Cost Inefficiency and Economies of Scale in the Japanese Electrical Appliances Industry

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ABSTRACT

We measure the cost inefficiency and scale economies in the Japanese electrical appliances industry during the period 1980–2000. SUR model, in which the cost function is described in translog form, is used for our purpose. Based on the complete database, estimation results are presented. Then, structural change is checked, and the conclusion is drawn that product behavior changed around year 1990. Taken into consideration the structural change, data is divided into two groups. After that, firm and time inefficiencies are estimated in two separate periods. Finally, existence of scale economies is observed in both periods.

1. Introduction

The present study aims at clarifying the process of change in the Japanese electrical appliances industry by the econometric analysis using panel data. Before making a quantitative analysis, the special features of the industry should be presented. There are relatively few published studies of the Japanese electrical appliances industry using econometric model analysis.

Truett and Truett (1998) investigated the existence of scale economies in Mexican electrical equipment industry using SUR (seemingly unrelated regression) model. The article is among the earliest papers on electrical equipment industry. Similar models will be used in the present study to find production behavior in electrical appliances industry of a developed country. Nakajima, Nakamura and Yoshioka (1998) presented an index number method to estimate scale economies and technical progress for Japanese manufacturing using the panel data from 1964 to 1988. They found that electric machinery industry enjoyed both a high rate of technical progress and a high elasticity of scale.

Section 2 describes the special features of the industry and traces the development from 1980 to 2000. Section 3 presents econometric models in our study. SUR model will be used for our study, and the cost function is expressed in translog form. A more descriptive data will be defined in section 4. Estimations are carried out by Limdep (Greene (1991)) and results are presented in section 5. Japan has witnessed a serious recession from 1991. We believe this fact affects the production behavior of the industry and structural change will be checked in section 6. The results show that the serious recession in the 1990s have a profound effect on the firms' production behavior. Thus data will be divided into two parts (years before 1990 and years after 1990) and estimation will be done separately in sections 7 and section 8. While calculating inefficiency, we employ an approach in which the use of panel data is indispensable. By taking into account the structural change mentioned above, we have obtained interesting results, which show that inefficiency increases (efficiency decreases) during most of the observed years but with a decrease during "Bubble Economy" in Japan. Larger firms tend to have relatively lower inefficiency. Economies of scale are observed in both periods in section 9. Higher scale economies can be discovered in the recession period. Larger firms tend to benefit more from scale economies than their smaller competitors. Conclusion remarks are finally made in section 10.

2. History and development of the Japanese electrical appliances industry

In early 1980s', Japanese economy kept a moderate growing rate of 4% attributed to the increasing demand abroad, but the domestic entities were in ebb with a high unemployment rate. From middle 1980s', Japanese economy has recovered from a recession due to the enlarged consumption and investment. In the following years, both stock prices and real estate prices rose to unprecedented levels. However, in 1990, aggregate demand began to decrease, stock prices and real estate prices took a nose-dive and Japan witnessed a serious recession from 1991.

Japanese household electrical appliances industry experienced an astounded development in the post-war period. As early as in 1980s, it had entered a mature stage. The key factors of the fast development of this industry are (see Wakabayashi (1992)):

1) Introduce new technology from abroad and adopt it in their new products.
2) Shift from exporting to producing locally to lower the cost and avoid trade friction.
3) Create leading products and innovate new functions of electrical appliances.
4) Reform the circulation channel.
5) Unified standard and diversified commodity.
6) Improve the management.

Figure 2-1 shows the changes of several variables of the 22 selected firms[1] between 1980 and 2000. The variables are value-added, total assets, sales, net profits and material cost[2].

Total assets and sales increased rapidly from 1980 to 1991 and the increasing speed slowed down after the "Bubble Economy". Value-added and material cost increased a bit before 1991 and remained the same after that. In most of the observed years, net profit remained positive and reached its peak during the "Bubble Economy", but it dropped down afterwards and went to negative in year 1999 and year 2000.

1) The 22 selected firms included in our research are: Matsushita Electric Industrial, Hitachi, Sony, Fujitsu, Toshiba, Mitsubishi Electric, Sharp, Sanyo Electric, Fuji Electric, Matsushita Communication Industry, Omron, Pioneer, Casio, Alps Electric, Hitachi Maxell, Yasukawa Electric, Matsushita Seiko, Shibaura Mechatronics, Takaoka Electric Industrial, Nihon Dempa Kogyo, Hitachi Electronics and Meisei Electric.

2) Details of the data are included in section 4.

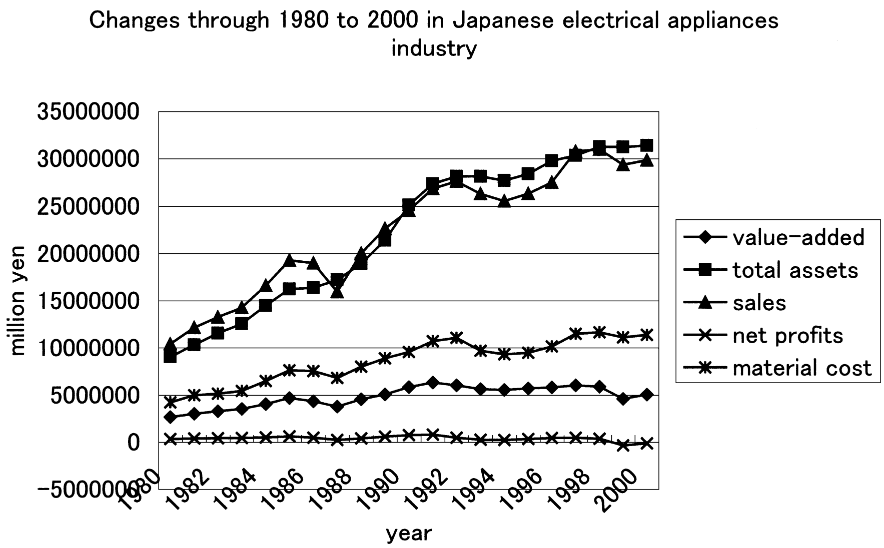

Fig. 2–1. Changes through 1980 to 2000
(Source of data: Nikkei Financial Data CD-ROM, 2000.12, published by Nikkei Quick Information)

Fig. 2–2. The number of employees changes through 1980 to 2000
(Source of data: Nikkei Financial Data CD-ROM, 2000.12, published by Nikkei Quick Information)

Figure 2-2 gives the corresponding number of employees from 1980 to 2000 of the 22 firms.

The number of employees increased gradually from 1980 to 1986 and remained almost unchanged till 1990. It increased again from 1990 to 1993 but dropped from 1994 to 2000.

3. Models and theories

According to the neoclassical microeconomic theory, the minimum cost function is the result of a profit maximizing process. The minimum cost for any given level of output can be expressed as a function of the output level and factor input prices.

Translog (transcendental logarithmic) cost function is the most frequently used model in empirical work. This function is obtained by expanding ln C in a second-order Taylor series about the point ln $P = 0$, where C is the cost and P is a vector of factor input prices and output level. Details of this function are included in Greene (1997). The function can be written as:

$$\ln C = \alpha_0 + \alpha_1 \ln \mathrm{Y} + \sum_{i=1}^{n} \beta_i \ln p_i + \delta_Y \cdot \frac{1}{2} \cdot (\ln Y)^2 + \sum_{i=1}^{n} \sum_{j=1}^{n} \delta_{ij} \cdot \frac{1}{2} \cdot \ln p_i \ln p_j + \sum_{j=1}^{n} \rho_j \ln Y \ln p_j \quad (3\text{-}1)$$

where C is the total cost, Y is the output, $p_i (i = 1, \ldots n)$ are factor input prices and n is the number of factor inputs.

The minimum requirements for the cost function to describe a well-behaved technology are as follows:

1) Linearly homogenous in input prices.
2) Non-negative and monotonically increasing in output and input prices.
3) Concave in input prices.

