Patterns and Determinants of Productive Efficiency in Korean Manufacturing Firms during Trade Liberalization.

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- 무역자유화 기간을 중심으로 -

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PATTERNS AND DETERMINANTS OF PRODUCTIVE EFFICIENCY IN KOREAN MANUFACTURING FIRMS DURING TRADE LIBERALIZATION[1)]

우리나라 제조업의 생산적효율성 결정요인 분석
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- 요 약 -

본 연구는 한국 제조업의 기업별 <패널>자료를 이용하여 확율적 생산함수를 추정한 다음, 우리나라의 주종 수출산업인 섬유산업과 전자산업의 기술적 효율성이 1980년대에 하락한 이유를 규명하기 위하여 동종산업내의 각 기업들의 기술적 효율성의 결정요인을 계량분석을 통해 분석하였다. 성장산업인 전자산업과 사양산업인 섬유산업의 산업내 (intra-industry) 기술적 효율성의 결정요인은 相異하였다. 성장산업인 전자산업의 경우, 상대적인 기업의 크기와 노동비용의 상대적 크기는 기술적 효율성과 각각 正의 관계를 보이고 있는 데 비해, 사양산업인 섬유산업의 경우, 총 매출액에서 수출이 차지하는 비중과 기술적 효율성은 正의 관계를 보인 데 反해, 총 생산비에서 노동비용이 차지하는 비중은 기술적 효율성과 負의 관계를 보였다. 즉 1980년대 섬유산업의 기술적 효율성이 하락한 중요한 요인은 동 산업의 수출부진과 상대적인 노동비용의 상승을 들 수 있으며, 성장산업인 전자산업의 경우는 일부 대기업의 집중도 심화가 동 산업의 평균적 기술적효율성의 하락요인이 되었음을 알 수 있다. 따라서 본 연구는 경쟁의 촉진과 기업 집중도의 완화가 기술적효율성을 향상시키는 데 중요하다는 점을 보여주고 있다.

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I. INTRODUCTION

Korea liberalized its trade policy in the early 1980s, hoping that exposing its industrial sector to more foreign competition would increase productive efficiency. Suh (1992) and Suh, Tybout, and Westbrook (1994) focus on the effect of trade liberalization on the productive efficiency of Korean manufacturing firms. Even though they provide some empirical evidence of import liberalization on productive efficiency, they can not explain why the average technical efficiency of export-oriented industries such as textiles and electrical machinery declined over the 1980s.

The purpose of this paper is to provide an answer to that question. That requires an empirical analysis of intra-industry determinants of technical efficiency. To do so, I estimate stochastic frontier production functions (SFPF) with firm-level panel data and estimate firm-specific technical efficiency measures. Then I examine the main determinants of firm-level technical efficiency.

The theoretical literature that deals with the association between the firm-level technical efficiency and firm-level characteristics is almost not available. The empirical studies mainly from industrial organization literature focus on the inter-industry determinants of technical efficiency. Caves (1992) and Caves and Barton (1990) also focus on the inter-industry determinants of technical efficiency for other several countries. Haddad, et al (1992) use firm-level export data to examine the relationship between export share and the growth of total factor productivity (TFP) using Moroccan data. Still it is also important to uncover some stylized facts through firm-specific, intra-industry empirical works particulary using panel data that has many advantage.[2)]

2) Schmidt and Sickles (1984) first apply SFPF model to firm-level panel data

The recent World Bank project, *The East Asian Miracle* (World Bank; 1993), reports the ineffectiveness of government intervention in industrial policy to enhance productivity except directed credit polices and export-push strategies. The report also argues that, in Korea, the so-called "promoted" sectors (iron & steel) achieved low TFP growth, while "not-promoted" sectors (textiles) achieved high TFP growth. The similar argument can be made by using location of production frontier. This paper will show that the production frontiers of iron & steel are very low and declining over time, while those of the textiles are high and increasing. The interpretation should be careful, however. The concept of production frontier and technical efficiency (*i.e.*, the discrepancy of individual firms from the best-practiced frontier) should be separated. My results will give another interpretation.

This paper consists of this brief Introduction, two sections, and the Conclusion. Section Two presents the stochastic production function model with time-varying technical efficiency that we used. Section Three reports the empirical results on firm-level determinants of technical efficiency.

II. ESTIMATION OF TECHNICAL EFFICIENCY

2.1. Concept of Technical Efficiency

Changes in productivity derive from two sources: technical change and changes in technical efficiency. Technical change is the output growth that comes from the shift of production frontier itself, that is, improvements in

set to estimate time-invariant technical efficiency. Cornwell, Schmidt, and Sickles (1990) first apply SFPF model to firm-level panel data to estimate time-varying, firm-level technical efficiency. For the advantages of using panel data to estimate technical efficiency and problems of TFP measure by using macro-level data, see Schmidt (1985).

