KIET Occasional Paper No. 55

How have the Korea's Core Manufacturing Sectors Performed under the Market Interferences?

An analysis of the production frontier, technical efficiency, and determinants of technical efficiency by industry

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ISBN 89-90789-45-1 93320

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Introduction

Ⅰ. Introduction

This study seeks to delineate the extent to which exogenous shocks of the Korean government's Heavy Machinery and Chemical Industries(HCI) Drive Policies in the 1970s and the 1997 Asian financial crisis affected the production frontiers and technical efficiency as well as the determinants of technical efficiency of Korea's core manufacturing sectors.

The industrial policies to be reviewed are the pre-1980 "Governed Market(GM)" regime and the post-1980 "Simulated Free Market(SM)" regime on the basis of the role of the government.[1] The overwhelmingly direct role of the government in the "Big-Push[2] HCI policy" in the 1970s was intended to foster the HCI for export promotion, which is characterized as GM policy. In this sense, the HCI promotion policies during the 1970s may well be considered as strong external interferences in the market-oriented economy of Korea.

In contrast, the government began implementing economy-wide structural adjustments by converting its role to a fine-tuning neutral supporter of the free market mechanism through SM policies during the 1980s.

Turning to the 1990s, the unexpected Asian financial crisis at

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1) See Wade(1990).
2) Refer to Murphy *et al.*(1989).

the end of 1997 overwhelmingly pounded the financial system of Korea, and finally gave rise to another massive exogenous shock to the system. The 1997 Asian financial crisis erupted mainly due to excessively indiscreet investment; triggering IMF[3] supervision along with pervasive measures intended to adjust the structure of Korea's industries--another strong exogenous market-disturbance shock. Although the strength and direction of the impact of the unanticipated financial crisis of 1997 were different from those of the anticipated HCI Drive on production units, both the Asian financial crisis and the HCI Drive were major disturbances to the essentially free-market economy.

Therefore, the effects of the exogenous shocks on the technical efficiency of the industry groups are discussed based on the hypothesis that exogenous shocks to the economy affect the technical efficiency of individual establishment.

Also the determinants for the technical efficiency of an individual establishment are estimated using technological, institutional, and endowment-type explanatory variables for the purpose of efficient factor combination and eventually for promoting world competitiveness.

Section 2 presents the methodology and Section 3 describes the data used. The interpretations of the empirical results are presented in Section 4 and concluding remarks follow in Section 5.

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3) IMF stands for the International Monetary Fund.

II

Estimation of Production Frontier Function

Ⅱ. Estimation of Production Frontier Function

Measuring technical efficiency has been one of the major objectives in the estimation of the frontier production function. The theoretical production function defines a functional relationship between a bunch of inputs and output, which enables one to calculate the maximum possible output from a given set of inputs. The frontier of the production function represents the uppermost limit to the range of possible production points of all observations in the sample. Hence, by definition, no point can exist above the production frontier, *i.e.*, all production points must lie on or below the frontier of production.

Since Farrell(1957) first formulated a measurement of production frontier and technical efficiency including price efficiency, quite a number of methodologies have been developed so far on the subject of specification and estimation of the frontier production function in relation to the technical efficiency.

1. Stochastic Frontier Production Function(SFPF)

The stochastic frontier model has a composed error term, which can be characterized in two parts as in (2.1). A symmetric component, v, allows random variations of the frontier across firms and captures the effects of measurement error, misspecification of econometric model, usual white noise, and random exogenous shocks beyond the firm's control. On the other hand, the one-sided component u is supposed to capture the overall effects of inefficiency.

$$y = f(x)\ \exp(v - u)$$
$$= f(x)\ \exp(\varepsilon), \quad \varepsilon = (v - u), u > 0 \qquad (2.1)$$

In the above econometric model, $f(x)\ \exp(v)$ denotes the stochastic production frontier where v has some symmetric distribution to capture white noise, measurement error, and uncontrollable exogenous shocks, which cause the placement of the deterministic kernel $f(x)$ to vary across firms. Thus, the technical inefficiency relative to the stochastic production frontier is then caught by the one-sided error component, $exp(-u)$, $u \geq 0$. Although the stochastic frontier model seems to be theoretically attractive, it has a few intrinsic shortcomings.[4]

First of all, the choice of assumptions on the distribution of u and v are imposed without a justifiable theoretical basis.