Using Shephard's Lemma, the derivatives of the minimum cost function with respect to the factor prices (in logarithm form) yield the corresponding share equations:[3)]

$$\begin{aligned} S_1 &= \partial \ln C(Y, p)/\partial \ln p_1 = \beta_1 + \sum_{j=1}^{n} \delta_{1j} \ln p_j + \rho_1 \ln Y \\ S_2 &= \partial \ln C(Y, p)/\partial \ln p_2 = \beta_2 + \sum_{j=1}^{n} \delta_{2j} \ln p_j + \rho_2 \ln Y \\ &\ldots\ldots \\ S_n &= \partial \ln C(Y, p)/\partial \ln p_n = \beta_n + \sum_{j=1}^{n} \delta_{nj} \ln p_j + \rho_n \ln Y \end{aligned} \quad (3\text{-}2)$$

Three-factor inputs model is used in this study. Equation (3-3) is derived from equation (3-1), and the three factor input prices are defined as p_1, p_2 and p_3.

$$\ln C = \alpha_0 + \alpha_1 \ln Y + \beta_1 \ln p_1 + \beta_2 \ln p_2 + \beta_3 \ln p_3 + \delta_Y \cdot \frac{1}{2} \cdot \ln^2 Y + \delta_{11} \cdot \frac{1}{2} \cdot \ln^2 p_1 + \delta_{12} \cdot \frac{1}{2} \cdot \ln p_1 \ln p_2 + \delta_{13} \cdot \frac{1}{2} \cdot \ln p_1 \ln p_3 + \delta_{21} \cdot \frac{1}{2} \cdot \ln p_1 \ln p_2 + \delta_{22} \cdot \frac{1}{2} \cdot \ln^2 p_2 \quad (3\text{-}3)$$

3) Shephard's Lemma states that the firm's optimum input demand function can be acquired by taking the derivative of the cost function with respect to the price of the inputs (Nicholson (1998)).

$$+ \delta_{23} \cdot \frac{1}{2} \cdot \ln p_2 \ln p_3 + \delta_{31} \cdot \frac{1}{2} \cdot \ln p_1 \ln p_3 + \delta_{32} \cdot \frac{1}{2} \cdot \ln p_2 \ln p_3 + \delta_{33} \cdot \frac{1}{2} \cdot \ln^2 p_3$$

$$+ \rho_1 \ln Y \ln p_1 + \rho_2 \ln Y \ln p_2 + \rho_3 \ln Y \ln p_3 + \varepsilon_c$$

where ε_c is the disturbance and $E(\varepsilon_c) = 0$.

Because of the symmetry restrictions, $\delta_{ij} = \delta_{ji} (i, j = 1, \dots n)$, equation (3-3) can be simplified to (3-4):

$$\ln C = \alpha_0 + \alpha_1 \ln Y + \beta_1 \ln p_1 + \beta_2 \ln p_2 + \beta_3 \ln p_3 + \delta_Y \cdot \frac{1}{2} \cdot \ln^2 Y$$
$$+ \delta_{11} \cdot \frac{1}{2} \cdot \ln^2 p_1 + \delta_{22} \cdot \frac{1}{2} \cdot \ln^2 p_2 + \delta_{33} \cdot \frac{1}{2} \cdot \ln^2 p_3 + \delta_{12} \ln p_1 \ln p_2 + \delta_{13} \ln p_1 \ln p_3 \quad (3\text{-}4)$$
$$+ \delta_{23} \ln p_2 \ln p_3 + \rho_1 \ln Y \ln p_1 + \rho_2 \ln Y \ln p_2 + \rho_3 \ln Y \ln p_3 + \varepsilon_c$$

Getting the partial derivatives of (3-4) with respect to the log input prices yield the share equations:

$$\begin{aligned} S_1 &= \partial \ln C(Y, p)/\partial \ln p_1 = \beta_1 + \delta_{11} \ln p_1 + \delta_{12} \ln p_2 + \delta_{13} \ln p_3 + \rho_1 \ln Y + \varepsilon_1 \\ S_2 &= \partial \ln C(Y, p)/\partial \ln p_2 = \beta_2 + \delta_{12} \ln p_1 + \delta_{22} \ln p_2 + \delta_{23} \ln p_3 + \rho_2 \ln Y + \varepsilon_2 \\ S_3 &= \partial \ln C(Y, p)/\partial \ln p_3 = \beta_3 + \delta_{13} \ln p_1 + \delta_{23} \ln p_2 + \delta_{33} \ln p_3 + \rho_3 \ln Y + \varepsilon_3 \end{aligned} \quad (3\text{-}5)$$

where ε_1, ε_2, ε_3 are disturbances and $E(\varepsilon_1) = E(\varepsilon_2) = E(\varepsilon_3) = 0$.

Although Greene (1997) assumes constant returns to scale, the same assumption won't be made in this study. Only two of the factor share equations are linearly independent since their sum must be equal to unity[4].

$$S_1 + S_2 + S_3 = 1 \quad (3\text{-}6)$$

To solve the problem of singularity, one share equation should be removed. (see Greene (1997)). As for which factor is chosen to be deleted, Greene (1997) gives the following statements:

> In principle, it is immaterial which factor is chosen as the numeraire. Unfortunately, the FGLS parameter estimates in the now nonsingular system will depend on which one is chosen. Invariance is achieved by using maximum likelihood estimates instead of FGLS. These can be obtained by iterating FGLS or by direct maximum likelihood estimation.

The invariance results are proved by Barten (1969), and as far as iterating FGLS and direct maximum likelihood estimation are considered, we can refer to Revankar (1976).

We will choose the third factor price, p_3, and use p_1/p_3, p_2/p_3, C/p_3 to delete the third share

4) Under this restriction, $\beta_1 + \beta_2 + \beta_3 = 1$, $\delta_{11} + \delta_{12} + \delta_{13} = 0$, $\delta_{12} + \delta_{22} + \delta_{23} = 0$, $\delta_{13} + \delta_{23} + \delta_{33} = 0$, and $\varepsilon_1 + \varepsilon_2 + \varepsilon_3 = 0$ hold.

equation. In this case, the constraint that cost shares add up to 1 ($S_1 + S_2 + S_3 = 1$) is satisfied automatically (see Greene (1997)). At the same time, linear homogeneity in the input prices is satisfied, too (see Greene (1997)). Using pp_1 to represent as p_1/p_3 and pp_2 to represent as p_2/p_3, the translog model can be rewritten as:

$$\ln(C/p_3) = \alpha_0 + \alpha_1 \ln Y + \beta_1 \ln pp_1 + \beta_2 \ln pp_2 + \delta_Y \cdot \frac{1}{2} \cdot \ln^2 Y + \delta_{11} \cdot \frac{1}{2} \cdot \ln^2 pp_1 + \delta_{22} \cdot \frac{1}{2} \cdot \ln^2 pp_2 + \delta_{12} \ln pp_1 \ln pp_2 + \rho_1 \ln Y \ln pp_1 + \rho_2 \ln Y \ln pp_2 + \varepsilon_c \tag{3-7}$$

The corresponding cost share equations are:

$$\begin{aligned} S_1 &= \partial \ln(C/p_3)/\partial \ln pp_1 = \beta_1 + \delta_{11} \ln pp_1 + \delta_{12} \ln pp_2 + \rho_1 \ln Y + \varepsilon_1 \\ S_2 &= \partial \ln(C/p_3)/\partial \ln pp_2 = \beta_2 + \delta_{12} \ln pp_1 + \delta_{22} \ln pp_2 + \rho_2 \ln Y + \varepsilon_2 \end{aligned} \tag{3-8}$$

Our empirical study is based on model (3-7) and (3-8).

4. Data description

Out data is publicly available accounting data of 22 firms from year 1980 till 2000[5)]. The 22 firms (ordered by total assets of year 2000) are: Matsushita Electric Industrial, Hitachi, Sony, Fujitsu, Toshiba, Mitsubishi Electric, Sharp, Sanyo Electric, Fuji Electric, Matsushita Communication Industry, Omron, Pioneer, Casio, Alps Electric, Hitachi Maxell, Yasukawa Electric, Matsushita Seiko, Shibaura Mechatronics, Takaoka Electric Industrial, Nihon Dempa Kogyo, Hitachi Electronics and Meisei Electric.

Among the 22 firms, the largest firms in Japanese electrical appliance industry are included because they make up large proportion of this industry. Some middle or small size firms are also comprised in order to have a better understanding of the industry and to compare larger firms with smaller firms.

The factor inputs included in the present study are capital (*K*), labor (*L*) and intermediate goods (*M*).

The cost of each factor is defined as follows:

CK, cost of capital, includes depreciation and interest expense on total assets, in million yen.

CL, cost of labor, includes the salaries and wages during the fiscal year, in million yen.

CM, cost of intermediate goods, defined as the expense on raw material, in million yen.

The corresponding volumes of these factor inputs are as defined below:

NK, volume of capital, is defined as total assets, in million yen.

NL, the number of labor, is defined as both the workers and the employees, in person.

NM, the volume of intermediate goods, is assumed to be equal to output. Thus the amount of

5) Data source: Nikkei financial data CD-ROM (2000. 12).

output acts as the proxy of the volume of intermediate goods.

Price of each factor inputs can be defined easily by:

PK = *CK/NK*, price of the capital is the depreciation and interest expense on each million yen of the total assets.

PL = *CL/NL*, price of the labor is the average wage and salary.

PM = *CM/NM*, price of the intermediate goods is defined as the cost on raw material for a "unit" of output.

Other variables used in our research are as defined below:

For *Y*, output, we chose value-added as our output, which includes net profits, salaries and wages, income tax payment, rent expense, interest expense and depreciation (Hiramatsu, Yamaji and Yurikusa (1998)). It is measured in million yen.

C, total cost, defined as the sum of cost on capital, labor and intermediate goods.