"best practice" production technology, under the assumption that production is continuously technically efficient. Increased technical efficiency, on the other hand, implies movement of inefficient firms toward the best practice production technology.

Farrell (1957) proposes an empirically tractable measure of technical efficiency that is based on firms' departures from frontier production functions[3]. Arguments for trade liberalization generally suggest that exposure to foreign competition forces firms to operate close to the production frontier, and provides an incentive for firms to shift the frontier outward.

2.2. The Stochastic Frontier Production Function With Time-Varying Efficiency

To represent technical efficiency in a stochastic production function we adopt the model of Cornwell, Schmidt, and Sickles (1990):

$$(1) \qquad \mathbf{y}_{it} = \mathbf{X}'_{it}\boldsymbol{\beta} + \mathbf{W}'_{it}\boldsymbol{\delta}_i + \mathbf{v}_{it} \qquad i = 1,\ldots, N. \quad t = 1,\ldots, T.$$

3) In Farrell's analysis, inputs are the choice variables for the production unit. Let the input requirement set, V(y), be the subset of all input vectors X capable of producing output y where $y \in R_+$; f(x) be the maximum output attainable from the input vector X where $X = (x_1, \ldots, x_m)\ \varepsilon\ R_n^m$. Then the production technology can be defined by an input correspondence, i.e., $V: y \rightarrow V(y) \subseteq R_+^m$. Then the inverse relationship between the input correspondence V(y) and the production function f(X) is defined by $V(y) = \{X: y \leq f(X)\}$. And an isoquant of V(y) is: $Q(y) = \{X: X \in V(y),\ \theta X \notin V(y),\ \theta\ \varepsilon\ [0,1)\},\ y \geq 0$. An efficient subset of V(y) is: $E(y) = \{X: X \in V(y),\ z \leq X ==> z \notin V(y)\},\ y \geq 0$. Thus, the Farrell measure of technical efficiency of input vector $x\ \varepsilon\ v(y)$ is defined by $F(X;y) = \min\{\theta: \theta X \in V(y),\ \theta \geq 0\}$. This implies that $V(y) = \{X: 0 < F(X;y) \leq 1\}$ and $Q(y) = \{X: F(X;y) = 1\}$. For more interpretation of the Farrell measure of productive efficiency, see C.A. Knox Lovell and Peter Schmidt, "A Comparison of Alternative Approaches to the Measurement of Productive Efficiency," *Applications of Modern Production Theory: Efficiency and Productivity,* Edited by Ali Dogramaci and Rolf Fare, Boston: Kluwer Academic Publishers, 1988, pp.3-32.

The i^{th} firm's output rate in period t is y_{it}, the vector of corresponding input rates is X'_{it}, and the time-varying firm-specific effects are represented by $\alpha_{it} = W'_{it}\delta_i$, where $W'_{it} = [1, t, t^2]$ and $\delta_i = \delta_0 + \mu_i$. Here, μ_i is a one-sided firm-specific technical inefficiency measure, which in conjunction with W_{it} has time-varying effects on output, and v_{it} is a symmetric error term that is uncorrelated with the regressors. Under the fixed-effects assumption, the *within* estimator is consistent for coefficient vector β, even if the efficiency effects are correlated with the regressors. Under the random-effects assumption, if the efficiency effects are uncorrelated with the regressors, a Generalized Least-Squares (GLS) estimator is consistent for β and is efficient relative to the within estimator. Comparing the within and GLS estimates is the basis for a well-known test for whether the technical efficiency effects are correlated with the production function inputs [*cf.* Hausman and Taylor (1981)]; however, this is a weak test, and it is inappropriate in the pressence of measurement error.

Once we have obtained estimates for β, firm-specific estimates of the δ_i are recovered by regressing the residuals $(y_{it} - X'_{it}\hat{\beta})$ for firm i on W_{it}. Then the time-varying firm-specific technical inefficiency measure, μ_{it}, is calculated from the fitted value of $\hat{\alpha}_{it} = W'_{it}\hat{\delta}_i$. That is, $\hat{\alpha}_t = \max_j(\hat{\alpha}_{jt})$ and $\hat{\mu}_{it} = \hat{\alpha}_t - \hat{\alpha}_{it}$. We define our measure of technical efficiency as $[1/(1 + \mu_{it})] \times 100\%$, which yields 100% efficiency for the most efficieny for the most efficient firm in each year.

2.3. Productive Efficiency of Korean Manufacturing Firms

In this section, we apply the time-varying efficiency model presented in the previous section to firm-level panel data for seven Korean manufacturing industries. Firm-specific technical efficiency measures based on Cobb-Douglas production technologies with constant returns to scale are estimated. The details of data preparation are given first, in Section 2.3.1; the empirical results are summarized in Section 2.3.2

2.3.1. Data

The firm-level panel data are based on the annual business reports of manufacturing firms that are listed on the Korean stock exchange over the time period 1981 - 1988. These data include output, price, employment, wage, and sales data in addition to financial statements. The financial statements of Korean manufacturing firms are standardized and include 685 variables.