Second, it is not easy to decompose the entire error term, $\varepsilon = (v - u)$ into u and v separately after estimating the deterministic kernel $f(x)$ to extract technical inefficiency term, $(-u)$ on a single firm basis. Jondrow *et al.* (1982) suggest a solution to decomposing the $(u - v)$ to v and u separately on the basis of the expected value of u, conditional on $(u - v)$ when u has the

4) Greene(1980) noted on this in details.

half-normal or the exponential distribution. They generate statistical formulas for the half-normal and exponential cases, and from which the technical inefficiency of an individual plant is calculated.

Third, the technical inefficiency being estimated in this model includes input price inefficiency as well. However, as Caves and Barton (1990) noted, the lack of appropriate data on factor input prices and accruing input demand makes it difficult to extract the sole technical inefficiency from the total.

Fourth, in the SFPF approach, there detected troublesome statistical errors such as, "type I failure" or "type II failure" in the estimation of technical inefficiency term u.[5)]

Lastly, Caves and Barton(1990) pointed out the sensitivity of SSPF to outliers. Yoo(1991) in his research using "1978 Manufacturing Census" of Korea[6)] also discovered that the variations of technical efficiency results from the SSPF being highly sensitive to both the specification of the production function and the selection of the dependent variable.

2. Full Frontier Production Function(FFPF) with a Gamma Distribution

Forsund *et al.* (1980) emphasized that the deterministic frontiers

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5) See Caves and Barton(1990), Yoo(1990) and Pai(1995) fore more details.

6) Furthermore, he failed to show the validity and robustness of technical efficiency estimates in his study.

are consistent with economic theory and are the absolute frontiers, which represent current technology, though they are often argued to be sensitive to outliers. In contrast with a *half normal* or an *exponential distribution*, a *gamma distribution* has several strengths in its application to the estimation of the full frontier production model.[7)]

Greene(1980) pointed out that OLS(Ordinary Least Squares) estimators are unbiased and consistent but generally not efficient when residuals are asymmetric. MLE(Maximum Likelihood Estimation) generally provides asymptotically efficient estimators since it utilizes all the information on the residuals. He also noted several theoretical strengths of the gamma distribution in MLE.

First, the functional relationship between μ and σ^2, assumed in a half-normal and an exponential distribution, seems to be unwarranted ; however, the two free parameters, P and λ in the *gamma distribution* would eliminate the rigid functional relationship between μ and σ^2. Thus, it allows high flexibility in the shape of error distribution.

Second, the *gamma distribution* is originally asymmetric. Therefore, MLE of the parameters in (2.2) is more efficient than the least squares estimation and verifies that MLE for the full frontier using *gamma density* is distinguishably different from the parameter estimates obtained from OLS, MLE for the stochastic frontier.

The concept of absolute frontier is constructed from the FFPF, since the estimation methods draw a maximum possible output

7) See Greene(1980) for more details.

frontier from the full set of observations[8] under the current technology with an assumption of one-sided error distribution.[9]

Greene(1980) proves that the desirable asymptotic properties of maximum likelihood estimators such as *consistency*, *asymptotic efficiency*, and *asymptotic normal distribution* are to be recovered under the following conditions for the density of ε, $f(\varepsilon)$ in (2.2).[10]

Let the production function be specified as

$$y_t = \alpha + \beta' x_t + \varepsilon_t, \quad t = 1, \ldots, T. \tag{2.2}$$

where y_t is output, x_t is a vector of exogenous variables, ε_t is a random disturbance indicating managerial inexperience, weather, and inefficiencies. The α and β are unknown parameters, and T is the size of sample.