It is necessary to deflate some of the quantities presented above. The cost of capital is deflated by GDP investment deflator, and the cost of labor and intermediate goods are deflated by GDP deflator[6)].

Our data is normalized by their mean values, thus the means' of the factor input prices and output are unity. The reason for this stems from the fact that translog model is obtained by expanding ln *C* in a second-order Taylor series about the point ln *P* = 0, where *P* is a vector of factor input prices and output level. Thus we can expand ln *C* at the mean value of factor input prices and output level.

5. Empirical analysis of the electrical appliances industry (1980–2000)

In this section, the estimation by SUR model is based on the complete database. Cost inefficiency, the failure to produce at minimum cost (cost frontier) given the output and the set of input prices, will also be calculated. To grasp the cost inefficiency in production of the firms during the observed years, we add firm and year dummies to the standard SUR model (3-7) and (3-8). We use $Year_i$ (i = 1981 ... 2000) and $Firm_j$ (j = 2 ... 22) as dummy variables. $Year_i$ is unity for year i, but zero otherwise, and $Firm_j$ is unity for firm j, but zero otherwise. We delete $Year_{1980}$ and $Firm_1$ to avoid perfect collinearity, thus we choose year 1980 and the 1st firm as benchmark.

Schmidt and Sickles (1984) describe how to obtain the consistent estimates of the cost inefficiency. The most efficient firm (year) is counted as 100% efficient and the inefficiency is measured by the distance from the inefficiency of the 100% efficient firm (year).

In our model given in (5-1) and (5-2), *PK/PM*, *PL/PM* and *PM* are used instead of pp_1, pp_2 and p_3.

$$\ln(C/PM) = \alpha_0 + \alpha_1 \ln Y + \beta_1 \ln(PK/PM) + \beta_2 \ln(PL/PM) + \delta_Y \cdot \frac{1}{2} \cdot \ln^2 Y + \delta_{11} \cdot \frac{1}{2} \cdot \ln^2 PK/PM + \delta_{22} \cdot \frac{1}{2} \cdot \ln^2 PL/PM$$

6) Data source of deflator index: National Economy Annual Report, published by Cabinet Office (Government of Japan).

Table 5–1 Results of SUR estimation from 1980 to 2000
(firm and time effects are not included here)

Coefficient	Estimated Coefficient	t-ratio
α_0	0.2913800	9.71694
α_1	0.6656810	31.3806
β_1	0.9048210	516.728
β_2	0.0258688	41.7680
δ_Y	–0.0466955	–5.45427
δ_{11}	0.0665848	34.0160
δ_{12}	–0.0145495	–19.4099
δ_{22}	0.0148268	19.8209
ρ_1	0.0073058	7.42117
ρ_2	–0.0039038	–11.1881

Table 5–2 Firm and time effects

Firm	Estimated Coefficient	t-ratio	Year	Estimated Coefficient	t-ratio1
1	0		1980	0	
2	0.0933013	3.59662	1981	0.0374819	1.60689
3	–0.234131	–7.35784	1982	0.0580599	2.46252
4	–0.16374	–6.72271	1983	0.0813028	3.42876
5	0.0480921	1.9646	1984	0.110823	4.56563
6	–0.091218	–3.60064	1985	0.140432	5.60318
7	–0.0901341	–3.72891	1986	0.19512	7.75278
8	–0.450741	–14.8681	1987	0.297293	12.0693
9	–0.343933	–10.6514	1988	0.271955	10.4362
10	–0.620482	–15.999	1989	0.265497	10.123
11	–0.799122	–17.7287	1990	0.261614	9.77584
12	–0.893239	–19.0368	1991	0.273034	9.88444
13	–1.2878	–37.9718	1992	0.315552	11.27
14	–0.865019	–16.488	1993	0.366441	13.1228
15	–0.871729	–16.8355	1994	0.390226	13.7978
16	–1.15828	–21.3018	1995	0.456956	15.293
17	–1.04533	–18.4844	1996	0.549593	17.5417
18	–1.21382	–19.481	1997	0.573475	17.4056
19	–1.35599	–18.3946	1998	0.593724	17.6703
20	–1.22255	–18.4159	1999	0.648129	19.2466
21	–1.4164	–16.7676	2000	0.644677	18.8074
22	–1.35822	–19.1714			

$$+ \delta_{12}\ln(PK/PM)\cdot\ln(PL/PM) + \rho_1\ln Y\ln(PK/PM)$$

$$+ \rho_2\ln Y\ln(PL/PM) + \sum_{i=1981}^{2000}\lambda_i Year_i + \sum_{j=2}^{22}\theta_j Firm_j + \varepsilon_c \qquad (5\text{-}1)$$

$$\begin{aligned} S_1 &= \partial\ln(C/PM)/\partial\ln(PK/PM) = \beta_1 + \delta_{11}\ln(PK/PM) + \delta_{12}\ln(PL/PM) + \rho_1\ln Y + \varepsilon_1 \\ S_2 &= \partial\ln(C/PM)/\partial\ln(PL/PM) = \beta_2 + \delta_{12}\ln(PK/PM) + \delta_{22}\ln(PL/PM) + \rho_2\ln Y + \varepsilon_2 \end{aligned} \qquad (5\text{-}2)$$

Table 5–3 Adjusted firm and time effects (cost inefficiency)

Firm	Adjusted Coefficient	Year	Adjusted Coefficient
1	1.41640	1980	0
2	1.50970	1981	0.037482
3	1.18227	1982	0.058060
4	1.25266	1983	0.081303
5	1.46449	1984	0.110823
6	1.32518	1985	0.140432
7	1.35627	1986	0.195120
8	0.96566	1987	0.297293
9	1.07247	1988	0.271955
10	0.79592	1989	0.265497
11	0.61728	1990	0.261614
12	0.52316	1991	0.273034
13	0.12860	1992	0.315552
14	0.55138	1993	0.366441
15	0.54467	1994	0.390226
16	0.25812	1995	0.456956
17	0.37107	1996	0.549593
18	0.20258	1997	0.573475
19	0.06041	1998	0.593724
20	0.19385	1999	0.648129
21	0	2000	0.644677
22	0.05818		

The estimated results are given in Table 5-1, firm and time effects are given in Table 5-2:

As could be expected, if the prices of capital and labor increase, the cost of production increases. The estimates of the coefficients of capital (β_1) and labor (β_2) are positive and significantly different from zero at 1% level, thus the assumption of monotonicity is satisfied. The elasticity of cost to capital (β_1) is 0.904821 and that to labor (β_2) is 0.0258688, which means in such a high-tech and automatic industry, dependence on cost of labor is relatively smaller than that of the capital.

The coefficient of output (α_1) is significantly different from zero at 1% level. This result tells us that the cost has a positive relationship with the output level. A coefficient less than unity indicates the presence of decreasing unit cost in the industry.

The interaction term between labor and output (ρ_2) is −0.0039038, and is significant at 1% level. This fact demonstrates that the impact upon total cost of an increasing in price of labor vanishes as the quantity of output increases.

The coefficients of $\ln^2 Y$ and $\ln(PK/PM)\cdot\ln(PL/PM)$ are significantly different from zero.

Since the 1st firm and year 1980 are used as benchmark, the inefficiency $\theta_i(i = 2, \ldots 22)$ and $\lambda_t(t = 1981 \ldots 2000)$ can be both positive and negative. The positive coefficient means that the cost is higher than the benchmark firm (year) keeping other things equal (output and input prices), so the firm (year) is less efficient than the benchmark firm(year). Negative coefficient means that it is more efficient than the benchmark firm (year). The larger the value is, the less efficient the firm (year) is.