Selection of Manufacturing Firms

While as many as 377 manufacturing firms are observable in 1989, I elect to construct a balanced sample to simplify estimation of the time-varying technical efficiency parameters. The data base contains 191 firms that report all data for the entire sample period. Since I plan to estimate industry-specific production functions, industries that have fewer than 8 firms are excluded from the sample. The final data set thus contains 118 firms covering seven industries over eight years. Table 1 gives the variable definitions, the number of observations, and the sample means for each industry in the final balanced sample.

The value of gross output of each industry accounted for by our balanced sample of firms is greater than 37 percent for each industry except iron and steel. The share of output of industrial chemicals and electrical equipment accounted for by our sample exceeds 50 percent. The fact that relatively small numbers of firms account for such large proportions of each industry's output implies relatively high concentration ratios in Korean industries.

Calculation of Relevant Variables

Various consistency checks were performed that convince us that the accuracy of the data is very high. However, as usual, measured capital may be subject to measurement error. The input variable of capital should capture the flow of services from the use of the capital input in the production process for each period. We use *net* fixed assets as a proxy for capital input. Note that, especially during the recovery from a recession, an increase in the capital utilization ratio may affect the estimated level of technical efficiency.

Calculation of Input and Output Price Deflators

Because the data include both physical quantities and unit values for major outputs and inputs, it was possible to construct price deflators of unusually high quality. Specifically, for the output price deflators, *firm-specific* Laspeyres price indices were calculated from the volumes and values of the

<Table 1> The Balanced Data Set

Industry	obs	Sample Means				
		Y	K	L	M	E
Food	152	129950.8	26780.3	2425	83551.1	4174.6
Textiles	144	159816.8	63668.1	4609	82120.5	12506.2
Industrial Chemicals	160	131845.5	49308.7	2353	75846.3	8762.4
Other Chemicals (Pharmaceuticals)	192	46290.0	8228.0	1203	19573.0	681.3
Cement & Refrctories	64	142756.2	95745.2	1674	60632.9	16421.2
Iron & Steel	72	125978.6	25714.6	1548	80492.5	5866.0
Electrical Machinery	160	240082.7	47752.6	4433	143682.5	2814.3

Note : Y = real gross value of output, million Won

K = real net capital stock, million Won

L = total number of employees

M = real value of materials, million Won

E = real value of energy, million Won

actual outputs of each firm. The Laspeyres price index for firm i in year t is defined as follows:

$$(2) \qquad LP_{it} = \Sigma_j P^j_t \cdot Q^j_{to} / \Sigma_j P^j_{to} \cdot Q^j_{to}, \quad j = 1,\ldots,n$$

where j indexes the outputs produced by firm i in year t. The base year is t_o = 1985. One possible problem with these price indices is that they may reflect changes of quality of products over time. Overall, however, firm-specific output price indices are stable over time relative to the WPI. Next, for input price deflators, *firm-specific* average price indices are obtained from the prices of (up to) five major intermediate inputs for each firm.

The gross value of output was deflated by the firm-specific Laspeyres output price index and the value of material inputs was deflated by the firm-specific input price deflators. The four categories of capital inputs were deflated by the relevant industry-specific wholesale price indices. For buildings and structures the WPI of construction materials is used; electricity is deflated by the WPI for industrial electricity; and fuels are deflated by the WPI of bunker C oil.

2.3.2. **Results for the Time-Varying Efficiency Model**

The specific production function that we estimate is Cobb-Douglas with constant returns to scale:

$$(3) \qquad ln(Y_{it}/K_{it}) = \alpha_{it} + \beta_{L/K}\, ln(L_{it}/K_{it}) + \beta_{E/K}\, ln(E_{it}/K_{it}) + \beta_{M/K}\, ln(M_{it}/K_{it}) + v_{it},$$

Where $\alpha_{it} = \delta_{i1} + \delta_{i2}t + \delta_{i2}t^2$.