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

$$F(\varepsilon) = G(\lambda, P) = \frac{\lambda^P}{\Gamma(P)} \varepsilon^{P-1} exp(-\lambda\varepsilon), \; \varepsilon \geq 0, \; \lambda > 0, \; P > 2, \tag{2.3}$$

where the *mean and variance* of ε are $\mu = \frac{P}{\lambda}$ and $\sigma^2 = \frac{P}{\lambda^2}$, respectively.

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8) This means all possible observations collected after deleting improper data.
9) See Forsund *et al.* (1979).
10) See more details in Greene(1980).

The log likelihood function for the gamma density model is represented as :

$$\log L = TP \log\lambda - T\log\Gamma(P) + (P+1)\sum_t \log(\alpha + \beta' x_t - y_t)$$
$$- \lambda \sum_t (\alpha + \beta' x_t - y_t) \qquad (2.4)$$

3. Measuring Technical Efficiency

The primary reason in estimating the production frontier function is to derive the technical efficiency.

Let the production function model be formulated as

$$y = F(x)\,u, \quad 0 < u \leq 1, \qquad (2.5)$$

where y is gross output, and x is an input bundle.

By log transformation of the above equation, we have

$$\log y = \log F(x) + \log u = \log F(x) - \varepsilon, \quad \varepsilon \geq 0 \qquad (2.6)$$

And the *technical* efficiency of each establishment (u) is converted from the corresponding *residual* (ε) as follows :

$$\log u = -\varepsilon \text{ and } u = e^{-\varepsilon} \qquad (2.7)$$

As a result, the most efficient establishment must be u = 1 by the technical inefficiency term ε=0. Therefore, all the ex- post observed production points of establishments in the industry should be traced beneath the production frontier $F(x)$ except *the best practice firm*, which exists only on the frontier.

The *mean* value of u for all the establishments in the industry group is denoted in percentage term, where u = 99.999 indicates the most efficient production unit in the sample.

For the purpose of maintaining consistency and validating the resulting differences in the comparisons of estimated parameter values, the most common and flexible functional form is employed as follows.

$$\begin{aligned} ln\ (GO/N) = &\ ln\alpha + \beta_L\ ln(N)\beta_K\ ln(K/N) + \beta_M\ ln(M/N) \\ &+ \beta_{LL}(lnN)^2 + \beta_{KK}(ln\ K/N)^2 + \beta_{MM}(lnM/N)^2 \\ &+ \beta_{LK}(lnN)(ln(K/N)) + \beta_{KM}(ln(K/N))(ln(M/N)) \\ &+ \beta_{ML}(lnM/N)(lnN) - \varepsilon,\ \ \varepsilon \geq 0 \qquad (2.8) \end{aligned}$$

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

For an utmost frontier of the production function in terms of current technology, all residuals should be positive as assumed in the FFPF model, *i.e.*, the y-axis intercept is shifted upward far enough until the minimum value of the residual is zero. Since the two free parameters in the gamma distribution, P and λ, are related to the residual term, ε, such that $E(\varepsilon) = \mathbf{P}/\lambda$ and $V(\varepsilon) = \mathbf{P}/\lambda^2$, **P** and λ will be obviously positive and **P** is greater than 2 in almost all applications. The *skewness coefficient*, $2/\sqrt{\mathbf{P}}$, is clearly positive in all FFPF models using the gamma distribution.

Ⅲ

Data Description

Ⅲ. Data Description

The data of 1978 *Census of Manufacturing Establishments of Korea* is used as the reference for the pre-1980 period under the GM regime, while those of the *1983* and *1988 Census of Manufacturing Establishments of Korea and the 1992, 1996, 1999, 2000, and 2001 Survey of Manufacturing Establishments* are used as the reference for the post-1980 period under the SM regime in Korea.