To calculate the cost inefficiency, we hold the assumption that the most efficient firm (year)

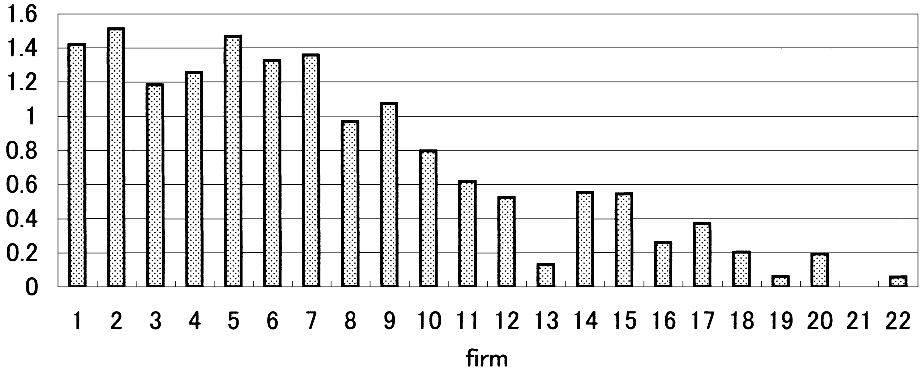

Fig. 5–1. Adjusted firm effects

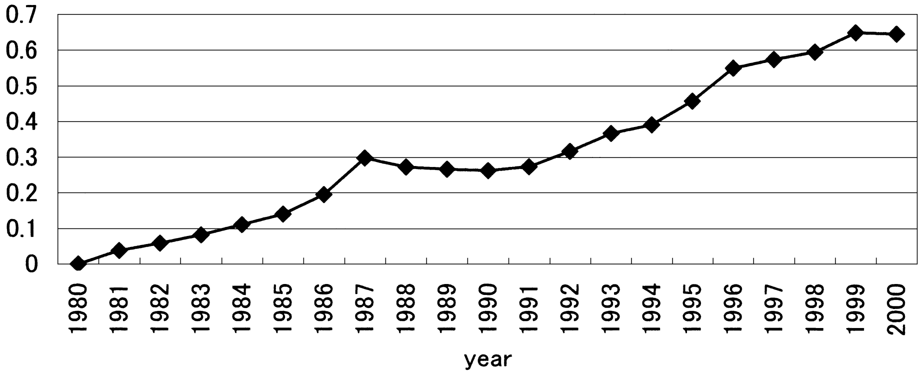

Fig. 5–2. Adjusted time effects

produces on the frontier of the cost function. The smallest firm effect is θ_{21}, and the smallest year effect is λ_{1980}, which suggest that the 21st firm and year 1980 are the most efficient firm and year, respectively. We adjust firm effects by $\theta_i - \theta_{21}(i = 1, 2 \ldots 22)$ and time effects by $\lambda_i - \lambda_{1980}(i = 1980, \ldots 2000)$. The adjusted firm effects and time effects (cost inefficiency) are given in Table 5-3 and also described in Figure 5-1 and Figure 5-2.

The firm effects are θ_1 (inefficiency of the largest firm in terms of total assets in 2000) through θ_{22} (inefficiency of the smallest firm). The adjusted firm effect of the 21st firm and time effect of year 1980 are zero because we assume that the 21st firm and year 1980 produce on the cost frontier. If we divide our observations into two groups according to their total assets, that is larger firms (the first 11 firms), and smaller ones (the last 11 firms), we will get interesting findings. Table 5-3 and Figure 5-1 show that larger firms have higher inefficiency than the smaller firms. The average cost inefficiency for larger firms is 1.178027, while that for smaller firms is 0.262911. This result is not surprising because larger firms usually will have larger absolute inefficiency. But it is hard to explain inefficiency of firms without taking into consideration of their total cost. To get the “real” inefficiency, we re-adjust our results (adjusted firm inefficiency) by dividing them by their total cost respectively. These results are described in Table 5-4 and Figure 5-3.

Table 5–4 Re-adjusted firm effects: adjusted firm effects/total cost

Firm	Adjusted Firm Effects/Total Cost
1	0.0000090226
2	0.0000085861
3	0.0000129151
4	0.0000118740
5	0.0000095931
6	0.0000106161
7	0.0000121420
8	0.0000170071
9	0.0000184322
10	0.0000278204
11	0.0000419496
12	0.0000357480
13	0.0000078330
14	0.0000397768
15	0.0000384046
16	0.0000279403
17	0.0000526866
18	0.0000378190
19	0.0000349990
20	0.0000615272
21	0
22	0.0000267551

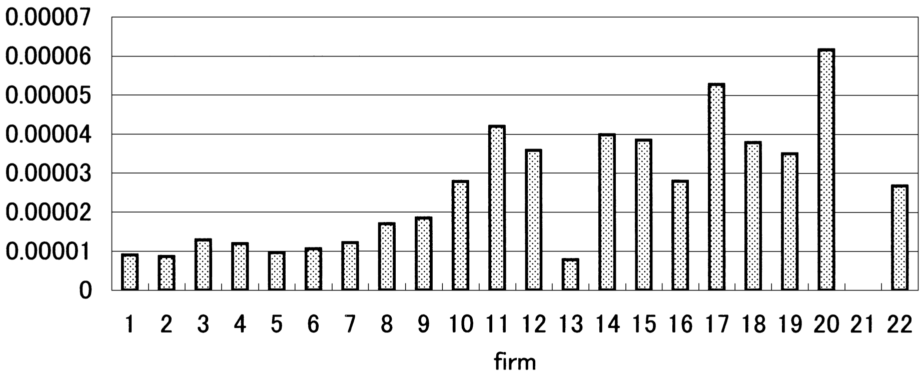

Fig. 5–3. Re-adjusted firm effects

After the re-adjustment, we may find that larger firms tend to have smaller inefficiency than smaller firms on average. The average cost inefficiency for larger firms is 0.0000163598 and that for smaller firms is 0.0000330445. The 21st firm is an exception because we have already assumed that it is the most efficient firm.

Time effects are captured by λ_{1980} (inefficiency of year 1980) through λ_{2000} (inefficiency of year 2000). From Table 5-3 and Figure 5-2, we know that inefficiency increased (efficiency decreased) from 1980 to 1987. Decrease in inefficiency (increase in efficiency) is found during the "Bubble Economy" from 1987 to 1990. Then, inefficiency began to increase rapidly again in the recession period.

6. Structural change

So far, we have assumed that the coefficients of the cost function are constant during the 20 years. The assumption of constant coefficients is examined in the present section.

In 1986, Japanese economy recovered from a recession. In the following three years, stock prices and real-estate prices rose to unprecedented levels and the boom was called "Bubble Economy". The real GNP increased by 6% in 1988. However, in 1990 the aggregate demand began to decrease. In 1991, Japan witnessed a serious recession, both stock prices and real estate prices started to crash down. We believe that the serious recession affects the production behavior of the electrical appliances industry and assume that the coefficients of the cost function changed around year 1990.

A dummy variable is used for this analysis. The value of dummy variable is zero from 1980 to 1989 while it is unity from 1990 to 2000. The dummy variable is denoted as D, and the model of (3-7) can be rewritten as equation (6-1) if we use *PK/PM*, *PL/PM* and *PM* to represent pp_1, pp_2 and p_3 respectively.

$$
\begin{aligned}
\ln(C/PM) = {} & \alpha_0 + \alpha_1 \ln Y + \beta_1 \ln(PK/PM) + \beta_2 \ln(PL/PM) \\
& + \delta_Y \cdot \frac{1}{2} \cdot \ln^2 Y + \delta_{11} \cdot \frac{1}{2} \cdot \ln^2 PK/PM + \delta_{22} \cdot \frac{1}{2} \cdot \ln^2 PL/PM \\
& + \delta_{12} \ln(PK/PM) \cdot \ln(PL/PM) + \rho_1 \ln Y \ln(PK/PM) \\
& + \rho_2 \ln Y \ln(PL/PM) + \gamma_0 D + \gamma_Y D \ln Y + \gamma_1 D \ln(PK/PM) \qquad (6\text{-}1) \\
& + \gamma_2 D \ln(PL/PM) + \gamma_{YY} \cdot \frac{1}{2} \cdot D \ln^2 Y + \gamma_{11} \cdot \frac{1}{2} \cdot D \ln^2 PK/PM \\
& + \gamma_{22} \cdot \frac{1}{2} \cdot D \ln^2 PL/PM + \gamma_{12} D \ln(PK/PM) \cdot \ln(PL/PM) \\
& + \gamma_{Y1} D \ln Y \ln(PK/PM) + \gamma_{Y2} D \ln Y \ln(PL/PM) + \varepsilon_c
\end{aligned}
$$

We also include firm dummies in (6-1) as we did in section 5. Our estimation will be based on equation (6-2):

$$
\begin{aligned}
\ln(C/PM) = {} & \alpha_0 + \alpha_1 \ln Y + \beta_1 \ln(PK/PM) + \beta_2 \ln(PL/PM) \\
& + \delta_Y \cdot \frac{1}{2} \cdot \ln^2 Y + \delta_{11} \cdot \frac{1}{2} \cdot \ln^2 PK/PM + \delta_{22} \cdot \frac{1}{2} \cdot \ln^2 PL/PM \\
& + \delta_{12} \ln(PK/PM) \cdot \ln(PL/PM) + \rho_1 \ln Y \ln(PK/PM) + \rho_2 \ln Y \ln(PL/PM) \\
& + \gamma_0 D + \gamma_Y D \ln Y + \gamma_1 D \ln(PK/PM) + \gamma_2 D \ln(PL/PM) + \gamma_{YY} \cdot \frac{1}{2} \cdot D \ln^2 Y \\
& + \gamma_{11} \cdot \frac{1}{2} \cdot D \ln^2 PK/PM + \gamma_{22} \cdot \frac{1}{2} \cdot D \ln^2 PL/PM + \gamma_{12} D \ln(PK/PM) \cdot \ln(PL/PM)
\end{aligned}
$$

