engineering proceedings

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Proceeding Paper

Applied Research on Optimal Scale and M&A Efficiency in the Natural Gas Energy Industry †

Ting-Kun Liu

Department of Finance Chaoyang, University of Technology, Taichung 41349, Taiwan; tkliu@cyut.edu.tw

† Presented at the 3rd IEEE International Conference on Electronic Communications, Internet of Things and Big Data Conference 2023, Taichung, Taiwan, 14–16 April 2023.

Abstract: Currently, the number of manufacturers in the natural gas energy industry in several regions is stagnant. However, to improve operating efficiency, it is necessary to review the current optimum number of public gas fuel utilities. Therefore, using the manufacturers of Taiwan's natural gas energy industry and the number of natural gas energy users as a network variable from 1995 to 1999 as panel data, the consideration of network effects of the translog cost function model is incorporated in this study in order to understand the difference from the previous research.

Keywords: natural gas energy; industry application; translog cost function; M&A; operating efficiency; optimal scale

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Citation: Liu, T.-K. Applied Research on Optimal Scale and M&A Efficiency in the Natural Gas Energy Industry. *Eng. Proc.* **2023**, *38*, 66. https://doi.org/10.3390/engproc2023038066

Academic Editors: Teen-Hang Meen, Hsin-Hung Lin and Cheng-Fu Yang

Published: 29 June 2023

1. Introduction

Compared with coal and oil, natural gas is a low-carbon and clean energy source, causing less air pollution. With the growing awareness of the importance of environmental protection, the world's energy policies are gradually changing to increase the proportion of low-polluting energy sources. At present, natural gas energy in Taiwan only accounts for 5% of total domestic energy, so there is still considerable room for flexibility in promoting the expansion of natural gas use. The natural gas energy utilization rate in the northern region is higher than that in the southern region. This is because population concentration and urbanization in the northern region are higher than those in the southern region, as pipeline erection cost is lower, gas supply price is lower, and public acceptance is also higher in the northern region. All natural gas use areas are located in the western part of Taiwan. Due to geography, there is currently no public gas manufacturer in the eastern part.

Since the industry requires a considerable amount of capital to be invested, it must endure more losses at the beginning of its operation. According to the survey data of this research, most natural gas energy manufacturers in Taiwan are currently making profits but not to a reasonable level. Given that manufacturers are unable to introduce new technologies, this limits the effective improvement of the quality of production and service. In addition, given that the number of natural gas energy companies in several regions is stagnating, it is necessary to review the current optimal number of public gas fuel companies to improve operational efficiency, and the discussion of the optimal scale is particularly critical.

There is no relevant empirical research on the optimal operating scale of this industry in Taiwan. There are few foreign studies on this industry [1–3]. Only Ref. [2] has tested the economic scale of this industry. It was found that, besides technological changes, the factor with the most significant contribution to the productivity increase in the U.S. natural gas energy industry is the economy of scale. Network industries such as aviation, transportation, hydropower, electricity, and telecommunications, were also found to affect the economies of scale of the industry [4–7]. Therefore, in this study, the panel data of the manufacturers of Taiwan's natural gas energy industry from 1995 to 1999 were constructed.

Using the translog cost function model, the economies of scale, density, and scope of industries were investigated.

2. Research Methodology

In the literature, MES is mainly discussed in terms of engineering and cost analysis [8–10]. In Ref. [11], the MES was estimated and compared with the cost analysis method and the engineering method, and it was found that the MES estimated by the engineering method was overestimated. In natural gas energy, product quality is uniform, which increases the applicability of the cost analysis method. Therefore, in the natural gas energy industry [1–3], the translog cost function is used as a model for empirical analysis. Therefore, the research framework of the cost analysis method was referred to from the literature, and the translog cost function was constructed as an empirical model for exploring the natural gas energy industry in this study.

