63***)
ll	0.137(85.65***)	0.054(4.55***)	fl	-0.001(-0.94)	0.004(1.20)
kk	0.144(24.41***)	0.026(2.19**)	fk	0.001(0.45)	0.027(7.17***)
qq	0.010(1.78*)	0.052(20.29***)	d1(public)	0.280(8.85***)	0.073(3.69***)
ff	0.012(6.81***)	0.022(12.83***)	d2(LNG)	-0.019(-1.00)	-0.063(-3.00***)
el	-0.062(-28.95***)	-0.078(-11.55***)	observations	(811)	(447)

(parenthesis: t-value, *significant at 10%, ** 5%, *** 1%)

Manufacturing suppliers: R^2=0.960, Labor cost: R^2=0.911, Energy cost: R^2=0.954

Pipeline suppliers : R^2=0.963, Labor cost: R^2=0.364, Energy cost: R^2=0.742

Here, I calculate scale economies by using the value of my estimation results above. I define scale economies as the growth rate of total cost when sales (Q) and additional revenue (Z) are increased at the same rate. If the value of scale economies is more than 1, scale economies exist in the industry, and in the case where the value of scale economies is larger, the effect of scale economies works strongly. In short, a rise of 1% in the sales quantity and additional revenue leads to an increase of less than 1% in the total cost, if and only if, there are scale economies.

$$\frac{1}{\varepsilon_1 + \varepsilon_2},$$

where ε_1, elasticity of sales; ε_2, elasticity of additional revenue.

Table 5 Scale economies (Returns to scale)

	Returns to scale
Manufacturing suppliers	1.07
Pipeline suppliers	1.21

The value of scale economies is the reciprocal of elasticity of sales and additional revenue. According to the definition of scale economies (returns to scale), in the case where there are scale economies, the growth rate of total cost is smaller than that of both sales and additional revenue. I used the translog function in this paper, and this function is set to assume that the amount of the inputs and the outputs are optimal every year. In addition, the scale economies of manufacturing suppliers might exist in both vaporizing facilities and the extent of pipelines in their own areas, and then the scale economies of pipeline suppliers might only exist to the extent of their pipelines. When manufacturing suppliers increase the amount of their sales, these suppliers have to increase both the vaporizing facilities and the length of pipelines. Meanwhile, when pipeline suppliers increase the amount of their sales, the suppliers need only to increase the length of their pipelines. According to my estimation results above, the scale economy of manufacturing suppliers is smaller than that of pipeline suppliers. That means that the manufacturing suppliers might not be able to obtain the effect of scale economies as well as pipeline suppliers can. In other words, it would be difficult for manufacturing suppliers to obtain scale economies compared to pipeline suppliers because the manufacturing suppliers generally have to use the vaporizing facilities which can only produce enough natural gas to supply in their own area.

6. Factor analysis

I have shown that both scale economies are different in the previous section. Next, I analyze whether scale economies influence the customers' price. The methodology is as follows. I define the customers' price as a dependent variable. Then, I carry out factor analysis by means of ordinary least square.

I set the amount of sales and the number of customers as proxy of the variables of scale, and the dependent variables are set both the approval price and 50m^3 charge. The 50m^3 charge means a household consumes the amount of 50m^3.

$$\mathrm{Pr}\,ice = \alpha + \beta 1 * Demand + \beta 2 * Coverage + \beta 3 * Quantity + \beta 4 * Household$$
$$+ \beta 5 * Wholesale + \beta 6 * Public + \beta 7 * HighCalori\,e.$$

(Dependent variable)

Approved-Price: The average of approved price or notified price

50 m^3 charge: The charge when a household consumes the amount of 50m^3

(Independent variable)

Customer (The number of customers): The number of customers in his own area

Quantity (The quantity of sales): The quantity of sales at the end of fiscal year

Coverage: the rate of customer supplying gas out of the whole customers in his own area

Household: The rate of the quantity of household out of the whole quantity

Wholesale (The wholesales dummy): Yes(1), No(0)

Public (Public dummy): Public(1), Private(0)

High-calorie (Transformed dummy): Finished (1), Otherwise(0)