Table 6–1 Results of estimation

Coefficient	Estimated Coefficient	t-ratio
α_0	0.466643	4.72090
α_1	0.619370	13.4822
β_1	0.412259	5.03690
β_2	0.489337	5.84135
δ_Y	–0.016086	–0.62342
δ_{11}	–0.344407	–2.03079
δ_{22}	0.471836	3.90218
δ_{12}	–0.104785	–0.95583
ρ_1	0.015541	0.52415
ρ_2	–0.031747	–1.07109
γ_0	0.076819	2.34953
γ_Y	0.030844	1.65515
γ_1	0.361646	4.30909
γ_2	–0.481738	–5.49792
γ_{YY}	0.023958	1.81760
γ_{11}	0.446734	2.53171
γ_{22}	–0.292533	–2.23748
γ_{12}	0.111937	0.92577
γ_{Y1}	0.002402	0.08471
γ_{Y2}	–0.023424	–0.88286

$R^2 = 0.994285$ $\bar{R}^2 = 0.99374$ $\chi^2\,(10) = 136$

$$+ \gamma_{Y1} D \ln Y \ln(PK/PM) + \gamma_{Y2} D \ln Y \ln(PL/PM) + \sum_{j=2}^{22} \theta_j Firm_j + \varepsilon_c \qquad (6\text{-}2)$$

In the test of structural change, the null hypothesis is that all γ_i are zero, while the alternative hypothesis is that at least one is non-zero. The test statistics is χ^2 with 10 degrees of freedom.

Table 6-1 shows the estimates of the coefficients as well as the estimates divided by the standard errors. Estimated coefficient of firm effects are given in Table 6-2.

Since the calculated χ^2 (10) is 136, with the P-value of 0.0 (rounded), therefore, it is demonstrated that structural change occurs in the serious recession. The null hypothesis is rejected at 1% level. In the subsequent sections, we take into consideration the structural change when we measure the cost inefficiency and inspect the scale economies. Thus, we divide the data into two groups, that before 1990 and that after 1990.

7. Estimation from 1980 to 1989

Model (5-1) and (5-2) are modified to (7-1) and (7-2) to capture inefficiency among different firms during 1980 to 1989.

Table 6–2 Firm effects

Firm	Estimated Coefficient	t-ratio
1	0	
2	–0.038622	–0.39841
3	–0.261022	–2.47202
4	–0.097701	–1.06945
5	–0.027085	–0.30149
6	–0.178305	–1.86904
7	–0.232165	–2.52816
8	–0.318278	–3.25709
9	–0.288644	–2.89721
10	–0.619371	–5.21463
11	–1.136710	–9.37419
12	–0.851331	–6.58004
13	–0.820320	–6.94381
14	–1.017400	–8.13121
15	–0.812343	–6.33904
16	–0.847673	–6.37323
17	–1.080850	–7.36980
18	–1.183390	–7.64821
19	–1.696410	–9.71132
20	–1.560970	–10.0771
21	–1.533610	–6.63416
22	–1.767860	–10.4776

$$\begin{aligned}\ln(C/PM) = {} & \alpha_0 + \alpha_1 \ln Y + \beta_1 \ln(PK/PM) + \beta_2 \ln(PL/PM) \\ & + \delta_Y \cdot \frac{1}{2} \cdot \ln^2 Y + \delta_{11} \cdot \frac{1}{2} \cdot \ln^2 PK/PM + \delta_{22} \cdot \frac{1}{2} \cdot \ln^2 PL/PM \\ & + \delta_{12} \ln(PK/PM) \cdot \ln(PL/PM) + \rho_1 \ln Y \ln(PK/PM) + \rho_2 \ln Y \ln(PL/PM) \\ & + \sum_{i=1981}^{1989} \lambda_i Year_i + \sum_{j=2}^{22} \theta_j Firm_j + \varepsilon_c \end{aligned} \tag{7-1}$$

$$\begin{aligned} S_1 &= \partial \ln(C/PM)/\partial \ln(PK/PM) = \beta_1 + \delta_{11} \ln(PK/PM) + \delta_{12} \ln(PL/PM) + \rho_1 \ln Y + \varepsilon_1 \\ S_2 &= \partial \ln(C/PM)/\partial \ln(PL/PM) = \beta_2 + \delta_{12} \ln(PK/PM) + \delta_{22} \ln(PL/PM) + \rho_2 \ln Y + \varepsilon_2 \end{aligned} \tag{7-2}$$

The results of the estimation are included in Table 7-1 and Table 7-2. Table 7-1 shows the estimates of the regression coefficients (firm and time effects are not shown) and those divided by the standard errors.

Cost is shown to be positively related to the output level. The coefficient on the output variable (α_1) is 0.775867 and is significantly different from zero at 1% level. A coefficient less than 1 indicates the presence of decreasing unit cost in the industry when output increases.

Coefficient on ln*PK/PM* is 0.9135 and coefficient on ln*PL/PM* is 0.022156 and they are both statistically significant at 1% level. As expected, if the price of capital or labor increases, the cost of

Table 7–1 Estimated results from year 1980 to 1989

Coefficient	Estimated Coefficient	t-ratio
α_0	0.317533	9.33769
α_1	0.775867	32.9938
β_1	0.913500	450.126
β_2	0.022156	28.4155
δ_Y	–0.039264	–4.67645
δ_{11}	0.061057	24.9930
δ_{12}	–0.010624	–8.32083
δ_{22}	0.009090	7.29162
ρ_1	0.008217	6.94358
ρ_2	–0.003910	–8.59367

Table 7–2 Firm effects and time effects (from 1980 to 1989)

Firm	Estimated Coefficient	t-ratio	Year	Estimated Coefficient	t-ratio
1	0		1980	0	
2	0.205017	9.22116	1981	0.0367376	2.85236
3	−0.237223	−6.52753	1982	0.0473888	3.52160
4	−0.075538	−3.75369	1983	0.0625393	4.49226
5	0.133302	6.78507	1984	0.0752896	5.00529
6	−0.073377	−3.28806	1985	0.0892726	5.54105
7	0.068774	3.46376	1986	0.1542740	8.28364
8	−0.373867	−13.1094	1987	0.2252740	11.1963
9	−0.260025	−9.12886	1988	0.2166910	9.76371
10	−0.400007	−11.1328	1989	0.1720960	8.47925
11	−0.531579	−11.7550			
12	−0.677967	−14.9251			
13	−1.005280	−32.0377			
14	−0.739920	−14.0345			
15	−0.716632	−16.5002			
16	−1.042110	−24.5154			
17	−0.701174	−13.5656			
18	−0.951528	−16.2232			
19	−0.682718	−9.53954			
20	−0.791222	−11.9887			
21	−1.062570	−12.4909			
22	−0.815178	−11.9354			

production increases as well.

The interaction term between the price of labor and output (ρ_2) is −0.003910 and is significantly different from zero at 1% level. This fact demonstrates that the impact on total cost of an increase in price of labor vanishes as the quantity of output increases.

Firm effects and time effects are included in Table 7-2.

The results show that the 21^{st} and year 1980 have the smallest estimated coefficient, thus they can

Table 7–3　Adjusted firm and time effects (cost inefficiency)

Firm	Adjusted Coefficient	Year	Adjusted Coefficient
1	1.062570	1980	0
2	1.267587	1981	0.0367376
3	0.825347	1982	0.0473888
4	0.987032	1983	0.0625393
5	1.195872	1984	0.0752896
6	0.989193	1985	0.0892726
7	1.131344	1986	0.1542740
8	0.688703	1987	0.2252740
9	0.802545	1988	0.2166910
10	0.662563	1989	0.1720960
11	0.530991		
12	0.384603		
13	0.057290		
14	0.322650		
15	0.345938		
16	0.020460		
17	0.361396		
18	0.111042		
19	0.379852		
20	0.271348		
21	0		
22	0.247392		

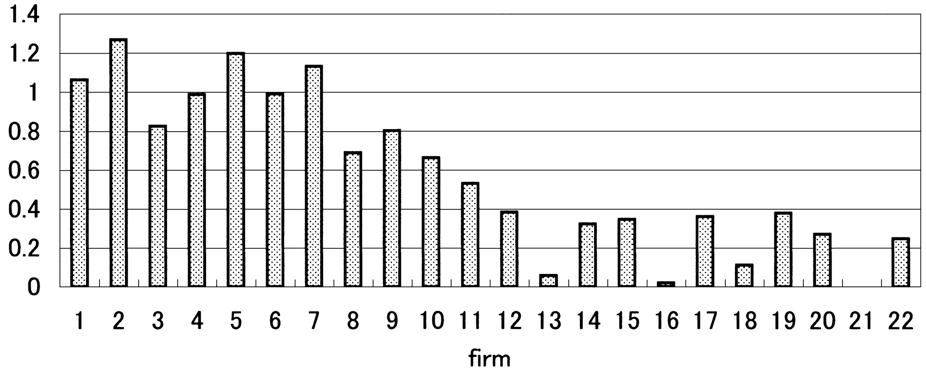

Fig. 7–1.　Adjusted firm effects

be assumed to be most efficient and produce on the cost frontier. We adjust our results in Table 7-2 assuming the 21st firm is the most efficient firm and year 1980 is the most efficient year, and give the adjusted firm and time effects (cost inefficiency) in Table 7-3. Figure 7-1 and Figure 7-2 give the relevant diagrams.

