THE KOREAN ECONOMIC REVIEW
Volume 18, Number 1, Summer 2002

VARIATIONS IN THE TECHNICAL EFFICIENCY OF KOREAN MANUFACTURING ESTABLISHMENTS UNDER TWO DISTINCTIVE INDUSTRIAL POLICIES

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This paper investigates the effects of two distinctive government industrial policies of Korea, the "GM"(Governed Market) in the pre-1980 and the "SM" (Simulated Free Market) in the post-1980, on RTE (Relative Technical Efficiency) of the two different groups, the "favored" and the "less favored."

The main contribution of this study is the use of micro-level establishment data to analyze the technical efficiency of Non-HCI (Non-Heavy machinery and Chemical Industries) and HCI (Heavy machinery and Chemical Industries) of Korea both in 1978 and 1989. Results indicate that the production frontier of individual industry in 1978 is found to be higher than that in 1989. Also the LEs' (Large Establishments') share and mean RTE of each industry in the sample are concurrently decreased and the distribution of RTE goes to normal distribution as the government converted its industrial policy form the GM to the SM.

JEL Classification: L1
Keywords: East Asian success, Governed Market, Simulated Market, HCI (Heavy Machinery and Chemical Industries), Production Frontier, Technical Efficiency

I. INTRODUCTION

The remarkable economic growth of Korea in the last three decades has frequently been cited as one of the great East Asian success stories and much attention have been paid on explaining Korea's economic growth. However, several studies interpreting and identifying the sources of Korea's as well as other NIC's[1] successful economic developments have generated controversies concerning

Received for publication: Sep. 18, 2001. *Revision accepted:* Jan. 12, 2002.

* This paper is partly based on the author's Ph.D dissertation at the University of Southern California, Department of Economics. The author is grateful to the dissertation adviser, Prof. Jeffrey Nugent and also to the committee members, Prof. Andrew Weiss and Prof. Elizabeth Graddy.

[1] The NICs (Newly Industrializing Countries) of East Asia are Korea, Hong Kong, Singapore and Taiwan.

the role of government.

As noted by Wade (1990), there have been essentially three different positions taken in the debate. They are "the Free Market (FM) Theory," "the Simulated Free Market (SM) theory" and "the Governed Market (GM) theory."

The "Free Market (FM)" theory claims that the success of Korea's economic-development strategies lie in the considerably less government interference with the market mechanism than in other countries.[2]

The "Simulated Free Market (SM) theory" says that the government played an active role of providing incentives that were very close to the relative prices of products and factors that would be prevailing in a situation of free trade. It is as though the government were "simulating a free market" (Berger (1979), p. 64). On the other hand, the "Governed Market (GM) theory" emphasizes on the more directive role of the government.

Based on the above three controversial theories, two distinctive periods can be identified according to the industrial policies of the government,[3] *i.e.*, the "GM" for pre-1980 and the "SM" for post-1980. From 1962 to 1972, the government adopted the "GM" policies for an export promotion coupled with various import restrictions. The government supported them by providing incentives[4] or eliminating disincentives in order to encourage export activities. Therefore, entrepreneurs tried to seek profits by exploiting their comparative advantages on world markets.[5]

Turning to 1973, the ambitious and risk-taking Heavy Machinery and Chemical Industries (HCI) Promotion Plan was officially[6] launched by government's strong initiatives up to late 1979. Especially, from 1973 to 1979, the government maintained the "GM" to foster the infant HCI by selective export-targeting industrial policies and strong governmental interventions. Government enforced a vigorous HCI Drive Policy and initiated a new incentive system[7] that included a

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[2] Balassa (1989) interprets Korea's relative success in economic development as the result of free-market, *laissez-faire* capitalism accompanied by an outward-oriented economic development strategy.

[3] Hereafter "government" means "Korean Government."

[4] The incentive regime such as preferential financing for export activities, reduction of corporate taxes for exporters, and exemption from import duties or from tariff on raw materials, intermediate goods and capital equipment needed for exports were applied across the board regardless of specific industries.

[5] During the first and second economic development plans (1962-1972) the government conferred favors on large business groups mainly to take advantage of *economies of scale* and *synergy effects* of *economies of scope* as well as to reduce the *transition costs* of penetrating the world market (Levy (1991)).