In particular, the years 1992 and1996 are selected as the references for the pre-IMF supervision era whereas the years 1999, 2000 and 2001 are selected as the references for the post-IMF supervision era in order to detect variations in the technical efficiency of establishments caused by industrial structural adjustments under the IMF supervision.

One of the main contributions of this study is the use of annual micro-level establishment data to analyze the technical efficiency of Non-HCI, HCI, and IT manufacturing sectors.

IV

Empirical Results

Ⅳ. Empirical Results

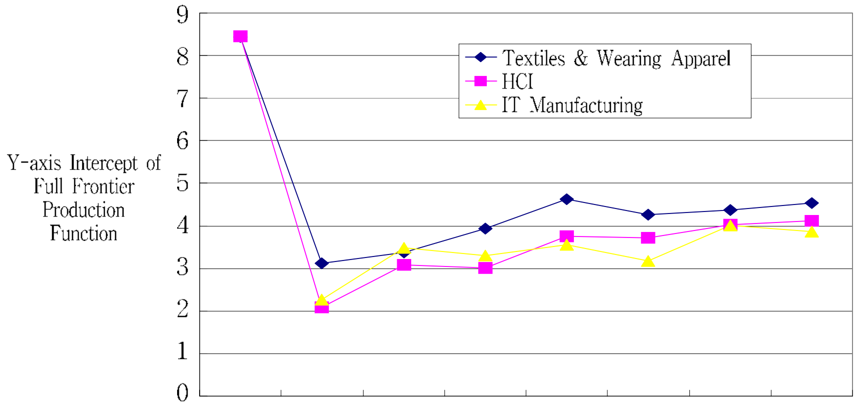
1. Production Frontier and Technical Efficiency

Figures 1 and 2 present the trends of production frontier and technical efficiency of the three industrial groups such as Textiles & Wearing Apparel(Non-HCI), HCI, and IT manufacturing. The production frontier and technical efficiency are estimated from the FFPF with a gamma distribution for each individual industry by year and then the referred industries are categorized into three industrial groups : Textiles & Wearing Apparel(Non-HCI), HCI, and IT manufacturing.

One of the shortcomings of the frontier production function model is that the estimates of technical efficiency depend partly upon the shape of the empirical distribution of regression residuals they are unable to reflect any movements of the production frontier itself over time. Under this constraint Caves and Barton(1990) reasoned that if an industry's production frontier is lifted concurrently with the upgrade of the technical efficiency level then the "productivity growth" may well be accomplished.

The estimation results are condensed into the following figures and the facts, which are significant based on one-tailed hypotheses tests at the 95% significance level.

Figure 1 *Production Frontier by Industry Group*

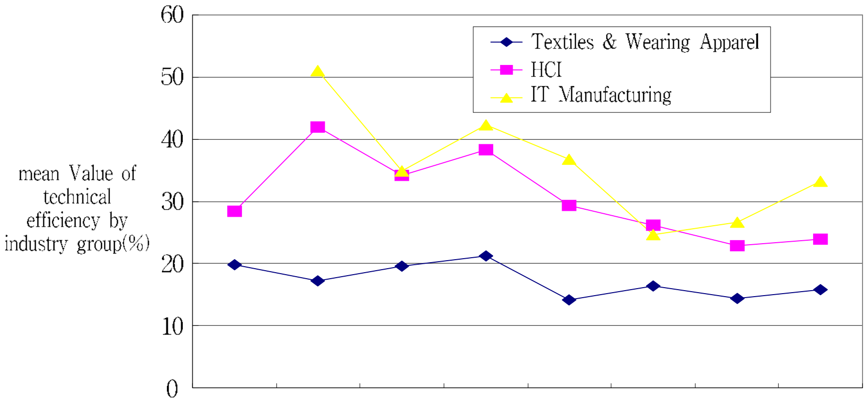


	1978	1983	1988	1992	1996	1999	2000	2001
Textiles & Wearing Apparel	8.4296	3.1122	3.3787	3.9363	4.627	4.2655	4.3722	4.533
HCI	8.4492	2.0816	3.0843	3.0187	3.7533	3.714	4.0307	4.1269
IT Manufacturing	-	2.2757	3.4796	3.3008	3.5477	3.1748	4.0183	3.8734

First, the production frontiers of the *Textiles & Wearing Apparel* industry and the HCI in 1978 under the GM regime are remarkably higher than those of the *Textiles & Wearing Apparel* industry and the HCI in 1983 under the SM regime. Concurrently, the technical efficiency level of the HCI is relatively upgraded partly due to a lower production frontier, however, that of the *Textiles & Wearing Apparel* industry become lower.