We use the Cobb-Douglas function instead of a more flexible functional form such as the translog because the number of firms in several of our industries is fairly small[4]. We impose constant returns to scale on the production function because our main concern is to estimate the technical efficiencies of firms. By imposing constant returns to scale, we force productivity differences due to scale effects to appear in the residual, along with other dimensions of productive efficiency. Finally, we select the within estimator to avoid the

<Table 2> Cobb-Douglas Production frontier parameter estimates: Time-varying efficiency model (within estimation)

Industry	In(L/K)	In(E/K)	In(M/K)
Food	0.364 (0.063)	0.048 (0.060)	0.398 (0.056)
Textiles	0.245 (0.083)	0.265 (0.078)	0.439 (0.056)
Industrial Chemicals	0.371 (0.064)	0.090 (0.053)	0.512 (0.052)
Pharmaceuticals	0.568 (0.055)	-0.006 (0.043)	0.434 (0.053)
Cement & Refractory	0.158 (0.119)	0.235 (0.061)	0.541 (0.113)
Iron & Steel	0.002 (0.108)	0.169 (0.127)	0.796 (0.109)
Electrical Machinery	0.397 (0.067)	0.102 (0.061)	0.513 (0.043)

Note : the standard errors are reported in parentheses.

omitted variables bias due to technical efficiency effects that are correlated with regressors.

The within and GLS estimates of the coefficients of the Cobb-Douglas production function for the time-varying efficiency model are given in Tables 2 and appendix A respectively. We report results from two estimation techniques, because commparing them sheds light on the nature of the firm-specific technical efficiency effects. The within and GLS estimates may be compared with a

4) Note that Griliches and Ringstad (1971) report that the change of functional form from Cobb-Douglas to other forms did not affect their results much.

Hausman test. Failure to reject the null hypothesis that the within and GLS results are the same indicates that the firm-specific effects (the technical efficiencies) are uncorrelated with the regressors and that measurements erroris unlikely to be a problem. Hausman test statistics and their P-values are given in the last column of Appendix A; each is asymptotically χ^2-distributed with three degrees of freedom; each is insignificant at conventional levels of significance. In fact, the Hausman statistics are unusually small, which we conjecture is due to the imposition of constant returns to scale. This suggests that technical efficiency depends upon factors not measured by input use.

The firm-specific time-varying technical efficiency measures are obtained from the estimated firm effects, $\hat{\alpha}_{it}$. Table 3 shows the value of $\hat{\alpha}_t$ estimated for each industry in each time period. This is the intercept of the frontier at each time period. Its evolution may be interpreted as indicative of changes in technology. It is this shifting frontier against which technical efficiency is

<Table 3> Location of Production Frontier Over Time ($\hat{\alpha}$)

Industry	1981	1982	1983	1984	1985	1986	1987	1988
Food	4.57	4.51	4.47	4.44	4.43	4.43	4.45	4.49
Textiles	3.33	3.34	3.36	3.39	3.43	3.47	3.52	3.66
Industrial Chemicals	4.23	4.20	4.33	4.44	4.52	4.56	4.57	4.54
Pharma-ceuticals	5.67	5.62	5.58	5.56	5.55	5.56	5.58	5.64
Cement & Refractory	2.77	2.69	2.70	2.69	2.66	2.65	2.67	2.67
Iron & Steel	1.36	1.39	1.41	1.40	1.36	1.31	1.23	1.28
Electrical Machinery	3.94	4.09	4.21	4.36	4.52	4.58	4.56	4.44

measured. We see that the import-competing sectors (Food, Other Chemicals & Pharmaceuticals, Cement & Refractores) experience small downward shift through 1985-1986, from which they mostly recovered during 1987-1988. Iron & Steel eperienced upward shifts of the production frontier during 1981-1983 followed by downward shifts during the remainder of the samole period. On the other hand, the export-oriented sectors (Textiles, Industrial Chemicals, and Electrical & Electronic Equipment) each experienced a generally upward trend in the production technology.

<Table 4> The average technical efficiency(%): Time-varying efficiency model (Within Estimation)

Industry	1981	1982	1983	1984	1985	1986	1987	1988
311-2	56.3	58.9	61.4	63.8	65.9	67.7	69.1	70.1
321	76.7	76.1	75.3	74.8	74.5	74.4	74.5	70.4
351	74.6	76.9	71.2	67.1	64.9	64.3	65.3	68.2
352	58.3	61.6	64.7	67.5	69.8	71.5	72.4	71.7
369	73.0	78.8	79.6	81.7	85.2	87.2	86.4	87.1
371	78.0	75.9	75.3	76.0	77.9	81.5	86.7	83.6
383	78.8	73.9	72.0	68.7	64.9	64.7	67.9	76.5

Note : 311-2 : Food
321 : Textiles
351 : Industrial chemicals
352 : Other Chemicals (pharmaceuticals included)
369 : Cement & refractories
371 : Iron & steel
383 : Electrical & electronic equipment

Table 4 reports the average time-varying technical efficiency measures for each industry for each year, based on within estimation. The levels of technical efficiency change over time with some patterns among industries. For one thing, the import-competing industries such as food, pharmaceuticals, and cement enjoyed efficiency gains during the 1980s. On the other hand, the export-oriented industries such as textiles and electrical & electronic equipment, experienced efficiency losses throughout the 1980s.