[6] Pohang Integrated Iron and Steel Mill was built in 1970, and Hyundai Shipyard was constructed in 1972.

[7] The most powerful element in the new incentive regime was surely its financial policy, including credit rationing. According to J. Lee (1986), "credit rationing is an important form of market distortion and a probable determinant of technical efficiency in the Korean economy" (J. Lee (1986), p. 86).

wide range of fiscal, monetary and trade policies to support and implement the "Big-Push HCI Plan" when the government took the position of "selective interventionist." A broad range of incentive schemes was established and enforced by the government in its active commitment to induce private initiatives, as part of its risky HCI Plan.[8]

As a matter of fact it didn't seem to be the prospective profitability of HCI ventures, but rather the great benefits granted by the new incentive system that attracted big business groups in Korea hastily to join the HCI Projects by *bandwagon effect.* Hence, the investments in HCI facilities constituted more than 75% of all investments in manufacturing at the sacrifice of Non-HCI between 1977 and 1979.

Therefore, LEs in the 1960s and LEs in the HCI in the 1970s were the "favored"[9], whereas the overall SMEs in the 1960s and the Non-HCI in the 1970s were the "less favored" under the "GM" policy. As a result, the size distribution of the firms in Korea during that period was substantially skewed toward the large firms.

In contrast, the government started to implement economy-wide structural adjustments by converting its role to a fine-tuning neutral supporter of the free market mechanism through SM policies since 1980.[10] At first the government tried to restructure the sluggish HCI and shift emphasis in its industrial policy away from selective intervention to fine-tuning functional support.

The new economic adjustment policies clearly reflected the government's strong determination to operate the economy by market forces.

In this regard the effects of the "GM" and "SM" policies on the *RTE (Relative Technical Efficiency)* of the "favored" and the "less favored" are to be investigated.

The data from the *1978 Census of Manufacturing Establishments*[11] are used as representing pre-1980, and the data from the *1989 Survey of Manufacturing Establishments* are used for the post-1980.

In each case, micro-level establishment data are used to estimate both cross-

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[8] Lee S. C (1991) characterized the HCI strategy as follows.

...The eventual consequence of these efforts was the transformation of a privately led market economy into a government-controlled one, in which the market mechanism was largely replaced by an imperative plan for the promotion of HCI....

[9] LEs had occupied the position of "winners" by the government's chronic favoritism for "Chaebol" during 1960s and 1970s, particularly by the HCI strategy. Thus, LEs in all industries generally receive more credit at below-market interest rates and other benefits than SMEs, especially in the highly "favored" under "GM" policy.

[10] Therefore, the pre-1980 restrictions on imports and foreign investments have been increasingly liberalized in the post-1980, and protection for the heavily patronized domestic industries has been eliminated. A variety of measures were taken to support SMEs and to accelerate the development of healthy subcontracting relationships between LEs and SMEs in Korea (Lee, K. U. (1989)).

[11] Manufacturing Survey Data at the micro-level are not available before 1978.

sectional and intertemporal variations in *RTE* of establishments under two distinctive industrial policies in Korea. Section 2 describes the methodology and Section 3 provides the details of data set utilized. The empirical results are presented in Section 4 and some concluding remarks in Section 5.

II. METHODOLOGY

2.1 Maximum Likelihood Estimation of FFPF (Full Frontier Production Function) with a Gamma Distribution

A FFPF (Full Frontier Production Function)[12] with a gamma distribution is used for an econometric frontier of translog production function and estimated through a modified procedure of the general MLE (Maximum Likelihood Estimation) with an assumption that the error term has a gamma distribution.

The Relative Technical Efficiency (*RTE*) of each establishment (u) is converted from the corresponding *residual* (ε) as follows:

$$y = F(x)u, \quad 0 < u \leq 1, \tag{2.1}$$

where y is gross output, x is an input bundle.
By log transformation of the above equation, we have

$$\begin{aligned} &log\ y = log\ F(x) + log\ u = log\ F(x) - \varepsilon, \quad \varepsilon \geq 0 \\ &log\ u = -\varepsilon \text{ and } u = e^{-\varepsilon}. \end{aligned} \tag{2.2}$$