Consequently, the government's excessive market interventionist big-push HCI promotion policy along with the strong export-drive policy overextended the production frontiers of the

Figure 2 Technical Efficiency by Industry Group



	1978	1983	1988	1992	1996	1999	2000	2001
Textiles & Wearing Apparel	19.78	17.215	19.61	21.205	14.11	16.355	14.41	15.76
HCI	28.45	41.975	34.158	38.346	29.343	26.213	22.858	23.923
IT Manufacturing	-	51.1	34.875	42.32	36.72	24.656	26.6	33.288

HCI, but failed to improve the technical efficiency thereof in 1978.

Though to a lesser degree, similar phenomena were captured in 1996 just before the 1997 Asian financial crisis occurred, which were the higher production frontiers with the lower technical efficiency levels compared to those of the year 1992.

In fact, there were huge investments in the HCI from the beginning of the 1990s until just before the Asian financial crisis of 1997. Hence, another similarity between the two phenomena is that the both epochs marked the final stages of ongoing HCI capital accumulation in the 1990s.

In other words, the *best-practice* firm, which maximizes production through optimal factor combination, can improve technical efficiency by lifting the production possibility curve. However, as Caves and Barton(1990) pointed out, over-investment of capital caused capital inefficiencies, so that when the additional production units failed to reach maximum production with given inputs, they dragged down the overall efficiency level of the industry. Therefore, the high growth rates of the HCI shall on the contrary give rise to the lower level of technical efficiency.[11)]

Second, under the SM regime, the *Textiles & Wearing Apparel* industry maintained the highest production frontier except in 1988 when the IT manufacturing marked the highest. However, the IT manufacturing marked the greatest technical efficiency, the HCI second, and the *Textiles & Wearing Apparel* industry the lowest among the three industry groups in the all eight separate years, except in 1999 when the HCI exceeded the IT manufacturing by a small margin.

Third, comparing the production frontiers of the HCI and the IT manufacturing, the production frontier of the IT manufacturing ranked higher in the years 1988 and 1992, but the opposite is held in the years of 1996 and 1999.

However, the production frontier of an each industry group is lifted and converged to a certain point in the year 2000.

Fourth, Pack and Westphal(1986)'s *dynamic efficiency* was gradually fulfilled among the HCI since 1983, which is explained

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11) Meeusen and Broeck(1977) noted that the permanent shift of the frontier production function let firms at any moment have less opportunity to get to their frontier than stable firms.

by the obvious technical efficiency gap between the HCI and the *Textiles & Wearing Apparel* industry. However, the technical efficiency of the IT manufacturing has worsened ever since 1983, partly due to an unstable growing industry that is experiencing a continuous upward shift of its production frontier.[12)]

Fifth, Caves and Barton(1990)'s *productivity growth* was finally accomplished in the *Textiles & Wearing Apparel* industry in 1988 and 1992 by simultaneous upward shifts of the production frontier and technical efficiency.

The year 1999 may well be thought of as a crop year of the industrial structural reforms triggered by the 1997 Asian financial crisis. However, the downshifts of production frontiers accompanied by the lowertechnical efficiency in the all three industrial groups imply that the industrial structural adjustments failed in the sense of technical efficiency.

Turning to the year 2000 there captured two notable phenomena in the trend of the production frontier and the technical efficiency.