It is noted that larger firms (the first 11 firms in the table) have a higher inefficiency than the

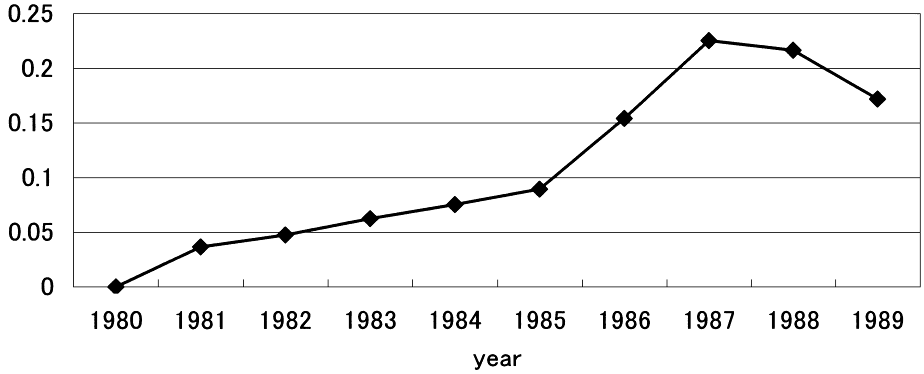

Fig. 7–2. Adjusted time effects

Table 7–4 Re-adjusted firm effects: adjusted firm effects/total cost

Firm	Adjusted Firm Effects/Total Cost
1	0.0000076523
2	0.0000074189
3	0.0000013023
4	0.0000121010
5	0.0000080426
6	0.0000093065
7	0.0000105433
8	0.0000139089
9	0.0000147076
10	0.0000235376
11	0.0000427417
12	0.0000337476
13	0.0000038643
14	0.0000276008
15	0.0000268318
16	0.0000021925
17	0.0000505788
18	0.0000198688
19	0.0002944566
20	0.0000938863
21	0.0000000000
22	0.0001167050

smaller ones (the last 11 firms) on average. The average inefficiency of larger firms is 0.922159 and that of the smaller firms is 0.227452. Cost inefficiency increase from 1980 to 1987, and is followed by a decrease from 1987 to 1989 during the "Bubble Economy".

We also re-adjust firm effects according to their total cost. The results are given in Table 7-4 and Figure 7-3.

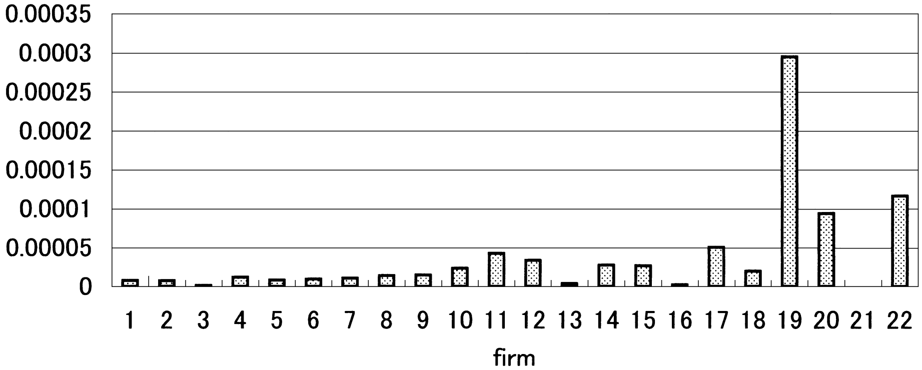

Fig. 7–3. Re-adjusted firm effects

After the re-adjustment of the cost inefficiency of each firm, we may find that larger firms tend to have lower inefficiency than smaller firms. The average cost inefficiency for larger firms is 0.0000137512 and that for smaller firms is 0.0000608848. The 21st firm is an exception because it was assumed that the 21st is the most efficient firm at the beginning.

8. Estimation from 1990 to 2000

Year dummies from 1990 to 2000 are used in this section, thus equation (8-1) and (8-2) give the corresponding model:

$$\begin{aligned}\ln(C/PM) = {} & \alpha_0 + \alpha_1 \ln Y + \beta_1 \ln(PK/PM) + \beta_2 \ln(PL/PM) \\ & + \delta_Y \cdot \frac{1}{2} \cdot \ln^2 Y + \delta_{11} \cdot \frac{1}{2} \cdot \ln^2 PK/PM + \delta_{22} \cdot \frac{1}{2} \cdot \ln^2 PL/PM \\ & + \delta_{12} \ln(PK/PM) \cdot \ln(PL/PM) + \rho_1 \ln Y \ln(PK/PM) + \rho_2 \ln Y \ln(PL/PM) \\ & + \sum_{i=1990}^{2000} \lambda_i Year_i + \sum_{j=2}^{22} \theta_j Firm_j + \varepsilon_c \qquad (8\text{-}1)\end{aligned}$$

$$\begin{aligned}S_1 &= \partial \ln(C/PM)/\partial \ln(PK/PM) = \beta_1 + \delta_{11} \ln(PK/PM) + \delta_{12} \ln(PL/PM) + \rho_1 \ln Y + \varepsilon_1 \\ S_2 &= \partial \ln(C/PM)/\partial \ln(PL/PM) = \beta_2 + \delta_{12} \ln(PK/PM) + \delta_{22} \ln(PL/PM) + \rho_2 \ln Y + \varepsilon_2\end{aligned} \qquad (8\text{-}2)$$

The results of the estimation are included in Table 8-1 and Table 8-2. Table 8-1 shows the estimates of the regression coefficients (firm and time effects won't be considered here) and those divided by the standard errors.

Cost appears to be positively related to the output level. The coefficient of the output variable (α_1) is 0.376171, which is much smaller than what we get from section 7, and is statistically significant at 1% level. A coefficient less than 1 indicates the presence of decreasing unit cost in the industry when output increases. Coefficient on ln*PK/PM* is 0.896672 and coefficient on ln*PL/PM* is 0.02851,

Table 8–1 Estimated results from 1990 to 2000

Coefficient	Estimated Coefficient	t-ratio
α_0	0.808804	19.1556
α_1	0.376171	11.8121
β_1	0.896672	339.962
β_2	0.028510	34.2410
δ_Y	–0.105900	–4.91100
δ_{11}	0.073751	24.3852
δ_{12}	–0.020380	–18.6115
δ_{22}	0.023940	18.0008
ρ_1	0.006534	4.48740
ρ_2	–0.003680	–7.90276

Table 8–2 Firm effects and time effects (from 1990–2000)

Firm	Estimated Coefficient	t-ratio	Year	Estimated Coefficient	t-ratio
1	0		1990	0	
2	0.028293	0.919222	1991	0.032912	1.69288
3	–0.331010	–8.27057	1992	0.066177	3.39467
4	–0.235460	–8.49911	1993	0.099618	5.10537
5	–0.072490	–2.52032	1994	0.110271	5.59282
6	–0.172450	–5.92878	1995	0.151009	7.45427
7	–0.301010	–10.8868	1996	0.210159	10.0479
8	–0.731180	–18.3718	1997	0.220049	10.2353
9	–0.701540	–15.3721	1998	0.240630	11.0097
10	–1.209260	–21.2080	1999	0.282115	12.3986
11	–1.488560	–23.2988	2000	0.303718	13.3922
12	–1.458860	–21.8147			
13	–1.819250	–39.3498			
14	–1.492820	–20.0662			
15	–1.434300	–18.2870			
16	–1.761300	–20.7802			
17	–1.908570	–22.9109			
18	–2.062590	–22.2625			
19	–2.409960	–22.5133			
20	–2.245190	–23.2646			
21	–2.233270	–17.6022			
22	–2.420320	–22.7036			

they are both significantly different from zero at 1% level. As expected, if the price of capital or labor increases, the cost of production increases. The interaction term between the price of labor and output (ρ_2) is –0.00368 and significant at 1% level. These facts demonstrate that the impact on total cost of an increase in price of labor disappears as the quantity of output increases.