As a result, the most efficient establishment in this model must be the one with $u = 1$.
To maintain the consistency and to make the resulting differences in the comparisons of estimated parameter values valid, the most common and flexible functional form is employed such as

$$\begin{aligned} &ln\ (GO/N) = \alpha + \beta_L\ ln\ (N) + \beta_K\ ln\ (K/N) + \beta_M\ ln\ (M/N) \\ &+ \beta_{LL}(ln\ N)^2 + \beta_{KK}(ln\ K/N)^2 + \beta_{MM}(ln\ M/N)^2 \\ &+ \beta_{LK}(ln\ N)(ln\ (K/N)) + \beta_{KM}(ln\ (K/N))(ln\ (M/N)) \\ &\beta_{ML}(ln\ (M/N)(ln\ N) - \varepsilon, \quad \varepsilon \geq 0, \end{aligned} \tag{2.3}$$

where GO = value of gross output in million won,
N = number of employees,
K = value of tangible fixed assets in million won,

[12] It is also called a deterministic frontier production function.

M = value of production costs including the cost of raw materials, fuel, electricity and water, contract work and repair and maintenance costs in million won.

In the above equation, ε denotes a random disturbance term which has a two-parameter gamma distribution such as

$$f(\varepsilon) = G(\lambda, P) = \frac{\lambda^P}{\Gamma(P)} \varepsilon^{P-1} \exp(-\lambda\varepsilon), \quad \varepsilon \geq 0, \quad \lambda > 0, \quad P > 2, \tag{2.4}$$

where the *mean* and *variance* of ε are $\mu = \frac{P}{\lambda}$ and $\sigma^2 = \frac{P}{\lambda^2}$ respectively.
The *log* likelihood function for the gamma density model is represented as:

$$\log L = TP \log \lambda - T \log \Gamma(P) + (P-1) \sum_t \log (\alpha + \beta' x_t - y_t) - \lambda \sum_t (\alpha + \beta' x_t - y_t). \tag{2.5}$$

To draw an utmost "frontier" of the production function under current technology, all residuals should be ensured to be positive as assumed in the FFPF model, *i.e.*, the intercept should be shifted upward as far as the minimum value of the residual is zero.
It is noteworthy that the concept of "absolute frontier" is constructed from the FFPF since the estimation methods draw a maximum possible output frontier from the full set of observations[13] under the current technology with an assumption of an one-sided error distribution.[14]

As Forsund *et al.* (1980) noted deterministic frontiers[15] are consistent with economic theory although they are often argued to be sensitive to outliers, however computation results from this econometric model in this study are proved to be robust throughout a sensitivity test. Furthermore, the gamma distribution is originally asymmetric and thus, MLE of the parameters in (2.5) is more efficient than the least square estimation.

III. DATA DESCRIPTION

The *1978 Census of Manufacturing* is used for the pre-1980 data and the *1989 Manufacturing Survey* is used for the post-1980 data. The primary reason for the selections are because the government's HCI policies were initiated and driven from the early 1970s, and thus the data up to the year 1978 seems to be sufficient to observe the effects of the HCI policy. Also, as a decade had

[13] This means all possible observations collected after deleting defect data.

[14] See Forsund *et al.* (1979).

[15] ...from a theoretical point of view, it is the absolute frontier which represents current technology....(Forsund *et al.* (1980), p.20)

passed since the government shifted its industrial policy from the GM (Governed Market) focus to the SM (Simulated Free Market) one, the data of year 1989 should be adequate to detect the effects of the more market-oriented industrial policies. Second, the latest possible data of the 1980s that can match with the KSIC (Korean Standard Industrial Classification) of 1978 is that of 1989.

Originally initial HCI Promotion Policy was gestated and implemented based upon the three-digit KSIC industries during 1970s, however, the analysis is conducted under the four-digit KSIC for the more homogeneous production technology. The details of the selected KSIC industries are explained in an Appendix.

IV. EMPIRICAL RESULTS

4.1 Intertemporal Analysis of *Mean Residual*: HCI vs. Non-HCI

Table 4.1 shows the intertemporal differences in *mean residual* (μ) of industries between 1978 and 1989. The production frontier of each industry in 1978 is found to be higher than that in 1989. In HCI, most of the industries show similar trend in *mean residual*, *i.e.*, they became less technically efficient in 1989 than in 1978. But, KSIC 351(Industrial Chemicals) and KSIC 371(Steel and Iron industry) show the opposite in the trend of *mean residual*.
In Non-HCI, most of the industries became less technically efficient in 1989 except KSIC 3216 (KSIC 3212 for 1989) and KSIC 3233.