The one is that the production frontiers of all three industrial groups are lifted and converge to *a certain point*, which implies that the M&A accelerated by the industrial structure adjustments eliminated those firms whose lack of competitiveness was holding back production frontiers.

The other is that the technical efficiencies of the *Textiles & Wearing Apparel* industry and the HCI become worse. The performance of IT manufacturing in the sense of technicale-

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12) See Meeusen and Broeck(1977) and Caves and Barton(1990).

fficiency is improved.

Eventually, the IT manufacturing gained Caves and Barton (1990)'s *productivity growth* both in the years 2000 and 2001, and the technical efficiency of the *Textiles & Wearing Apparel industry* and the HCI began to improve in the year 2001.

2. Determinants of Technical Efficiency

This section covers the determinants for the technical efficiency of an individual establishment using technological, institutional, and endowment-type explanatory variables by OLS estimation method for the purpose of efficient factor combination and promoting the world competitiveness (refer to appendix).

Also several issues on the measure of competitiveness via effects of factor intensity on technical efficiency, efficiency of investment and international comparative advantage are discussed as follows.

The following results are derived based on a 95% statistical significance level :

First, the *per capita capital equipment*, one of the major measures of factor intensity, though depending on the characteristics of an industry, can be a measure of over-investment by analyzing its effects on technical efficiency.

The estimation results show that the *per capita capital equipment* generally has a negative effect on technical efficiency, especially *Shipbuilding* industry in 1978 and 1996, when the ongoing intensive investments were under progress among the HCI. However, it has significant positive effects on the industries *Sewn Wearing apparel, except Fur Apparel* in 1983, *Basic Iron and Steel Manufacturing* in 1992, *I/O Units and Peripheral Equipment* in 1988, and *Television and Radio Receivers* in 1999.

Second, the *skill intensity* and the *energy intensity* has significant positive effects, although the *labor intensity* has a negative effect on technical efficiency. In other words, skilled labor clearly enhance the level of technical efficiency, but the greater the wage share in the total production the worse the technical efficiency accrues.

And the larger energy cost share in the direct production costs implies the higher operating capacity ratio, and which lift the level of technical efficiency.

Third, the *age of establishment*, as one of measures of the vintage effect, has a negative effect on technical efficiency, except for industries *Sewn Wearing Apparel, except Fur Apparel* in 1983 and 1999, as well as *Semiconductor and Other Components* in 1983. Therefore, the older the establishment the lower the technical efficiency level follows.

Fourth, the *asset generality*, the inverse of asset specificity, has significant negative effects on technical efficiency. It supports the hypothesis that the asset specificity enhances the production efficiency.

Fifth, the *mechanization ratio*, a proxy variable of degree of mechanization in the production process, generally has negative effects on technical efficiency partly due to an accelerated depreciation accounting.

However, it has significant and positive effects in the industries *Textiles, except Sewn Wearing apparel* in 1983, and *Sewn Wearing Apparel, except Fur Apparel* in all periods, *Shipbuilding* in 1978, *Motor Vehicles* and *Trailers Manufacturing* in 2000 and 2001, and *Motor Vehicles Parts & Engines Manufacturing* in 2001.

Sixth, the *newly embodied technology ratio*, which generally has a time lag to generate efficiency, has negative effects on technical efficiency in all years, partly due to the accelerated depreciation accounting, but it improves efficiency gradually.

However, it has significant and positive effects in the industries *Motor Vehicles and Trailers Manufacturing* in 1999, and *Basic Chemicals Manufacturing* and *Computers and Peripheral Equipment* in 2000.

In sum, the structural adjustments triggered by the 1997 Asian financial crisis turned the effect of the *newly embodied technology ratio* from negative into positive in the above industries.

Seventh, the *annual average inventory ratio* is supposed to generate cushion effect against market demand fluctuations, has a negative effect on the level of technical efficiency.