2.1. Definition of Variables

The data of 24 manufacturers from 1995 to 1999 for 5 years were obtained without unsuitable samples. Therefore, the data of 21 natural gas energy manufacturers from 1995 to 1999 for 5 years were used to construct the manufacturer-specific panel data for this empirical study.

Short-term variable cost (VC) was obtained by adding the cost of intermediate inputs to the cost of labor. The intermediate input price (P_1) was calculated by the annual cost of raw gas purchased by natural gas energy manufacturers and then deducted from the amount of raw gas purchased. The labor price (P_2) was calculated using the average price method, and the annual personnel cost of each natural gas energy manufacturer was divided by the total number of employees. Gas output (Q_1) was measured based on the annual gas sale volume of each natural gas energy manufacturer, installation output (Q_2) is the annual installation sales volume of natural gas energy manufacturers, and real capital (K) is the fixed assets of natural gas energy manufacturers. In terms of network variables in the model, the number of the manufacturer's natural gas energy users (N) in the current year was represented. The above basic statistics were arranged as shown in Table 1. Time trends (T) were dummy variables (dummy variable T = 1,2, … ,5 for 1995−1999). The other variables were deflated by the relevant price index of 1995 as the base period.

Table 1. Results of short-term translog cost function estimation (1995–1999).

Explanatory	Parameter	Explanatory	Parameter
Constant	−6.983 (−1.92) [c]	$\ln P_1 \ln N$	−0.094 (−4.35) [a]
$\ln P_1$	0.411 (6.14) [a]	$\ln P_1 \cdot T$	0.018 (4.52) [a]
$\ln P_2$	0.590 (8.81) [a]	$\ln P_2 \ln Q_1$	−0.640 (−2.01) [b]
$\ln Q_1$	3.961 (1.87) [c]	$\ln P_2 \ln Q_2$	0.064 (0.70)
$\ln Q_2$	−0.466 (−0.77)	$\ln P_2 \ln K$	0.266 (2.76) [a]
$\ln K$	−1.156 (−1.81) [c]	$\ln P_2 \ln N$	0.241 (0.70)
$\ln N$	0.777 (0.31)	$\ln P_2 \cdot T$	0.026 (0.66)
T	0.056 (0.25)	$\ln Q_1 \ln Q_2$	0.511 (4.11) [a]
$\ln P_1 \ln P_1$	−0.266 (−15.60) [a]	$\ln Q_1 \ln K$	−0.303 (−1.71) [c]
$\ln P_2 \ln P_2$	−0.253 (−12.75) [a]	$\ln Q_1 \ln N$	−0.079 (−0.20)
$\ln Q_1 \ln Q_1$	0.171 (0.36)	$\ln Q_1 \cdot T$	0.170 (2.69) [a]
$\ln Q_2 \ln Q_2$	0.033 (0.43)	$\ln Q_2 \ln K$	−0.087 (−1.78) [c]
$\ln K \ln K$	0.190 (2.89) [a]	$\ln Q_2 \ln N$	−0.408 (−3.37) [a]
$\ln N \ln N$	0.112 (0.30)	$\ln Q_2 \cdot T$	0.030 (1.73) [c]
$T \cdot T$	−0.084 (−5.05) [a]	$\ln K \ln N$	0.071 (0.32) [a]
$\ln P_1 \ln P_2$	−0.262 (−16.30) [a]	$\ln K \cdot T$	−0.025 (−1.70) [c]
$\ln P_1 \ln Q_1$	0.165 (7.36) [a]	$\ln N \cdot T$	−0.147 (−2.37) [b]
$\ln P_1 \ln Q_2$	0.012 (1.75) [c]		

Table 1. *Cont.*

Explanatory	Parameter	Explanatory	Parameter
R2			
Cost function 0.958			
Intermediate input share function 0.858			

Note: 1. Values in parentheses are T values. 2. [a], [b], and [c] represent significance at the 1%, 5%, and 10% statistical test levels, respectively.

