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THE DYNAMICS OF PRODUCTIVITY CHANGES IN THE KOREAN MANUFACTURING INDUSTRY: NONPARAMETRIC DIRECTIONAL DISTANCE FUNCTION APPROACH*

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Using the panel data set at the local level, we investigated the performance of local manufacturing industry and its changes across region over time, especially focusing on the dynamics of productivity changes between pre- and post-economic crisis. We found significant differences both in the performances of local manufacturing industry and in the dynamics of productivity changes across region. Our results indicate that the financial crisis may stimulate manufacturing firms to improve production efficiency and that manufacturing firms in Kwangju and Kangwon demonstrated relatively "small trade-offs" between efficiency and technical change.

JEL Classification: C61, D24, O18, O49
Keywords: Productivity Changes, Nonparametric Directional Distance Function, Luenberger's Shortage Function

I. INTRODUCTION

For many economists and policy makers who are interested in economic development and growth, the issues related to productivity have been a major concern. This is because productivity can be seen as a major source of growth and welfare improvement of an economy at both national and regional level. In particular, reliable estimates of the performances of regional economies or industries could shed light on the important regional economic issues such as the

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industrial location and economic growth differentials across regions. This makes measuring the productivity of an economy or its major industrial sector an important undertaking among many researchers.[1]

This study aims to investigate the dynamics of the performance of Korean manufacturing industry at the local level. We specifically focus on the productivity differentials over space and the dynamics of productivity changes across region for the period of 1991-2001. Furthermore, this study decomposes the productivity changes into technical change component and efficiency change component. This decomposition enables us to investigate the nature of productivity changes because technical change and efficiency change are associated with different sources in explaining productivity changes. Therefore, depending on the decomposition results at the local level, one can design suitable policies targeting productivity improvement. For example, if a region is found to be relatively inactive in technical progress, then a policy stimulating technical progress (e.g., more R&D investment) could be recommended.

In Korea, the last decade can be seen as a path-breaking period from the political and economic viewpoints. There were significant changes in political leaderships as well as economic environments represented by the IMF bail-out. Many people speculated that these changes in political and economic conditions might have significant impacts on the relative performance of manufacturing industry at both national and regional levels. In Korea, therefore, it is a timely attempt to investigate the effects of these changes on the performance of local manufacturing industry.

To estimate the regional productivity changes, we use a frontier approach. In the frontier literature, productivity differential is often termed "(technical) inefficiency"; the inability to produce maximum output given production resources and technology.[2] Specifically, we employ a nonparametric programming approach commonly referred to as data envelopment analysis (DEA). To represent the production technology, the directional distance function, a version of Luenberger shortage function, is employed. The data set used for this study is from the Mining and Manufacturing Survey conducted by the Korea National Statistical Office. This survey covers all mining and manufacturing establishments with five or more workers.

Previous studies on regional productivity issues generally assume that there exists no technical inefficiency. However, many researchers have shown the existence of significant differences in technical efficiency among regions (Beeson and Husted, 1989; Chambers et al., 1996a; Domazlicky and Weber, 1997; Kim,

[1] Agglomeration literature developed since the early 1970s provides a good example. See Gerking (1994), Richardson (1995), and Eberts and McMillen (1999).

[2] Economic efficiency is often considered as the sum of technical efficiency and allocative efficiency. Due to the lack of information on prices, we only focus on technical efficiency in this paper. In the rest of this paper, therefore, we use technical efficiency and efficiency interchangeably.

1997). In this line of research, taking this short-fall into consideration, the frontier production function approach has been increasingly used for regional productivity analysis in years (Koo and Kim, 1999; Puig-Junoy, 2001; Färe et al., 2001; An et al., 2003).

A number of studies conducting empirical analysis on the investigation of the performance of Korean manufacturing industry have been done. Most of them focused mainly on illuminating the effect of agglomeration externalities which is one of the major issues in the field of regional and urban economics (e.g., Kim, 1997; Lee, 2000; Park and Cho, 2001; Henderson et al., 2001: An et al., 2003). And relatively little attention has been paid to the investigation of the dynamics of productivity changes of this industry at the local level, in particular for the period of 1990s.