Table IV in Appendix presents the results of hypothesis tests for the intertemporal differences in *mean residual* in Table 4.1 are highly significant.
Intuitively, technical efficiency of LEs of HCI for 1978 are magnified because the huge economic incentives were given to LEs participating in the HCI Promotion Project by the government based on the rationale that if a level of production input is underestimated than a true value then the estimated technical efficiency thereof will be higher. On the other hand results indicate that the early 1980s various government reforms didn't seem to perform successfully to improve technical efficiency of the HCI. And also for a similar reason, if a level of production input and an output of a certain establishment is estimated close to true value in 1989 due to SM policies then the estimated technical efficiency thereof will be lower than that in 1978. Thus, the government changed its industrial policy from GM to the government's more neutral and fine-tuning industrial policies of the 1980s, SM, the levels of technical efficiency of HCI in 1989 have uniformly fallen as shown in Table 4.1.

[Table 4.1] Intertemporal Differences in *Mean Residual* (μ)

KSIC		*Mean Residual* for 1978	*Mean Residual* for 1989	*Mean Residual* for 1989- *Mean Residual* for 1978
Non-HCI		μ^{78}	μ^{89}	$\mu^{89}-\mu^{78}$
321	3211	1.0166	1.6287	0.6121
	3216/3212	1.6931	1.5315	-0.1616
322		1.5129	1.5464	0.0335
323	3231	0.7740	1.1660	0.3920
	3233	1.2577	0.8773	-0.3804
324		0.9793	1.2465	0.2672
HCI				
351		1.5745	1.3821	-0.1924
352	3521	0.4627	0.5277	0.0650
	3522	0.7193	0.8531	0.1338
	3523	0.5368	0.9528	0.4160
371		1.8636	1.5612	-0.3024
372		0.6725	0.8882	0.2157
381	3811	0.8465	1.3462	0.4997
	3812	0.6424	1.3371	0.6947
	3813	0.9943	1.4350	0.4407
382	3822	0.6219	0.8754	0.2535
	3823	0.8655	1.4032	0.5377
	3824	0.7056	1.0270	0.3214
383	3831	0.7706	1.0141	0.2435
	3832	1.0327	1.4796	0.4469
	3833	0.8726	1.3123	0.4397
384	3841	0.9310	0.8722	-0.0588
	3843	1.1870	1.7265	0.5395

Note: KSIC 3216 in 1978 is changed to KSIC 3212 in 1989.

The Table 4.2 shows that the share of LEs in both aggregate manufacturing by *employment* and *value added* in most of Non-HCI and HCI have declined in 1989. Table 4.1 and 4.2 together also indicates that the trends of RTE and the percentage share of LEs in aggregate manufacturing by *employment* of the HCI are similar.

[Table 4.2] Percentage Shares of Different Size Classes of Manufacturing Establishments in Aggregate Manufacturing by *Employment* and *Value Added* for 1978 and 1989 (%)