2.2. Empirical Model

In empirical research, it is not suitable for industries with a large number of fixed factors to use the long-term cost function to directly analyze since the production technology is not in the optimal equilibrium state. It is appropriate to use the short-term cost function that considers fixed factors to measure [12,13]. According to the setting of the translog cost function by Ref. [14], the second-order approximation equation of the cost function is expressed as follows.

$$\begin{aligned} \ln VC &= \beta_0 + \sum_{i=1}^{2} \beta_{P_i} \ln P_i + \sum_{i=1}^{2} \beta_{Q_i} \ln Q_i + \beta_K \ln K + \beta_N \ln N + \beta_T T \\ &+ \tfrac{1}{2} \sum_{i=1}^{2} \sum_{j=1}^{2} \beta_{P_i P_j} \left(\ln P_i \ln P_j\right) + \tfrac{1}{2} \sum_{i=1}^{2} \sum_{j=1}^{2} \beta_{Q_i Q_j} \left(\ln Q_i \ln Q_j\right) \\ &+ \tfrac{1}{2} \beta_{KK} (\ln K)^2 + \tfrac{1}{2} \beta_{NN} (\ln N)^2 + \tfrac{1}{2} \beta_{TT} (T)^2 \\ &+ \sum_{i=1}^{2} \sum_{j=1}^{2} \beta_{P_i Q_j} \ln P_i \ln Q_j + \sum_{i=1}^{2} \beta_{P_i K} \ln P_i \ln K \\ &+ \sum_{i=1}^{2} \beta_{P_i N} \ln P_i \ln N + \sum_{i=1}^{2} \beta_{P_i T} \ln P_i T + \sum_{i=1}^{2} \beta_{Q_i K} \ln Q_m \ln K \\ &+ \sum_{i=1}^{2} \beta_{Q_i N} \ln Q_i \ln N + \sum_{i=1}^{2} \beta_{Q_i T} \ln Q_i T + \beta_{KN} \ln K \ln N \\ &+ \beta_{KT} T \ln K + \beta_{NT} T \ln N + \varepsilon \end{aligned} \quad (1)$$

Adopting the concept of the augmented scale of economies (ASCE) [15], the augmented and estimated annual short-run cost function was used for total regional consolidated firms after merging ASCE to expand the number of users at a given price (the average price of consolidated manufacturers in each region).

$$\sum_i VC_i = \sum_i f_i(\overline{P}_1, \overline{P}_2, Q_{1i}, Q_{2i}, K_i, N_i, T),\ i = 1, \ldots, n \quad (2)$$

3. Results

The parameter estimation of the short-term translog cost function is shown in Table 2. The results show that the R2 of the short-term translog cost function and the intermediate input share function are 0.96 and 0.86, respectively, and the explanatory power is more than 85%. The results indicate that the regression model in this study had an ideal adaptation state. Therefore, in this study, the estimated parameters were used to measure the short-term economies of scale, density economies, category economies, and the Allen partial substitution elasticity of the natural gas energy industry. The estimated results are shown in Table 2.

The estimated value of short-term economies of scale in Taiwan's natural gas energy industry during 1995−1999 is greater than 1, indicating that Taiwan's natural gas energy industry does have the characteristics of economies of scale when considering the network effect. When faced with a given market factor price and real capital volume, increasing output and network density at the same time can reduce costs. The estimated value of density economics is 3.230, which is greater than 1. This means that, under the given input price, real capital volume, the number of users, and the output of Taiwan's natural gas energy industry increase, and the effect of cost reduction is extremely significant. In addition, the category economy was 15.247, indicating that Taiwan's natural gas energy industry produces two outputs of gas and equipment at the same time, which showed the advantages of the scope economy or diversification economy compared with the mode of only producing a single output.

Table 2. Short-term economies of scale, density, scope and Allen partial substitution elasticity.