Table 6 Descriptive statistics

	Approval Price	50Price	Demand	Coverage	Quantity	Household
Unit	yen/m^3	yen/m^3	people	%	1000MJ	%
Average	189.1168	11105.1	136626	65.90	7657531.89	0.4177
Variance	5877.724	15842129	7.58807E+11	6870.83	2.5956E+15	0.041
Min	65.82	3974.78	483	13.9	5047	0.014
Max	639.43	24133.2	10255644	1220	611487537	1
Observations	209	209	209	209	209	209

Table 7 Estimation results

Variable	Model-1	Model-2	Model-3	Model-4
Constant	6.193(28.50***)	6.079(28.18***)	10.202(49.75***)	10.088(49.49***)
Customer		-0.033(-2.56**)		-0.030(-2.44**)
Quantity	-0.043(-3.57***)		-0.040(-3.54***)	
Coverage	-0.056(-1.11)	-0.071(-1.39)	-0.063(-1.32)	-0.078(-1.61)
Household	-0.023(-0.65)	0.020(0.615)	-0.075(-2.23**)	-0.034(-1.09)
Wholesale	-0.244(-5.33***)	-0.260(-5.61***)	-0.264(-6.10***)	-0.279(-6.37***)
Public	-0.282(-4.53***)	-0.279(-4.43***)	-0.323(-5.50***)	-0.320(-5.37***)
High-Calorie	-0.178(-3.68***)	-0.197(-4.40**)	-0.144(-3.14***)	-0.161(-3.51***)
(observations)	209	209	209	209
(Adjusted-R^2)	0.436	0.419	0.471	0.455

(Parenthesis: t-value, *significant at 10%, ** 5%, *** 1%)

(Model-1,2: Approval price, Model-3,4: 50 m^3 charge)

Both parameter of the number of customers and the amount of sales are significantly negative. In short, when the scale of supplier is large, the customer price of gas is cheap, and vice versa.

7. Implication

I found that the organizational form of pipeline suppliers is significantly different from that of manufacturing suppliers. And furthermore, if the organizational scale of suppliers is extended, the consumer's price would decline strongly. The results lead to two implications.

Figure 6 The illustration of manufacturing suppliers(Iwate prefecture)