The efficiency losses of export-oriented sectors such as textiles and electronic industry may be partly due to quality upgrading of their products. This would cause price indices for the affected firms to rise relatively rapidly, or equivalently. It would obscure the fact that quality upgrades increase the real value of output. We examine this possibility by comparing firm-specific output price indices of export-oriented sectors. Overall the price change over time is relatively stable. We cannot detect any drastic increase in price for those firms in export-oriented sectors. The rates of price increase of export-oriented firms are less than five percent annually. Some firms even experience decreases in prices over the sample period. In particular, a measured increase in technical efficiency may be due merely to the increase in the rate of capital utilization; if this effect is present, it results in measurement error bias. The data set contains both actual output and potential output for some firms; the ratio is a proxy for the capacity utilization ratio. Thus, to check for the presence of a capacity utilization effect, we regressed the estimates of firm-specific technical efficiency against the firm-specific capacity utilization ratio. A positive relationship would be expected if increases in measured technical efficiency were driven by capacity utilization effects. In the case of the electronics industry, the relationship is *negative*, but there are only eleven firms (88 observations). We could not check this relationship for every industry because many firms did not report potential output.

III. DETERMINANTS OF FIRM-LEVEL TECHNICAL EFFICIENCY

In this section, we analyze the statistical association between the firm-level technical efficiency and firm-specific characteristics of Korean manufacturing firms. Due to the limitations of firm-level qualitative data, I use some proxy that may capture the determinants of firm-level technical efficiency. For the purpose of this paper, I focus on the analysis of two export-oriented industries: textiles and electrical & electronics equipments.

3.1. Some hypotheses (Korean specific)

First of all, we use the ratio of firm-level export to total sales (EXP) to measure the degree of exposure to foreign competitions. Haddad, et al.,(1992) shows the positive effect of export growth on the growth of total factor productivity with Moroccan data. Export can cause the growth of TFP because contacts with foreign competitors that arise from exporting may lead to more rapid technical change and the development of local entrepreneurship. second, the competitive pressure from international markets may reduce X-inefficiency and may lead to better product quality. Haddad & Harrison (1993) also find no evidence of technological spillovers of export using for Moroccan data.

Secondly, some empirical studies support a general positive relationship between relative plant size and efficiency. (Yoo,1992) The relationship between relative firm size and technical efficiency may provide another interpretation of Demsetz's (1973,1974) hypothesis of the positive relationship between concentration and profitability. Here, the relative firm size can be measured by the ratio of gross value of firm's output to total industrial output (RSIZE).

Thirdly, the changes in *relative* labor cost among firms due to the drastic increase in wage rates during the mid-1980s of Korea may affect the firm-level technical efficiency. Here, the relative labor cost can be measured by the ratio of firm-level labor cost to total manufacturing cost (RLC). The comparison of the effects of RLC on firm-level technical efficiency in "declining" industry (textiles) and in "rising" industry (electronics & electrical equipment) of Korea will be necessary and interesting. The relative wage differentials between

<Table 5> Sample Means of Selected Explanatory Variables and Technical Efficiency by Industry.

Industry	no.	Sample Means				
		AWR	RLC	EXP	WCW	TEW
Food	152	0.7414	0.0691	0.0432	0.4456	0.6414
Textiles	136	0.5338	0.1174	0.6541	0.1915	0.7459
Industrial Chemicals	144	0.7335	0.0790	0.4068	0.3819	0.6853
Other Chemicals (Pharmaceuticals)	192	0.6195	0.1072	0.0882	0.6614	0.6718
Cement & Refractories	64	0.8813	0.0998	0.0535	0.4034	0.8238
Iron & Steel	72	0.8406	0.0762	0.3309	0.2624	0.7937
Electrical Machinery	160	0.5758	0.1254	0.4889	0.2766	0.7093

Note: TEW= Simple average of firm-level Technical Efficiency.
AWR= Ratio of firm-level average wage rates of skilled workers to that of administratives.
RLC= Ratio of firm-level labor cost to total manufacturing cost.
EXP= Ratio of firm-level exports to total sales.
WCW= Ratio of firm-level non-production workers to total labor.