	Employment				Value Added			
KSIC								
	1978		1989		1978		1989	
Non -HCI	SMEs	LEs	SMEs	LEs	SMEs	LEs	SMEs	LEs
3211	18.55	81.44	22.46	77.53	12.78	87.21	18.13	81.86
3216	43.44	56.55	61.28	38.71	31.94	68.05	53.12	46.87
322	27.94	72.05	72.42	27.57	21.37	78.62	66.67	33.32
3231	40.64	59.35	76.04	23.95	27.25	72.74	78.99	21.00
3233	48.58	51.42	81.42	18.57	34.29	50.10	82.77	17.22
3240	21.98	78.01	55.37	44.62	20.54	79.45	47.10	52.89
HCI								
351	59.59	40.40	58.65	41.34	41.47	58.52	43.97	56.02
3521	53.58	46.41	45.17	54.82	43.08	56.91	32.63	67.36
3522	35.61	64.38	51.98	48.01	24.92	75.07	42.66	57.23
3523	14.67	85.32	31.51	68.48	6.36	93.63	16.03	83.96
371	34.12	65.87	41.85	58.14	22.89	77.10	34.40	65.59
372	68.65	31.34	62.97	37.02	44.29	55.70	49.99	50.00
3811	46.80	53.19	61.07	38.92	48.93	51.06	60.04	39.95
3812	87.85	12.14	95.43	4.56	86.47	13.52	94.67	5.32
3813	66.62	33.37	68.68	31.31	58.62	41.37	57.16	42.83
3822	54.10	45.89	75.38	24.61	33.30	66.69	53.67	46.32
3823	78.28	21.71	86.09	13.90	67.87	32.12	79.83	20.16
3824	75.30	24.69	91.45	8.54	73.61	26.38	86.02	13.97
3831	39.92	60.07	58.29	41.70	33.87	66.12	43.99	56.00
3832	16.40	83.59	45.62	54.37	11.81	88.18	32.16	67.82
3833	38.46	61.53	44.49	55.50	23.13	76.86	29.61	70.38
3841	15.31	84.68	14.87	85.12	7.40	92.59	14.48	85.51
3843	45.50	54.49	44.25	55.74	32.93	67.06	30.89	69.10

Note: Percentage shares of SMEs and LEs are derived from the sample. KSIC 3216 in 1978 is changed to KSIC 3212 in 1989.

Consistent with the above results, Nugent (1991) found out the two opposite trends in the percentage shares of LEs in Korea in Table 4.3. One is raising shares of LEs by 1976 and the other is subsequently declining shares of LEs by 1989.

[Table 4.3] Percentage Shares of Different Size Classes of Manufacturing Establishments in Aggregate Manufacturing by *Employment* and *Value Added* 1963-1989 (%)

Employment												
	1963	1966	1968	1970	1973	1976	1978	1982	1983	1986	1987	1989
SME	66.4	60.3	54.2	48.2	39.4	37.6	38.1	44.8	46.2	49.9	49.8	54.2
LE	33.6	39.7	45.8	51.8	60.6	62.4	61.9	55.2	53.8	50.1	50.2	45.8
Value Added												
	1963	1966	1968	1970	1973	1976	1978	1982	1983	1986	1987	1989
SME	52.8	42.5	35.8	28.0	27.2	23.7	26.5	27.9	28.6	31.5	32.4	37.9
LE	47.2	57.5	64.2	72.0	72.8	76.3	73.5	72.1	71.4	68.5	67.6	62.1

Source: J. B. Nugent (1991).
Economic Planning Board, *Report on Mining and Manufacturing Census* for census years 1963, 1968, 1973, 1978 and 1983 and *Report on Mining and Manufacturing Survey* for 1966, 1970, 1976, 1982, 1986, 1987 and 1989.

As shown in Table 4.3, the share of LEs in aggregate manufacturing employment rose from 33.6% in 1963 to 62.4% in 1976 before receding to 45.8% by 1989.

Also the share of LEs in manufacturing value added increased from 47.2% in 1963 to a remarkable 76.3% in 1976 before retreating to 62.1% by 1989.

Accordingly, the shares of SMEs in both aggregate manufacturing employment as well as in manufacturing value added have declined by 1976, but have increased after 1976.

4.2. Intertemporal Analysis for Asymmetry of the Distribution of the RTE

A unit-less *skewness coefficient* of distribution indicates the degree of *asymmetry* thereof. Table 4.4 show that the *skewness-coefficients* (sc) of the distribution of residual (ε) in both Non-HCI and HCI are larger in 1978 than in 1989. This explains that the every distribution of the residuals (ε) in 1978 is more positively skewed to the frontier under GM policy regime than that in 1989 under SM policy regime. In other words, the production points of establishments in each individual industry are more positively skewed to their production frontier for 1978 than for 1989. It is recalled from our earlier discussion that in 1989 there was no specific government intervention in market mechanism as strong as the HCI Drive Policy of the 1970s. If nothing disturbs

the market mechanism, the distribution of residuals produced by the regression model of the production frontier naturally goes to normal distribution in the context of the *central limit theorem*. In both HCI and Non-HCI, there found a similar trend in *skewness coefficient of the distribution of residuals* (ε), *i.e.*, distribution of the relative technical efficiency of the establishments became less skewed to the production frontier in 1989 than in 1978. But, 371 (iron and steel industries) show the opposite in the trend of *skewness coefficient of the distribution of residuals* (ε).