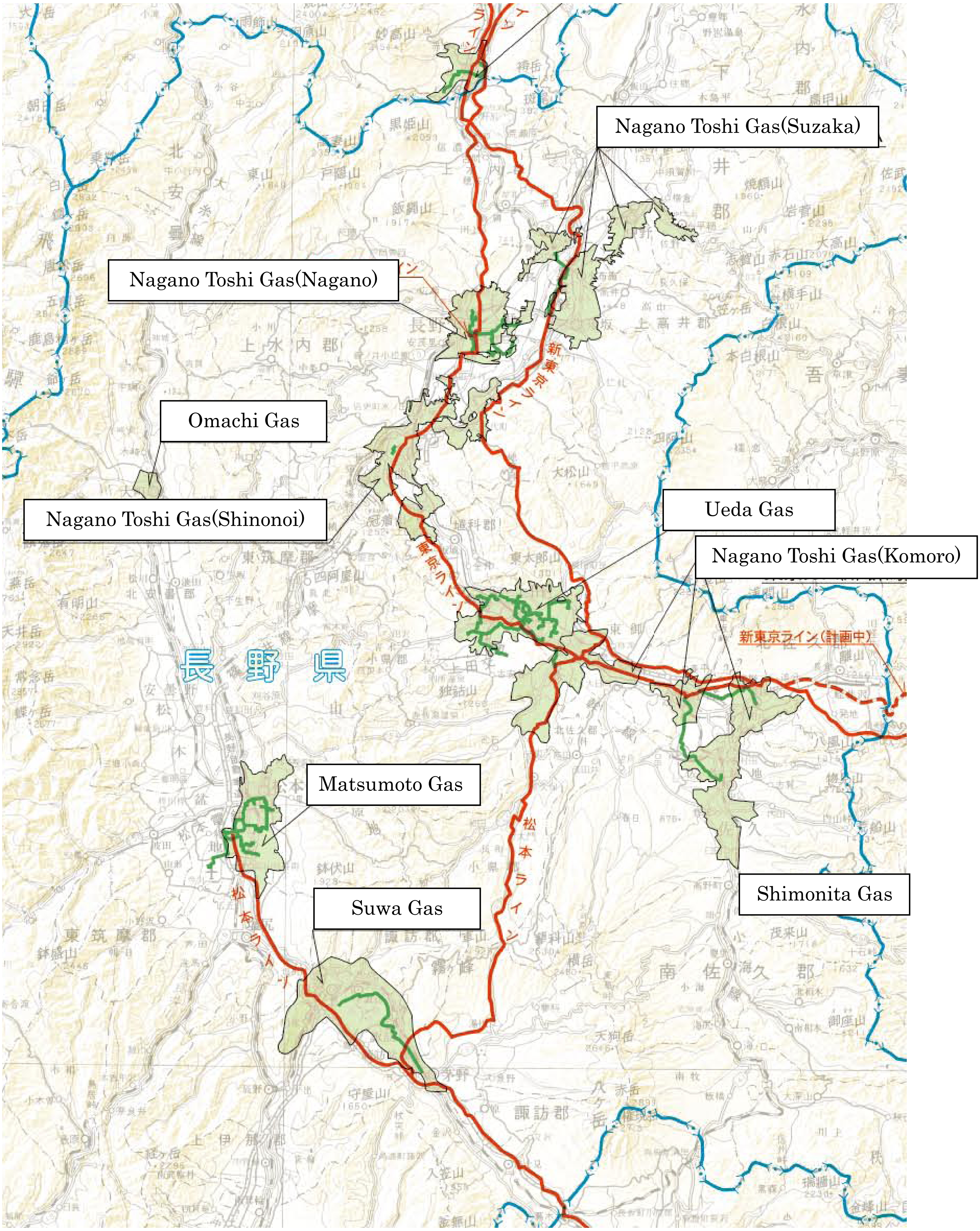

Figure 7 The illustration of pipeline suppliers(Nagano prefecture)

First, if a distribution utility constructs pipelines to other suppliers in the vicinity, and purchases natural gas from the suppliers through the pipelines, then the distribution utility could keep gas price at a lower level. And moreover, when two pipeline suppliers merge with each other, the gas price could be kept at a low level (See figure 6).

Second, if some suppliers could not tie pipelines to other suppliers because of far distance from these suppliers, then, these suppliers have to construct a vaporizing facility to transform LNG into natural gas (See figure 7). As a result, these suppliers could have difficulty in obtaining scale economies. Therefore, the price of these suppliers might be kept at a high level, and then the price differential between these suppliers (manufacturing suppliers) and pipeline suppliers would be also kept at a high level. It seems that the price differential would be extended gradually if the consignment supply is generalized.

Actually, it is natural that a supplier would take advantage of scale merit and perform his costs cut in the competitive dynamism. However, if a lot of suppliers take advantage of scale merit, the price differential between two kinds of suppliers would be expanded. It is not feasible to extinguish the differential by only exertion of each supplier because the differential depends on their location whether they would be able to construct pipelines or not.

We need to consider the significance of the city gas industry. If the city gas industry is not defined as a universal service[9] but as a gas supply service in a particular area, this price differential would be recognized as a peculiar problem in the area. In this case, the price differential is not a serious problem. In other words, when the gas price is expensive due to the location or the organizational forms, the nature of this differential is whether the consumers in this area could accept this price or not. Therefore, the price differential would not be a serious problem if the customers accepted high prices in their own area.

On the other hand, if the city gas industry is defined as a universal service, this differential might be a serious problem. We need to extinguish this differential. However, the factor of this differential is the distinction of organizational forms between pipeline suppliers and manufacturing suppliers. Even if some suppliers strive to reduce administration costs, it might be impossible to extinguish the price differential. In this case, we should solve this differential by political support such as a subsidy of the inside and the foundation of pipelines with public funds.

It is obvious that the liberalization since 1995 has offered management efficiency to the city gas distribution utilities. While the liberalization has been widely spread, the price differential could be larger due to dynamism of the market competition. Henceforth, we should create our next step policy and consider whether the city gas industry is universal or not.

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[9] Universal services are defined as follows.
(1) Essentiality: A service is indispensable for people.
(2) Affordability: People can make use of the service by paying appropriate charge.
(3) Availability: It is feasible to use the service anywhere.
(Source: The workshop of the perspective of universal services, The Ministry of Public Management, Home Affairs, Posts and Telecommunications)

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