	Estimates	Standard Deviation
Economies of scale (*SE*).	1.127	0.944
Economies of density (*DE*).	3.230	2.585
Category economy (*SCOPE*).	15.247	9.668
Intermediate input-labor (σ_{12}).	−0.423	0.367
Intermediate input-Intermediate input (σ_{11}).	−1.503	1.128
Labor-labor (σ_{22}).	−7.178	5.243

Note: Values are the average of sample estimates.

In addition, Allen's estimation of the elasticity of substitution showed complementarity between intermediate inputs and labor. That is, when the price of intermediate inputs rises, natural gas energy manufacturers cannot use labor to replace intermediate inputs to save costs. Thus, when the prices of intermediate inputs rise, they cannot slow down the rise in variable costs by increasing labor input. Therefore, with soaring raw material prices, manufacturers need to consider increasing the network effect or expanding the scale to reduce the pressure and risk of costs. The optimal production scale of the natural gas energy industry is discussed in this article later.

The comparison of the augmented scale economy coefficient form before and after M&A is shown in Table 3. The ASCE values of all regions after M&A, except for Northern Region III, were significantly higher than those of the manufacturers before the merger, indicating that the manufacturers in all regions after the merger had the benefits of expanded economies of scale. Among them, the northern region II had the most significant benefit after M&A. While the estimated value of ASCE after the merger in the southern region is less than 1, it is also close to the level of expanding fixed economies of scale. Therefore, the results of the ex-ante M&A imply that when the manufacturer faces scale expansion and market expansion after M&A, it does not harm the cost side, but increases the output and improves the user network through M&A to achieve the goal of reducing costs and pursuing optimal scale.

Table 3. Comparison of augmented economies of scale coefficients before and after M&A.

	Augmented Economies of Scale	
Regional Markets	**Before M&A**	**After M&A**
Northern Region I.	0.698 (0.1435)	1.877 (1.1732)
Northern Region II	0.4291 (0.399)	1.811 (0.032)
Northern Region III.	1.218 (0.677)	1.242 (1.427)
Central region	0.445 (0.282)	1.027 (0.693)
Southern region	0.448 (0.475)	0.955 (0.734)

Note: Estimates are the mean of the sample, and values in parentheses are standard deviations.

4. Conclusions

The results of this study show that the industry has the characteristics of scale economy, density economy, and category economy effect in the mode of simultaneously selling gas and equipment. Allen's estimates of partial elasticity of substitution show that there is complementarity between intermediate inputs and labor. This implies that when the price of intermediate inputs rises, natural gas energy manufacturers cannot use labor to replace intermediate inputs to save costs. According to the minimum effective scale output and the actual demand for natural gas energy, it is estimated that the optimal number of natural gas energy manufacturers is three in the north, one in the middle, and one in the south. Finally, the expanded economies of scale coefficients were compared before and after the merger, showing that the merged regional firms had the benefit of expanding economies of scale. Through the merger, they increased output and improved user networks, reducing costs and pursuing optimal scale.

Due to the limitation of the research sample investigated, only 5 years of panel data were used empirically. Whether structurally competitive utilities need to be merged, MES may not be the only consideration. It is necessary to continue to collect and construct more complete sample data to provide more detailed economic and policy implications. In this study, the annual data were used as the observation value, and the gas output varied due to different seasons and time points. The change in the cost structure at these time points could not be represented in the model of this paper. In addition, Ref. [16] proposed the AGEM (additive general error model) model, pointing out that, compared with the estimation of the translog cost function and the share equation, the AGEM model uses the demand function instead of the cost share function for estimation. The more informative the model, the more the error term can be explained by the input quantity. Empirical research results also showed that the AGEM model outperformed the translog cost function and cost share estimation models [17]. There authors of [18] also used the AGEM model [16] for empirical analysis in their research on technological changes, learning effects, and structures in the production of machinery and equipment in the United States. The above-mentioned parts were not included in the model, though they are important research directions. Thus, they will be further considered and adjusted in the future.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Taiwan natural gas energy manufacturers survey in 1995.

Conflicts of Interest: The author declares no conflict of interest.

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