Lee (2000) used data of 22 (2-digit) manufacturing industries for 73 local governments in Seoul Metropolitan area, and Park and Cho (2001) extended Lee's study by including all local governments. They estimated labor productivity functions of translog form with Henderson-type agglomeration factors (Henderson, 1986) and provided empirical evidences of agglomeration economies. These studies are basically cross-sectional analyses, even though Park and Cho used a two-year panel data set. Unlike these studies, Henderson et al. (2001) used a set of panel data for 21 manufacturing industries categorized by five sectors. They confined their observations to the cities with population greater than 50,000 and estimated labor productivity function for the period of 1983~1993. It is noticeable that these studies are based on non-frontier approach. Thus, they ignored the possible presence of technical inefficiency. This again motivates our nonparametric frontier approach based on Luenberger's shortage function.

On the contrary, Kim (1997) employed a frontier approach for analyzing the performance of manufacturing industries of 50 large cities in the year of 1986. He calculated technical efficiency by using the DEA technique. He found the existence of significant technical efficiency differentials in manufacturing industries across regions. More recently, An et al. (2003) estimated the stochastic production frontier function to explain the determinants of technical efficiency in this industry at local government level. Although these studies take technical inefficiency into consideration by using frontier approach, they fail to analyze the dynamics of productivity changes, i.e., the pattern of productivity changes over time, because of their use of cross-sectional data. As witnessed by the previous studies listed above, regional productivity studies on the Korean manufacturing industry focused mainly on investigating agglomeration effects by using the cross-sectional data.[3] In other words, relatively little efforts have been devoted to the analysis of the pattern of productivity changes in this industry over time.

[3] Koo and Kim (1999) used panel data for manufacturing industries in Korea. By employing a stochastic frontier approach, this study found the existence of considerable size of technical inefficiency in this industry. However, they did not pay attention to the productivity changes over time, since they focused on the effects of financial services on the technical efficiency.

Using the 11-year-panel data set for 221 local governments' manufacturing industry and considering explicitly the technical inefficiency, we investigate the dynamics of productivity changes, and compare the performance of local industry and its changes across region. We found significant differences both in the performances of local manufacturing industry and in the dynamics of productivity changes across region. Our results indicate that the financial crisis may stimulate manufacturing firms to improve production efficiency, and that the effects of the changes in political environments in the late 1990s on the performance of regional industry are non-negligible.

The structure of this paper is as follows. The next section provides a conceptual model estimating productivity and discusses the data employed for this study. The subsequent section presents estimation results and their implications. Finally, concluding remarks are presented with suggestions for future research.

Ⅱ. A CONCEPTUAL MODEL FOR MEASURING PRODUCTIVITY

The empirical literature on frontier production has used two broadly defined approaches: (i) the nonparametric programming approach (Charnes et al., 1978); and (ii) the parametric stochastic approach (Aigner et al. 1977).[4] We use the nonparametric approach, i.e., DEA technique, which does not require any assumption on the functional form of production technology and the distribution of error terms.[5] In particular, this study estimates the directional distance function, a version of Luenberger's shortage function (Luenberger, 1992, 1995) rather than Shephard's input or output distance function.[6] Shephard's input (output) distance function measures the largest 'radial contraction' of an input vector (the largest 'radial expansion' of an output vector) with each remaining technically feasible (Chambers et al., 1998). That is, Shephard's distance function is defined by either contracting inputs or expanding outputs while satisfying feasibility conditions. However, the directional distance function is defined by simultaneously contracting inputs and expanding outputs. Therefore, the directional distance function is more general than Shephard's input or output distance function (Chambers et al., 1998).

Consider a production technology producing an M-vector of outputs, $y \in R^M_+$, by using an N-vector of inputs, $x \in R^N_+$. Using netput notation, where outputs

[4] Although these two approaches are based on similar theoretical foundations, they have own merits and shortcomings and often produce different empirical results.

[5] Unlike the parametric stochastic frontier approach (e.g., Aigner et al., 1977; Battese and Coelli, 1995), however, the nonparametric approach does not take into account random factors affecting inputs and outputs due to its deterministic characteristics.