Firm and time effects are presented in Table 8-2. The results show that the 22nd firm has the

Table 8–3 Adjusted firm and time effects (cost inefficiency)

Firm	Adjusted Coefficient	Year	Adjusted Coefficient
1	2.420320	1990	0
2	2.448613	1991	0.032912
3	2.089312	1992	0.066177
4	2.184858	1993	0.099618
5	2.347874	1994	0.110271
6	2.247874	1995	0.151090
7	2.119309	1996	0.210159
8	1.689145	1997	0.220049
9	1.718778	1998	0.240630
10	1.211060	1999	0.282115
11	0.931760	2000	0.303718
12	0.961460		
13	0.601070		
14	0.927500		
15	0.986020		
16	0.659020		
17	0.511750		
18	0.357730		
19	0.010360		
20	0.175130		
21	0.187050		
22	0		

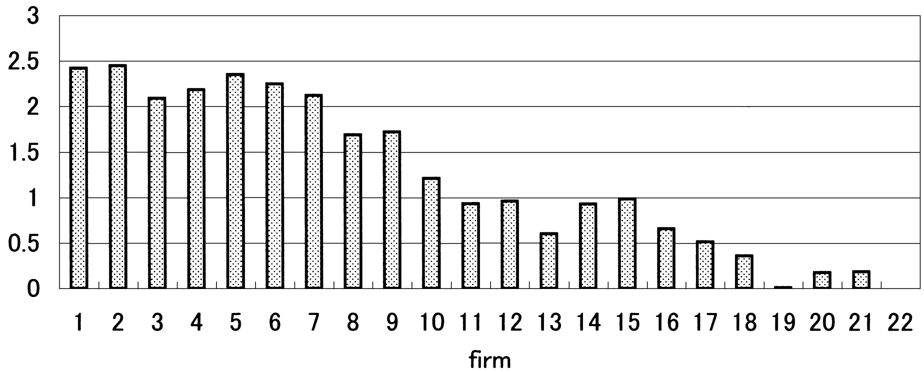

Fig. 8–1. Adjusted firm effects

smallest estimated coefficient of firm effects, thus it could be considered the most cost efficient firm and thus produces on the cost frontier. The coefficient of year 1990 is the smallest one, and it will still be taken as the benchmark, and therefore the most efficient year. We adjust our result in Table 8-2 assuming the 22^{nd} firm and year 1990 are the most efficient firm(year), then give the cost inefficiency in Table 8-3 and Figure 8-1 and Figure 8-2. Larger firms (the first 11 firms) have a lower

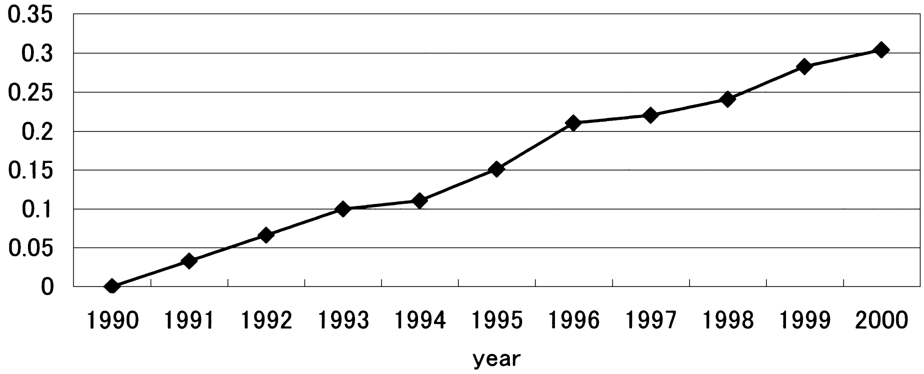

Fig. 8–2. Adjusted time effects

Table 8–4 Re-adjusted firm effects: adjusted firm effects/total cost

Firm	Adjusted Firm Effects/Total Cost
1	0.0000139530
2	0.0000135770
3	0.0000178903
4	0.0000171697
5	0.0000150246
6	0.0000158659
7	0.0000183178
8	0.0000266495
9	0.0000279595
10	0.0000417210
11	0.0000554684
12	0.0000546978
13	0.0000336444
14	0.0000585678
15	0.0000642157
16	0.0000719995
17	0.0000736329
18	0.0000695233
19	0.0000048812
20	0.0000517001
21	0.0000909213
22	0.0000000000

efficiency than the smaller ones (the last 11 firms) on average. The average inefficiency of larger firms is 1.946264 and that of the smaller firms is 0.488826. Cost inefficiency increased from 1990 to 2000 in the serious recession.

We also re-adjust the firm effects according to their total cost. The results are given in Table 8-4 and Figure 8-3. After re-adjustment by the total cost of each firm, larger firms are founded to have

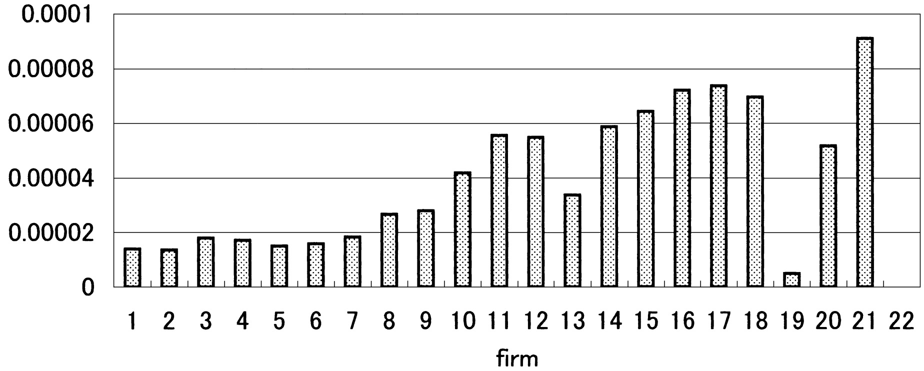

Fig. 8–3. Re-adjusted firm effects

an average smaller inefficiency than the smaller firms. The average cost inefficiency for larger firms is 0.0000239633 and that for smaller firms is 0.0000521622.

9. Scale economies

Numerous models have pointed out the importance of economies of scale to sustain a country's long run growth (i.e. Romer (1986), Helpman (1984)). Therefore, economies of scale in manufacturing industry might be a prominent factor for industrialization and economic growth.

The partial derivative of (3.7) with respect to log output yields the cost elasticity with respect to output level, which provides a reciprocal measure of returns to scale (Binswanger (1974)). Let us denote the cost elasticity as E_Y and use PK/PM, PL/PM and PM instead of pp_1, pp_2 and p_3, scale economies can be written as:

$$E_Y = \partial \ln(C/PM)/\partial \ln Y = \alpha_1 + \delta_Y \ln Y + \rho_1 \ln(PK/PM) + \rho_2 \ln(PL/PM) \qquad (9\text{-}1)$$

Since our data (factor input prices and output) are normalized by their means, $\ln PK/PM$, $\ln PL/PM$ and $\ln Y$ are all zero at their means. (9-1) becomes:

$$E_Y = \alpha_1 \qquad (9\text{-}2)$$

We use a cost function instead of a production function for it can give us more information of the production behavior. In our study, if E_Y is less than unity, economies of scale exist in this industry. The smaller the value is, the more the firm benefits from the economies of scale. If E_Y is greater than unity, diseconomies of scale is found; if E_Y is unity, then the industry exhibits constant returns to scale.

To test whether the economies of scale exist in the Japanese electrical appliances industry, we proceed the following one-tail hypothesis testing:

Hypothesis H_0: $\alpha_1 = 1.0$ vs. H_a: $\alpha_1 < 1.0$ (9-3)

We calculate the t-value by

$$t = \frac{\hat{\alpha}_1 - 1.0}{\sigma_{\hat{\alpha}_1}} \tag{9-4}$$

where $\hat{\alpha}_1$ is the coefficient estimated and $\sigma_{\hat{\alpha}_1}$ is the corresponding standard error.

For the data from 1980 to 1989, $\hat{\alpha}_1$ is found to be 0.775867 (see Table 7-1). The calculated t is 9.53, with the P value of 0.00 (rounded). The hypothesis that $\alpha_1 = 1.0$ is rejected at 1% level. From the analysis above, it is possible to conclude that economies of scale exist in the Japanese electrical appliances industry from 1980 to 1989.

For the data from 1990 to 2000, the estimated $\hat{\alpha}_1$ is 0.376171(see Table 8-1), which is much smaller than what we get from 1980–1989. The calculated t is 19.59, with the P value of 0.00 (rounded). The hypothesis that $\alpha_1 = 1.0$ is rejected at 1% level. Again economies of scale are observed.

Economies of scale are found in both periods. Since $\hat{\alpha}_1 = 0.775867$ during year 1980 and 1989, and $\hat{\alpha}_1 = 0.376171$ between year 1990 and 2000, it is reasonable to expect that opportunities to benefit from further economies of scale exist.

Based on equation (9-1), we calculate the scale economies of each firm in each year. Results are given in Table 9-1 (from 1980 to 1989) and Table 9-2 (from year 1990 to 2000).

It is easy to find that the industry enjoy the economies of scale from 1980 to 1989 because they are all less than unity. And the value tends to go smaller during year 1980-1989, which suggests that firms benefit more from economies of scale as time passes by. Larger firms have higher economies of scale than their smaller peers.