<Table 6> Changing Patterns of Selected Explanatory Variables:

Textile and Electronic Industry of Korea

INDUSTRY	VARIABLES	YEAR							
		1981	1982	1983	1984	1985	1986	1987	1988
321	TEW	0.7674	0.7605	0.7530	0.7482	0.7451	0.7439	0.7454	0.7041
	AWR	0.4880	0.5072	0.5042	0.5287	0.5353	0.5439	0.5857	0.5774
	RLC	0.1064	0.1115	0.1134	0.1077	0.1118	0.1193	0.1317	0.1373
	EXP	0.6786	0.6641	0.6273	0.6429	0.6569	0.6720	0.6674	0.6237
	WCW	0.1717	0.1816	0.1814	0.1874	0.1958	0.2027	0.2137	0.1977
	RSIZE (Std Dev)	0.0424	0.0450	0.0420	0.0405	0.0434	0.0417	0.0403	0.0412
383	TEW	0.7882	0.7394	0.7201	0.6870	0.6492	0.6466	0.6794	0.7646
	AWR	0.5952	0.5112	0.5262	0.5494	0.5737	0.5927	0.6095	0.6489
	RLC	0.1461	0.1412	0.1276	0.1259	0.1204	0.1089	0.1101	0.1229
	EXP	0.4559	0.4416	0.4712	0.4664	0.4920	0.4924	0.5462	0.5458
	WCW	0.2258	0.2606	0.2598	0.2702	0.2909	0.3181	0.2866	0.3007
	RSIZE (Std Dev)	0.0716	0.0733	0.0831	0.0947	0.0946	0.0902	0.0893	0.0937

Note: TEW= Simple average of firm-level Technical Efficiency.
AWR= Ratio of firm-level average wage rates of skilled workers to that of administratives.
RLC= Ratio of firm-level labor cost to total manufacturing cost.
EXP= Ratio of firm-level exports to total sales.
WCW= Ratio of firm-level non-production workers to total labor.
RSIZE(Std Dev.)= Standard deviation of relative firm size.
RSIZE= Ratio of firm's value of output to total Industrial output in sample.
321: Textiles.
383: Electrical & electronics equipments.

blue-collar workers and white-collar workers (AWR) may also affect the firm-level technical efficiency. Finally, for organization reasons, the ratio of non-production workers to total labor may aggravate technical efficiency.

Table 5 provides the sample means of the explanatory variables by industry. For textiles and electrical machinery, AWR (ratio of firm-level average wage rates of skilled workers to that of administratives) and RLC (ratio of firm-level labor cost to total manufacturing cost) are similar between two industries. Textiles is more export-oriented than electrical machinery.

Table 6 shows the changing patterns of selected explanatory variables and technical efficiency for textiles and electrical machinery. One common thing is the decrease of the simple average of firm-level technical efficiency in both industries during the 1980s except 1987 and 1988 for electrical machinery. The export share of "rising" sector (electrical machinery) is increasing, while EXP of "declining" industry (textiles) is decreasing except 1985 and 1986. The ratio of labor cost to total manufacturing cost (RLC) increased in textiles, while RLC of electrical machinery sector decreased except 1987 and 1988. The ratio of non-production workers to total labor (WCW) increased in electrical machinery.

3.2. Regression results

We now examine the determinants of inter-firm differences of technical efficiency of manufacturing firms. We estimate an *ad hoc* regression model in which the dependent variable is the measure of technical efficiency and the explanatory variables are the firm-specific characteristics mentioned above; separate regressions are run for each of two export-oriented industries: textiles and electronics. For these regressions, the data sets are panels of 17 firms (textiles) and 20 firms (electronics) over the eight years from 1981 to 1988. The regression equation we estimated is as follows:

$$(4)\ TE_{ijt} = \alpha_{ij} + \beta_{1i}RLC_{ijt} + \beta_{2i}AWR_{ijt} + {}_{2i}WCW_{ijt} + \beta_{2i}RSIZE_{ijt} + \beta_{2i}EXT_{ijt} + v_{ijt}.$$

where TE is the firm-specific technical efficiency estimated from the time-varying efficiency model, i indexes the industries, j indexes the firms and t indexes time periods. Within estimation methods are applied to (4). The estimation results are reported in Table 7.

Four main results come out. First of all, RSIZE is the most significant positive factor to determine the firm-level technical efficiency in export-oriented, "rising" industry (electronics).

Table 6 shows that the standard deviation of RSIZE of electronics industry increased from 0.0716 in 1981 to 0.0946, and then declined to 0.089 in 1987 and to 0.937 in 1988. In view of the constant mean of RSIZE (0.05) of electronics over time, the increase in the standard deviation means that the gaps between big firms and small firms in terms of firm size widened. Due to the positive association between RSIZE and TE in electronics sectors, a few big firms gain efficiency while many other relatively small firms lose efficiency. That reduces the average technical efficiency of electronics during the 1980s except 1987 and 1988. Actually, in electronics sector (total 20 firms in my sample account for 56.9% of total industrial output in 1985 data; Suh(1992)), the maximum RSIZE of firms rapidly increased from 23.9 % in 1981 to 36.5% in 1985 and declined slightly to 32.5% in 1988. In the case of textiles (total 17 firms in my sample account for 37.9% of total output in 1985 data), the maximum RSIZE of firms decreased from 18.1% in 1982 to 10.9% in 1988. These facts imply that economic concentration of "growing" industry such as electrical and electronics equipment by a few big firms is notable. RSIZE has a positive sign but insignificant for textiles industry that is also export-oriented, but "declining" sectors in Korean standards.