However, it has significant positive effects on industries *Textiles, except Sewn Wearing Apparel in* 1983, *Basic Iron and Steel Manufacturing, General Purpose Machinery Manufacturing*, and *Semiconductor and Other Components in* 1988, *Motor Vehicles and Trailers Manufacturing in* 1996, *Basic*

Chemicals Manufacturing, Computers and Peripheral Equipment, and *Semiconductor and Other Components* in 1999, and *Semiconductor and Other Components* and *Television and Radio Receivers* in 2000.

Eighth, the *subcontracting ratio* displays a subcontracting share between LEs and SMEs[13] in the production process, has generally a positive effect on technical efficiency except the industries *Textiles and Sewn Wearing Apparel* in 1999, *Basic Chemicals Manufacturing* in 1983 and 1992. Notably significant and positive effects are detected in the industries *General Purpose Machinery Manufacturing, Motor Vehicles and Trailers Manufacturing*, and *Shipbuilding*. Also, clear positive effects are found in the IT manufacturing, especially when firms are growing rapidly.

Lastly, the *relative size of establishment* has a negative effect on the technical efficiency of the industries *Textiles, Except Sewn Wearing Apparel* and *Sewn Wearing Apparel, Except Fur Apparel*. In other words, the larger the establishment the worse the technical efficiency follows, and which supports the estimating results that LEs and SMEs showed similar efficiency level or better for the SMEs.

Especially, among the HCI, clear negative effects are discovered just before the year 1996 except the industries *Basic Chemicals Manufacturing, Basic Iron and Steel Manufacturing*, and which explains why the technical efficiency of LEs in the HCI rapidly grew worse than that of SMEs in the year 1996.

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13) LEs and SMEs stand for Large Establishments and Small & Medium-sized Establishments, respectively.

In particular, the negative effect on the industry *Motor Vehicles and Trailers Manufacturing* in 1996 became double than in 1992.

Among the IT manufacturing, the *relative size of establishment* has a positive effect on the technical efficiency of the *Computer Industry* whereas it has a evidently negative effects on the technical efficiency of *Semiconductor and Other Components* in 1992 and 1996, and *Television and Radio Receivers* in 1988, 1992, 1996 and 2000.

V

Concluding Remarks and Policy Implications

Ⅴ. Concluding Remarks and Policy Implications

In sum, there have been significant effects of the HCI Drive Policy and the Asian financial crisis of 1997 with respect to the production frontier and the level of technical efficiency of the rapidly growing core industries in Korea.

Moreover, the technical efficiency level of the rapidly growing core industries targeted by the government at the each economic developmental stage of Korea was higher than that of the industries not targeted, which proves that *the winners of the government industrial policy* gained *static efficiency* as well as *dynamic efficiency*[14] in the last three decades.

Therefore, we can say that the targeted industries led economic growth at the each economic developmental stage of Korea and technically efficient industries proved themselves to be highly competitive in the world market.

Concerning the determinants of technical efficiency, several policy implications can be derived from the estimation results.

First of all, there is urgent need for specific industrial policy by industry to improve investment efficiency to escape form the low or negative capital productivity.

Second, *on the job-training* program for the higher skilled

14) Refer to Pack and Westphal(1986).

labor are strongly recommended.

Third, the lower efficiency level of old establishments may well be improved by maximization of inter- and intra- industry technology *spill-over* effects.

Fourth, it is evident that the new technology embodied specific production assets enhance the technical efficiency. Hence, it is essential to construct efficient system for supporting R&D activities and accelerating industrial innovation aiming at invincible competitiveness in the world market.

Fifth, the healthy subcontracting system should be consolidated and maintained. Especially, subcontracting system is proved to be essential for the *machinery, automobiles*, and *ship-building* industries as well as *IT manufacturing* for the higher technical efficiency and world competitiveness.

Lastly, the *Textiles & Wearing Apparel* industry needs to be encouraged to maintain proper size of high value-added production. Among the HCI, except *Basic Chemicals Manufacturing* and *Basic Iron and Steel Manufacturing*, downsizing is recommendable for the higher technical efficiency and from preventing waste of resources.