Again we find that economies of scale are exhibited in the electrical appliances industry. The values we get in Table 9-2 are much smaller than what we get in Table 9-1, which shows that firms enjoy more from economies of scale after 1990 than before 1990. But we cannot find enough proof that scale economies increase after 1990 as we can find before 1990. Larger firms are still found to have higher economies of scale than smaller ones on average.

10. Conclusions

The Japanese electrical appliances industry marked a steady growth in the postwar period. However, the industry faces financial difficulties caused by the serious recession in the 1990s. So far only few studies concentrated on empirical analyses of this industry and took into consideration the impact of the economic change.

This study tries to clarify the production behaviors of Japanese electrical appliances industry bases on econometric analyses using publicly available financial accounting data. SUR model in which translog form is used for our cost function is chosen as the suitable model.

The structural change test clarifies the occurrence of change in the industry in the serious

Table 9–1 Scale economies from 1980 to 1989

Firm	1	2	3	4	5	6
1980	0.752255	0.737629	0.783816	0.779385	0.748643	0.772768
1981	0.744247	0.733362	0.772902	0.774427	0.746197	0.764809
1982	0.741914	0.728858	0.772367	0.767898	0.739124	0.758478
1983	0.738929	0.725508	0.77784	0.760375	0.737748	0.752732
1984	0.732519	0.716476	0.766132	0.752916	0.732415	0.746835
1985	0.729532	0.711714	0.762301	0.741686	0.724115	0.736979
1986	0.732234	0.71507	0.770268	0.744176	0.72536	0.737047
1987	0.778767	0.716481	0.808574	0.743189	0.72662	0.737977
1988	0.73003	0.714429	0.767094	0.744785	0.723275	0.733865
1989	0.724526	0.711097	0.759986	0.740411	0.717598	0.730915

Firm	7	8	9	10	11	12
1980	0.752887	0.808206	0.797045	0.811433	0.834181	0.842935
1981	0.747575	0.799854	0.792536	0.806992	0.825608	0.835182
1982	0.743905	0.793752	0.790241	0.803524	0.821074	0.831581
1983	0.741517	0.786266	0.788792	0.800628	0.815649	0.831753
1984	0.737594	0.779714	0.782752	0.799496	0.811414	0.824324
1985	0.731905	0.772872	0.779412	0.794159	0.811053	0.818376
1986	0.733332	0.766993	0.788869	0.793992	0.810962	0.822589
1987	0.732181	0.765894	0.764753	0.794149	0.855733	0.821784
1988	0.728148	0.765228	0.760603	0.791445	0.808994	0.814817
1989	0.72227	0.76223	0.757784	0.789302	0.807784	0.807005

Firm	13	14	15	16	17
1980	0.791109	0.861001	0.86089	0.86473	0.859447
1981	0.783967	0.850516	0.84955	0.849413	0.851623
1982	0.796797	0.847245	0.837318	0.833666	0.845561
1983	0.792008	0.841853	0.834307	0.8249	0.847852
1984	0.790371	0.839657	0.825071	0.824261	0.848496
1985	0.790797	0.834095	0.816086	0.821145	0.842535
1986	0.784656	0.827059	0.821215	0.823138	0.838453
1987	0.780928	0.83254	0.821352	0.831096	0.845766
1988	0.776321	0.827657	0.820322	0.835783	0.844984
1989	0.803338	0.823056	0.822077	0.833138	0.838939

Firm	18	19	20	21	22
1980	0.857551	0.898001	0.879882	0.941488	0.888282
1981	0.85851	0.901591	0.878979	0.933239	0.880975
1982	0.859184	0.900151	0.879937	0.930449	0.876871
1983	0.861254	0.903983	0.888151	0.928517	0.883778
1984	0.862926	0.900021	0.882847	0.917496	0.885887
1985	0.858427	0.897757	0.877371	0.908547	0.883367
1986	0.855964	0.895575	0.873292	0.911626	0.883292
1987	0.884978	0.894702	0.863599	0.909639	0.883454
1988	0.851233	0.890741	0.863481	0.902807	0.881091
1989	0.850408	0.886803	0.861972	0.898622	0.877996

Table 9–2 Scale economies from 1990 to 2000

Firm	1	2	3	4	5	6
1990	0.279644	0.246496	0.378761	0.295935	0.259575	0.295619
1991	0.271094	0.23659	0.356241	0.284121	0.255165	0.291759
1992	0.273857	0.238276	0.37369	0.289138	0.26044	0.298826
1993	0.289659	0.245967	0.357589	0.300433	0.263431	0.301049
1994	0.294731	0.246385	0.364407	0.298699	0.259696	0.298829
1995	0.289537	0.243588	0.354752	0.293769	0.253062	0.292545
1996	0.280434	0.234394	0.362457	0.286605	0.243767	0.282531
1997	0.273656	0.236839	0.343335	0.275979	0.251837	0.285572
1998	0.270881	0.249617	0.32782	0.275705	0.25533	0.283131
1999	0.275583	0.311684	0.34956	0.295402	0.265832	0.36567
2000	0.282841	0.266686	0.345626	0.292573	0.314035	0.279485
Firm	7	8	9	10	11	12
1990	0.27234	0.373569	0.373657	0.451771	0.509403	0.49561
1991	0.270291	0.3637	0.364233	0.431749	0.49452	0.485274
1992	0.270724	0.363057	0.378003	0.42423	0.49557	0.487777
1993	0.274353	0.37107	0.38427	0.429235	0.50147	0.497648
1994	0.274357	0.368897	0.376906	0.438673	0.50282	0.490201
1995	0.269439	0.355822	0.372397	0.439338	0.497593	0.49129
1996	0.256996	0.353032	0.491639	0.438323	0.485992	0.485096
1997	0.261101	0.347535	0.372381	0.431773	0.441312	0.478715
1998	0.276077	0.356679	0.367725	0.429857	0.44097	0.47828
1999	0.308566	0.365696	0.381703	0.454212	0.436602	0.494832
2000	0.278318	0.344885	0.406962	0.460045	0.431054	0.505594
Firm	13	14	15	16	17	
1990	0.383572	0.544071	0.539385	0.576774	0.581897	
1991	0.372878	0.533218	0.536249	0.581809	0.565855	
1992	0.362812	0.520315	0.536422	0.594928	0.572481	
1993	0.373308	0.524405	0.558929	0.594085	0.592507	
1994	0.385148	0.538326	0.603806	0.599068	0.586756	
1995	0.390207	0.534731	0.582166	0.656179	0.585681	
1996	0.40386	0.533174	0.579774	0.596485	0.576274	
1997	0.416787	0.524034	0.576875	0.588106	0.571714	
1998	0.411604	0.502047	0.546711	0.573449	0.570734	
1999	0.408069	0.572654	0.529621	0.577831	0.594308	
2000	0.397641	0.53749	0.549268	0.558767	0.603054	
Firm	18	19	20	21	22	
1990	0.620202	0.716287	0.653431	0.733969	0.695516	
1991	0.620108	0.700812	0.639921	0.720553	0.683616	
1992	0.634789	0.675294	0.629609	0.72375	0.676079	
1993	0.634327	0.673846	0.638619	0.743386	0.669684	
1994	0.62569	0.681738	0.636405	0.744529	0.674488	
1995	0.621975	0.670513	0.639784	0.723647	0.667933	
1996	0.61386	0.65808	0.633651	0.722438	0.667256	
1997	0.608302	0.660944	0.634794	0.730101	0.660591	
1998	0.616464	0.657019	0.638587	0.730331	0.66442	
1999	0.635014	0.675137	0.635306	0.74655	0.672944	
2000	0.632866	0.673653	0.65176	0.730945	0.684584	

recession period. Data is divided into two parts, and estimation is carried out separately. Increasing cost inefficiency is found in the serious recession period. In fact cost inefficiency increased during most of the observed period, but with a little decrease during the "Bubble Economy". Larger firms with solid financial basis tend to have lower inefficiency rate than smaller firms.

Some published studies indicated the existence of economies of scale in the industry. Our data also reveals substantial economies of scale in both periods, suggesting that further opportunities for reduction in long-run cost exist. Larger firms are found to benefit more from economies of scale than smaller ones both before and after "Bubble Economy". The finding that economies of scale are strongly observable during 1980–2000 periods suggests that firms in Japanese electrical appliances industry are able to improve their cost competitiveness by increasing firm size.

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The conclusions reflect the view of the authors only.

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わが国電気機器産業の費用非効率と規模の経済

方　　健雯
宮下　　洋

わが国電気機器産業 22 社について，1980 年から 2000 年までのパネルデータを使用して費用非効率が計測された．推定されたモデルはトランスログ費用関数とシェア方程式から成る SUR 同時方程式モデルである．データはバブル崩壊の影響を捉えるために 2 分割され，規模の大きい企業ほど非効率が少なく，またバブル崩壊後に非効率が増大する傾向が観察された．さらに規模の経済の存在が検証され，バブル崩壊前後でその存在が明らかとなった．