<Table 7> Regression Results of Firm-level Technical Efficiency on Explanatory Variables: Inter-firm determinants of Technical efficiency.(Within Estimation)

Independent Variables	Export-oriented Industry	
	Textiles	Electronics
RLC	-0.68275*** (-2.5259)	0.76811*** (2.9056)
AWR	0.04276 (0.6005)	0.06207 (1.1528)
WCW	0.28157* (1.8857)	-0.23220** (-2.1701)
RSIZE	0.64883 (1.1776)	1.3441*** (4.2688)
EXT	0.26323*** (4.35653)	-0.10303 (-1.5552)

Second, the estimated coefficients of the RLC (the ratio of labor cost to total manufacturing costs) has a *negative* sign and is highly significant for "declining" sector. Table 6, the changing patterns of explanatory variables over time, shows that the sample mean of RLC of textiles sector has increased steadily from 10.6% in 1981 to 13.7% in 1988, especially in 1987 and 1988. The RLC of electronics sector has decreased during the 1980s except 1987 and 1988. It is interesting to note, on the contrary, that the relative increase in the labor compensation in the "growing" industry has a *positive* and highly significant effect on the technical efficiency. According to Table 6, the sample mean of RLC of electronics sector has decreased from 14.6% in 1981 to 10.9% in 1986, and increased to 12.3% in 1988. These contradict effects and responds to labor-related dispute in both export-oriented industries may reflect the painful transition from low-wage to high-wage society in Korea after the mid-1980s. These empirical findings may explain, in part, why the technical efficiencies of both export-oriented sectors decline during the 1980s.

Third, the negative relationship between WCW and TE of "rising" sector lends support to arguments that building-up of bureaucracy in decision-making process (*i.e.*, increase the non-production workers relative to production workers) may aggravate the level of technical efficiency of manufacturing firms. Table 6 reveals that the WCW (the ratio of non-production worker to total labor) of "rising" industry (electronics) increased from 22% in 1981 to 32% in 1988.

Finally, Table 7 reports that the firm-level export share and technical efficiency of "declining" sector has a significant *positive* relationship. While the statistical relationships measured by the regressions do not allow an interpretation of causality, they do support the arguments recounted in Section I, according to which exposure to competitive discipline forces firms to become more efficient.[5] Table 6 shows, however, that the sample mean of firm-level export share in textiles sector declined from 67.9% in 1981 to 62.4% in 1988. The competitive effect of trade liberalization (*i.e.*, import competition) on technical efficiency of Korean manufacturing firms is examined by Suh, Tybout and Westbrook (1994) using the same panel data as this paper. They relate the change in effective rate of tariff protection on sectoral-level technical efficiency and find some moderate *negative* (enhancement) effect except the cement and iron & steel sectors.

To formally test whether the industry difference in estimated coefficients is statistically significant, a structural difference test has been performed. A

5) To check the possible endogeneity bias, Instrumental Variable (IV) Estimation was performed with Price-cost margin as an extra instrument. The IV estimation did not produce any qualitative difference in coefficient estimates. The detailed result of IV estimation and Hausman test is available from the author upon request. Haddad, et al.(1992) performed Sims causality test to check the same problem for Moroccan data and reject the hypothesis that the growth of TFP causes the growth of exports.

dummy variable (INDDUM) has been defined to take 1 for electronics industry and 0 for textile industry. To test all the coefficients except the firm dummies, interaction terms have been created for RLC, AWR, WCW, RSIZE, and EXT. The result is presented in Table 8.

In Table 8, all the dummy terms are statistically significant except AWR interaction term and RSIZE interaction term. The exceptions are not surprising because AWR was not a statistically significant explanatory variable for both industries, and RSIZE was not significant at all for textile industry. Overall, the two industries, textiles and electronics, show significantly different determinants of productive efficiency.

〈Table 8〉 Industry Difference Test

Varialbes	Coefficients
INDDUM	0.7042*** (12.02)
INDDUM*RLC	1.4509*** (3.369)
INDDUM*AWR	0.0193 (0.183)
INDDUM*WCW	-0.5138** (-2.354)
INDDUM*RSIZE	0.6953 (0.8998)
INDDUM*EXT	-0.3663*** (-3.647)
RLC	-0.6828* (-1.955)
AWR	0.0428 (0.4647)
WCW	0.2816 (1.459)
RSIZE	0.6488 (0.9113)
EXT	0.2632*** (3.371)
Adjusted R^2	0.6573
# of observations	296