Table IV in the Appendix presents the results of hypothesis tests for the intertemporal differences in *skewness coefficient* in Table 4.4 are highly significant.

[Table 4.4] Table 4.4 Intertemporal Differences in the *Skewness Coefficient of the Distribution of Residuals* (ε) by Industry

KSIC		*Skewness Coefficient of the Distribution of Residuals for* 1978 (sc^{78})	*Skewness Coefficient of the Distribution of Residuals for* 1989 (sc^{89})	$sc^{78} - sc^{89}$
Non-HCI				
321	3211	0.9775	0.5901	0.3874
	3216 / 3212	0.4510	0.4808	-0.0298
322		0.4955	0.4660	0.0295
323	3231	1.2887	0.8591	0.4296
	3233	0.9779	0.8245	0.1534
324		1.0122	0.7873	0.2249
HCI				
351		0.5439	0.5779	-0.0340
352	3521	1.4377	1.4495	-0.0118
	3522	1.2147	1.0989	0.1158
	3523	1.5751	1.1782	0.3969
371		0.5605	0.6546	-0.0941
372		0.3362	0.7306	-0.3944
381	3811	0.9014	0.6422	0.2592
	3812	1.3085	0.6276	0.6809
	3813	0.8888	0.5403	0.3485
382	3822	1.3645	0.8882	0.4763
	3823	0.9467	0.4975	0.4492
	3824	0.9794	0.6701	0.3093
383	3831	1.1186	0.7895	0.3291
	3832	0.9069	0.5277	0.3792
	3833	1.2127	0.6569	0.5558
384	3841	0.9695	0.8578	0.1117
	3843	0.7667	0.4360	0.3307

Note: KSIC 3216 in 1978 is converted to KSIC 3212 in 1989.

V. CONCLUSION

In conclusion, results indicate that there exist the convincing effects of strong industrial policies such as HCI promotion plan on the technical efficiency of the "favored" and the "less favored." Most of the HCI show similar trend in *mean residual*, *i.e.*, they became less technically efficient in 1989 than in 1978. But, KSIC 351(industrial chemicals) and KSIC 371(Steel and Iron industry) show the opposite in the trend of *mean residual*. We find that the *RTE* levels of HCI have uniformly fallen over a decade after the government changed its industrial policy from "GM (Governed Market)" to the government's more neutral and fine-tuning industrial policies of the 1980s, "SM (Simulated Market)." In Non-HCI, most of the industries became less technically efficient in 1989 except KSIC 3216(KSIC 3212 for 1989) and KSIC 3233.

In both HCI and Non-HCI, there detected a similar trend in *skewness coefficient of the distribution of residuals* (ε), *i.e.*, distribution of the relative technical efficiency of the establishments became less skewed to the production frontier in 1989 than in 1978. But, 371 (iron and steel industries) show the opposite in the trend of skewness coefficient of the distribution of residuals (ε). This explains that the every distribution of the residuals (ε) in 1978 is more positively skewed to the frontier under "GM" policy regime than that in 1989 under "SM" policy regime. Also the share of LEs in both aggregate manufacturing employment and manufacturing value added in most of Non-HCI and HCI has declined in 1989 and the trends of *RTE* and the percentage share of LEs in aggregate manufacturing by employment of the HCI are similar.

APPENDIX

1. Categorization of Non-HCI and HCI

I. Non-HCI (Non-Heavy machinery and Chemical Industries)

Industries those are free of the government's selective industry-targeting HCI Project in the 1970s.

1978	1989
321 manufacture of textile	
3211 spinning textiles and silk reeling	3211 silks reeling and yarns spinning
3216 weaving textiles	3212 weaving textiles
322 manufacture of wearing apparel except footwear	
323 manufacture of leather and products of leather, leather substitutes and fur	
3231 tanneries and leather finishing	3231 tanneries and leather finishing
3232 fur dressing	3232 manufacture of dressed fur skins and its products
3233 manufacture of products of leather and leather substitutes	
324 manufacture of footwear, except vulcanized or molded rubber or plastic footwear	

II. HCI (Heavy machinery and Chemical Industries)

Industries those are targets of the government's selective industry-targeting HCI Project in the 1970s.