Appendix

1. Categorization of Industries

2. Determinants of Technical Efficiency

Appendix

1. Categorization of Industries

The industries selected are core industries that have driven the sustained economic growth of Korea, and are classified into three categories: Non-HCI, HCI, and IT Manufacturing.

Non-HCI(Heavy Machinery and Chemical industries)

KSIC 17 *Textiles, Except Sewn Wearing Apparel*
KSIC 181 *Sewn Wearing Apparel, Except Fur Apparel*

HCI(Heavy Machinery and Chemical industries)

KSIC 241 *Manufacture of Basic Chemicals*
KSIC 271 *Manufacture of Basic Iron and Steel*
KSIC 291 *Manufacturing of General Purpose Machinery*
KSIC 34 *Motor Vehicles & Trailers Manufacturing*
KSIC 343 *Parts for Motor Vehicles and Engines Manufacturing*
KSIC 3511 *Building of Ships*

IT(Information and Communication Technology) Manufacturing

KSIC 3001 *Computers and Peripheral Equipment*
KSIC 30013 *Input/Output Units and Peripheral Equipment*
KSIC 321 *Semiconductor and Other Components*
KSIC 32202 *Communication Apparatuses*
KSIC 323 *Television and Radio Receivers*

2. Determinants of Technical Efficiency

The relationships between the estimated technical efficiency and the selected variables are explained below.

Definitions of Variables

I. *Endogenous Variable*

Technical Efficiency : The *Relative Technical Efficiency(RTE)* of an each establishment(u) is converted from the corresponding residual(ε) derived in Section 2.

II. *Exogenous Variables*

II.1 Measure of Technology

1) CAPINT *Capital-Labor ratio* : (Annual Tangible Fixed Assets / Number of Employees), *i.e., per capita capital equipment*

2) SKILLINT *Skill Intensity* : (Annual Compensation of Non-Production and Production Workers/Number of Employees), *i.e.*, Remuneration per Employee, used as a proxy for level of skilled labor

3) ENININT *Energy Intensity* : {(Fuel+Electricity) Costs/Direct Production Costs}, Fuel and Electricity Costs as a Percen-

tage of Direct Production Costs(%)

4) LABINT *Labor Intensity*: (Annual Compensation of Non-Production and Production Workers / Total Sales), Total Labor Costs as a Percentage of Total Sales(%)

5) ASGEN *Asset Generality*: {(Buildings+Land) / Annual Tangible Fixed Assets}, Share of Real Estate in Annual Tangible Fixed Assets, an inverse measure of Asset Specificity

6) MACH *Mechanization Ratio*: {(Machinery+Equipment) / Annual Tangible Fixed Assets}, Machinery and Equipment as a Percentage of Annual Tangible Fixed Assets (%), a measure of production mechanization and standardization of products

7) NT *Newly Embodied Technology Ratio*: {Newly Equipped Machinery and Equipment / Annual Tangible Fixed Assets}, Newly Equipped Machinery and Equipments as a Percentage of Annual Tangible Fixed Assets(%)

8) TINVEN *Annual Average Inventory Ratio*: {Annual Average Inventory / Total Sales}, Annual Average Inventory as a Percentage of Total Sales, a measure of cushion from market demand fluctuations

II.2 *Endowment Variables*

1) LAGE *Logarithm of the Age of Establishment*: log(Present Year Establishment Year), a measure of the vint-

age effect on production process

II.3 Institutional Variables

1) SUBCON *Subcontracting Ratio*: (Cost of Contract Work / Direct Production Costs), Cost of Contract Work as a Percentage of Direct Production Costs(%), possibly influenced by government policies for improving subcontracting relations between LEs and SMEs since the 1980's

2) RSIZE *Relative Size*: (Total Sales of Individual Establishment / Industry Total Sales), Individual Establishment's Total Sales as a Percentage of Industry Total Sales(%), a measure of firm size.

The numbers in parentheses are t-ratios.

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