[6] While Shephard's input and output distance functions are respectively dual to the cost function and the revenue function, while the directional distance function is dual to the profit function (Chambers et al., 1998).

are positive and inputs are taken to be negative, let a closed set $T \subset R_{-}^{N} \times R_{+}^{M}$ represent the production possibility set. That is, $(-x, y) \in T$ means that outputs y can be produced from inputs x. Then, Luenberger's shortage function is defined as

$$S(x, y, g_x, g_g) = \min\{\beta : (-x - \beta g_x, y - \beta g_y) \in T\}, \text{ for some } \beta$$
$$= +\infty, \text{ otherwise} \quad (1)$$

where $g_x \in R_{+}^{N}$ and $g_y \in R_{+}^{M}$ are nonzero directional (reference) vectors representing the direction in which the netput vector $(-x, y)$ is expanded. This measures how far the point (x, y) is from the frontier technology, expressed in units of the reference input bundle g_x and output bundle g_y.

The Luenberger's shortage function $S(x, y, g_x, g_y)$ has a number of important properties.[7] First, $(-x, y) \in T$ implies $S(x, y, g_x, g_y) \leq 0$. Second, under free disposal,[8] $T = \{(-x, y) : S(x, y, g_x, g_y) \leq 0\}$. Then, the equation $S(x, y, g_x, g_y) = 0$ is an implicit production function representing the upper boundary of the production technology. Hence, $S(x, y, g_x, g_y) \leq 0$ means that outputs $y - S(x, y, g_x, g_y) g_y$ could be produced by using inputs $x + S(x, y, g_x, g_y) g_x$. That is, both a revenue increase of $-S(x, y, g_x, g_y) g_y p$ and a cost reduction of $-S(x, y, g_x, g_y) g_x w$ are possible at the same time under the current technology available, where $p \in R_{+}^{M}$ and $w \in R_{+}^{N}$ represent the prices of outputs and inputs, respectively. Third, if the set T is convex, the shortage function $S(x, y, g_x, g_y)$ is convex in (x, y).

Following Chambers et al. (1996a), the directional distance function as a variation of Luenberger's shortage function can be defined as

$$\vec{D}(x, y; g_x, g_y) = \sup\{\theta : (x - \theta g_x, y + \theta g_x) \in T\}. \quad (2)$$

Here, the vector g_x and g_y represent the directions in which the input vector x is contracted and the output vector y is expanded, respectively. This function also measures the distance in a preassigned direction to the frontier technology. According to Luenberger's shortage function approach, this distance can be interpreted as a shortage of (x, y) to reach the frontier, while it can be interpreted as an efficiency measure using the directional distance function approach.

Under free disposability of inputs and outputs, the directional distance function in equation (2) can completely depict the production technology and is dual to

[7] See Luenberger (1995), pp. 20-22.

[8] Under free disposal, $(-x, y) \in T$ implies that $(-x', y') \in T$ for all $(-x', y') \leq (-x, y)$.

the profit function (Chambers et al., 1998). If and only if (x, y) is feasible, the directional distance function is nonnegative, i.e. $\vec{D}(x, y: g_x, g_y) \geq 0$. And the directional distance function completely generalizes Shephard's input or output distance function. Recall that Shephard's input and output distance functions are defined as $D_i = \sup_\theta \{\theta > 0: (x/\theta, y) \in T\}$ and $D_o = \inf_\theta \{\theta > 0: (x, y/\theta) \in T\}$, respectively. If we take $g_y = 0$ and $g_x = x$ in equation (2), then the directional distance function can be represented by Shephard's input distance function, i.e., $\vec{D}(x, y: x, 0) = 1 - 1/D_i(x, y)$. Second, if we take $g_x = 0$ and $g_y = y$ in equation (2), then the directional distance function can be represented by Shephard's output distance function, i.e., $\vec{D}(x, y: 0, y) = 1/D_o(x, y) - 1$.

The shortage function and the directional distance function defined above can be estimated econometrically. However, econometric estimation requires assumptions on the functional form and the distribution of error terms. On the contrary, a nonparametric programming approach can be used to estimate $S(x, y, g_x, g_y)$ or $\vec{D}(x, y: g_x, g_y)$ without such assumptions.