351 manufacture of industrial chemicals

352 manufacture of other chemical products

3521 manufacture of paints, varnishes and lacquers

3522 manufacture of drugs and medicines

3523 manufacture of soap and cleaning preparations, perfumes and cosmetics

3523 manufacture of soap and cleaning preparations, surface-active agents, cosmetics (for 1989)

371 iron and steel industries

372 non-ferrous metal industries

381 manufacture of fabricated metal products, except machinery and equipment

3811manufacture of cutlery, hand tools and general hardware

3812 manufacture of furniture and fixtures primarily of metal

3813 manufacture of structural metal products

382 manufacture of machinery, except electrical
3822 manufacture of agricultural machinery and equipment
3823 manufacture of metal and wood- working machinery
3824 manufacture of special industrial machinery and equipment
3825 manufacture of office, computing and accounting machinery
383 manufacture of electrical and electronic machinery, apparatus, appliances and supplies
3831 manufacture of electrical machinery and apparatus
3832 manufacture of sound, image equipment and apparatus
3833 manufacture of electrical appliance and house wares
384 manufacture of transport equipment
3841 ship building repairing
3842 manufacture of railroad equipment
3843 manufacture of motor vehicles

2. Editing Rules by Individual KSIC Code

Table I shows the definitions of variables employed for the editing rules and Tables II presents the excluded observations that have fundamental defects to avoid the problem of excluding authentic outliers from the raw data as noted by Caves and Barton (1990).

[Table I] Definitions of Variables

(1) OPER	Number of Production Workers At Year-End for 1978 Monthly Average Number of Production Workers for 1989
(2) OPAY	Annual Compensation of Production workers
(3) TPAY	Annual Compensation of Non-Production and Production Workers
(4) K	Annual Tangible Fixed Assets
(5) M	Direct Production Costs
(6) S	Value of Shipments
(7) GO	Gross Output: Shipments plus net addition of inventories of finished goods, semi-finished goods and work-in-progress
(8) VA	Value Added

Note: Monthly Average Number of Production Workers for 1978 is not available.

[Table II] Editing Rules for the Observations in the Sample of 1978 and 1989

(1) OPER = 0 (2) OPAY = 0 (3) TPAY = 0 (4) K = 0
(5) M = 0 (6) S = 0 (7) GO = 0 (8) VA = 0
(9) (GO/N) > MEAN(GO/N)+4.5*STD(GO/N)
(10)(K/N) > MEAN(K/N)+ 4.5*STD(K/N)
(11)(M/N) > MEAN(M/N)+4.5*STD(M/N)
(12)(VA/N) > MEAN(VA/N)+4.5*STD(VA/N)

Note: (9)-(12) show that the observations that exceed *4.5 calculated standard deviation above the mean* are excluded from the original sample.

[Table III] Summary of Data for Analysis in 1978 and 1989

KSIC	1978				1989			
	Total (A)	Editing Rules	Retained (B)	B/A (%)	Total (A)	Editing Rules	Retained (B)	B/A (%)
3211	594	28	566	95.2	757	34	723	95.5
3216	1834	62	1772	96.6	2727	101	2626	96.2
322	2918	100	2818	96.5	6362	102	6260	98.3
3231	107	2	105	98.1	446	14	432	96.8
3233	272	15	257	94.4	794	51	743	93.5
3240	252	17	235	93.2	704	33	671	95.3
Non-HCI Total	5977	224	5753	96.2	11282	458	10824	95.9
351	838	37	801	95.5	947	43	904	95.4
3521	73	7	70	95.8	113	3	110	97.3
3522	219	17	202	92.2	302	15	287	95.0
3523	80	6	74	92.5	170	5	165	97.0
371	524	20	504	96.1	797	21	776	97.3
372	310	18	292	94.1	671	24	647	96.4
3811	418	18	400	95.6	723	26	697	96.4
3812	154	7	147	95.4	532	14	518	97.3
3813	440	21	419	95.2	1116	34	1082	96.9
3822	183	16	167	91.2	320	10	310	96.8
3823	401	12	389	97.0	2130	68	2062	96.8
3824	513	13	500	97.4	1389	43	1346	96.9
3831	290	12	278	95.8	985	26	959	97.3
3832	678	46	632	93.2	2218	87	2131	96.0
3833	167	8	159	95.2	651	18	633	97.2
3841	282	9	273	96.8	436	21	415	95.1
3843	379	18	361	95.2	1835	54	1781	97.0
HCI Total	5949	281	5668	95.2	15335	512	14823	96.6
Total	11926	505	11421	95.7	26617	970	25647	96.3

3. Results of Hypothesis Testing

Table IV presents the results of Hypothesis Testing for the Intertemporal Differences in *Mean residuals* (μ) *and the Skewness Coefficient of the Distribution of Residuals* (SC) by Industry.