The East Asian Miracle (World Bank: 1993) reports the ineffectiveness of government intervention in industrial policy to enhance productivity. The report argues that, in Korea, the so-called "promoted" sectors (iron & steel) achieved low TFP growth, while "not-promoted" sectors (textiles) achieved high TFP growth. The similar argument can be made by using Table 3 of this paper, location of production frontier. The production frontiers of iron & steel are very low and declining over time, while those of the textiles are high and increasing. The interpretation should be careful, however. The concept of industry-level production frontier (similar to TFP) that representst technical change and technical efficiency (*i.e.*, the discrepancy of individual firms from the best-practiced frontier) should be clear. Moreover, the production frontier (Table 3) was estimated from stochastic frontier production function with micro-level panel data, the total factor productivity (TFP) calculated from growth equation with macro-level, cross-section data. My results give another interpretation. In textile industry--i.e., "declining" and "not promoted" export-oriented sector--the success in the world market is crucial to the survival of business entreprise. And their success in world market will enhance their technical efficiency---i.e., worker's morale, attitude, effort and entrepreneurship. In the "rising" and "promoted" export-oriented sectors (electronics), however, the relationship between export share(EXT) and technical efficiency is *negative* but statistically insignificant.[6]

It is interesting to note that as the firms in "not promoted" industry become exposed to foreign competition, their levels of technical efficiency are enhanced. On the contrary, the firms in "promoted" industries can not enhance their technical efficiency from exposure to more foreign competitions.

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6) Lee(1992) examined the relationship between productivity change and government policy and concluded that trade restrictions and subsidized credit aggravated the total factor productivity by using 38 korean manufacturing industries over four 5-year subperiod (1963-1983).

Ⅳ. SUMMARY AND CONCLUSION

This paper estimated changes in productive efficiency by applying SFPF model to the firm-level panel data for Korean manufacturing firms. Then I examined the determinants of firm-level technical efficiency.

The main findings can be summarized as follows: (1) the relative firm size (RSIZE) is the most significant determinants for firm-level technical efficiency (TE). The positive effect of RSIZE on TE is especially notable for firms operated in "more promoted", "rising" industry. In fact, electrical and electronics sector is more concentrated than textiles sector in Korea. This finding supports Demsetz (1973, 1974) hypothesis indirectly. (2) The relative labor cost (RLC) has a strong negative effect on TE of firms in "declining" and "less concentrated" industry (textiles), and a strong positive effect on TE of firms in "rising" and "more concentrated" industry (electronics) in Korea. (3) The export share (EXP) has a positive relation with TE of firms that operate in "declining" and "less promoted" industry (textiles).

These findings explain why the average industry-level technical efficiency of export-oriented sectors such as textiles and electronics declined during the 1980s. In the case of "declining" (textiles) sector, the increase of relative labor cost (RLC) and the decline of export share play an important role to reduce industrial average TE. In the case of "rising" (electronics) sector, however, the decrease of RLC except 1987 and 1988, and the increase of RSIZE by a few big firms play a major role to reduce industrial average TE. In short, more competition and less concentration is very important to enhance the level of technical efficiency.

APPENDIX

The main nominal variables used in this study were defined following Griliches and Ringstad(1971). They are:

Total income (Y)	:	gross sales - returns and allowances
Gross value of Output	:	Y + net inventory of resale + net inventory of goods produced + net inventory of goods in process + units transferred out - units transferred in during the production process
Capital	:	net tangible fixed assets (buildings & structures, machinery & equipment, vehicles, tools, appliances, & fixtures)
Labor	:	total number of employees (executives, administratives, engineers, skilled workers, apprentices)
Materials	:	Purchases of materials during the year + material inventory of the end of year
Energy	:	electricity + fuels + water

<Apendix A>

Cobb-Douglas Production frontier parameter estimates and Hausman Test Statistics for Comparing Within and GLS Estimates: Time-varying efficiency model (GLS estimation)

Industry	In(L/K)	In(E/K)	In(M/K)	Hausman Test
Food	0.277 (0.047)	0.056 (0.044)	0.516 (0.053)	0.0091 (0.9998)
Textiles	0.181 (0.041)	0.293 (0.052)	0.466 (0.044)	0.2151 (0.9751)
Industrial Chemicals	0.308 (0.051)	0.095 (0.035)	0.577 (0.036)	0.0629 (0.9959)
Pharmaceuticals	0.568 (0.042)	0.003 (0.038)	0.404 (0.046)	0.0370 (0.9981)
Cement & Refractory	0.309 (0.089)	0.266 (0.056)	0.369 (0.110)	0.1611 (0.9836)
Iron & Steel	0.112 (0.071)	0.099 (0.044)	0.745 (0.054)	0.1181 (0.9896)
Electrical Machinery	0.365 (0.049)	0.067 (0.044)	0.569 (0.041)	0.2429 (0.9704)

Note : the standard errors of the coefficients are reported in parentheses; the P-values of the Hausman test statistics are also reported in parentheses

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