I. Hypothesis Testing for the Intertemporal Differences in *Mean residuals* (μ)

The null hypothesis is set up in a way that the level of inefficiency remains unchanged for the same industry across the two different years 1978 and 1989. Therefore, we have $H_0: (P_w^{78}/\lambda_w^{78}) = (P_w^{89}/\lambda_w^{89})$,
where the superscripts 78 and 89 represent the year 1978 and 1989 respectively and the subscript w represents each individual industry as a whole.
If H_0^1 were rejected, then it suggests that $\mu_W^{89} > \mu_W^{78}$, *i.e.*, the level of mean inefficiency of the referred industry for 1989 is greater than 1978. If H_0^2 were rejected, then it suggests that $\mu_W^{89} < \mu_W^{78}$, *i.e.*, the level of mean inefficiency of the referred industry for 1978 is greater than 1989.

II. Hypothesis Testing for the *Skewness Coefficient of the Distribution of Residuals (SC)* by Industry.

The null hypothesis is set up as follows.
$H_0: 2/\sqrt{P_w^{78}} = 2/\sqrt{P_w^{89}}$, where the superscripts 78 and 89 represent the year 1978 and 1989, respectively and the subscript w represents the individual industry as a whole. The null hypothesis states that the *skewness coefficients* of the two identical industries are the same for 1978 as for 1989.

If H_0 were rejected, then it would suggest that the *skewness coefficient* of distribution of residuals for the referred industry for 1978 would be greater than that for 1989.

[Table IV] Result of Hypothesis Testing for the Intertemporal Differences in *Mean residuals* (μ) and the *Skewness Coefficient* of the Distribution of Residuals (SC) by Industry

KSIC	E (μ)		SC	
	z-statistic	result	*z-statistic*	result
3211	8.2629	Reject H_0^1	14.9185	Reject H_0^1
3216/3212[16]	6.1523	Reject H_0^2	0.3342	Accept H_0^2
322	1.7123	Accept H_0^1	2.7390	Reject H_0^1
3231	3.5567	Reject H_0^1	3.3350	Reject H_0^1
3233	10.3636	Reject H_0^2	5.5501	Reject H_0^1
3240	3.3108	Reject H_0^1	2.9969	Reject H_0^1
351	5.0136	Reject H_0^2	1.4114	Accept H_0^2
3521	1.2809	Accept H_0^1	0.0887	Accept H_0^2
3522	2.9866	Reject H_0^1	2.0663	Reject H_0^1
3523	4.1640	Reject H_0^1	3.7852	Reject H_0^1
371	4.1633	Reject H_0^2	3.2829	Reject H_0^2
372	7.4451	Reject H_0^1	10.4986	Reject H_0^1
3811	6.8920	Reject H_0^1	5.5271	Reject H_0^1
3812	5.9851	Reject H_0^1	6.2331	Reject H_0^1
3813	10.7699	Reject H_0^1	25.7441	Reject H_0^1
3822	4.1793	Reject H_0^1	8.2514	Reject H_0^1
3823	18.4027	Reject H_0^1	43.6265	Reject H_0^1
3824	16.5527	Reject H_0^1	21.4113	Reject H_0^1
3831	5.4428	Reject H_0^1	4.3729	Reject H_0^1
3832	9.0468	Reject H_0^1	9.3619	Reject H_0^1
3833	4.8103	Reject H_0^1	5.1620	Reject H_0^1
3841	1.0393	Accept H_0^2	15.9650	Reject H_0^1
3843	8.8279	Reject H_0^1	10.0006	Reject H_0^1

[16] KSIC 3216 for 1978 is converted to KSIC 3212 for 1989.

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