Consider a set of observations on K firms, (x^k, y^k), $k = 1, \ldots, K$. Assume that the set T is convex and that the technology exhibits free disposal. When there is no assumption on the return to scale of the technology (variable return to scale: VRS),[9] a nonparametric representation of the technology is

$$T_{VRS} = \{(-x, y): \Sigma_{k=1}^K \lambda^k x^k \leq x,\ \Sigma_{k=1}^K \lambda^k y^k \geq y,\ \Sigma_{k=1}^K \lambda^k = 1, \\ \lambda^k \geq 0, k = 1, \ldots, K\}. \tag{3}$$

Then, a nonparametric estimate of the shortage function under VRS for k-th firm is

$$\begin{aligned} S_{VRS}^k(x^k, y^k, g_x^k, g_y^k) = \min_{\beta,\lambda} \{\beta: &\Sigma_{k=1}^K \lambda^k x^k \leq x^k + \beta g_x^k, \\ &\Sigma_{k=1}^K \lambda^k x^k \geq y^k - \beta g_y^k, \\ &\Sigma_{k=1}^K \lambda^k = 1, \\ &\lambda^k \geq 0, k = 1, \ldots, K\}. \end{aligned} \tag{4}$$

And the directional distance function can be estimated by solving the following linear programming problems. Here, the value of θ is a measure of "(technical) inefficiency," which represents the inability to produce maximum output given production resources and technology and, hence, the productivity (or performance) gap compared with the most efficient production unit.

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[9] For the technology with the constant return to scale, the equation (3) can be modified by eliminating $\Sigma_{k=1}^K \lambda^k = 1$. That is, under constant return to scale (CRS), the nonparametric representation of the technology is $T_{CRS} = \{(-x, y): \Sigma_{k=1}^K \lambda^k x^k \leq x,\ \Sigma_{k=1}^K \lambda^k y^k \geq y,\ \lambda^k \geq 0,$ $k = 1, \ldots, K\}$.

$$\vec{D}(x^k, y^k, g_x^k, g_y^k) = \max_{\theta,\lambda}\theta$$
$$\begin{aligned} s.t. \quad & \beta \textstyle\sum_{k=1}^{K}\lambda^k x^k \le x^k - \theta g_x^k, \\ & \textstyle\sum_{k=1}^{K}\lambda^k x^k \ge y^k + \theta g_y^k, \\ & \textstyle\sum_{k=1}^{K}\lambda^k = 1, \\ & \lambda^k \ge 0, k=1,\dots,K \end{aligned} \tag{5}$$

Following Chambers (1996) and Chambers et al. (1996a), we define Luenberger productivity indicator for k-th firm in equation (6) measuring productivity changes based on the directional distance function:

$$\begin{aligned} L(x_t^k, y_t^k, x_{t+1}^k, y_{t+1}^k) = \frac{1}{2}[&\vec{D}_{t+1}(x_t^k, y_t^k{:}\, g_x, g_y) - \vec{D}_{t+1}(x_{t+1}^k, y_{t+1}^k{:}\, g_x, g_y) \\ &+ \vec{D}_t(x_t^k, y_t^k{:}\, g_x, g_y) - \vec{D}_t(x_{t+1}^k, y_{t+1}^k{:}\, g_x, g_y)], \end{aligned} \tag{6}$$

where $\vec{D}_t(\cdot)$ and $\vec{D}_{t+1}(\cdot)$ represent the directional distance functions for the periods t and $t+1$, respectively. Note that for estimating productivity indicator, the input-output vector for the period $t(x^t, y^t)$ and for the period $t+1(x^{t+1}, y^{t+1})$ should be evaluated using different reference technologies, i.e. $\vec{D}_{t+1}(x^t, y^t)$ and $\vec{D}_t(x^{t+1}, y^{t+1})$. This can be represented by the following linear programming problems.

$$\vec{D}_{t+1}(x_t^k, y_t^k{:}\, g_x^k, g_y^k) = \max_{\theta,\lambda}\theta$$
$$\begin{aligned} s.t. \quad & \textstyle\sum_{k=1}^{K}\lambda^k x_{t+1}^k \le x_t^k - \theta g_x^k, \\ & \textstyle\sum_{k=1}^{K}\lambda^k y_{t+1}^k \ge y_t^k + \theta g_y^k, \\ & \textstyle\sum_{k=1}^{K}\lambda^k = 1, \\ & \lambda^k \ge 0, k=1,\dots,K \end{aligned} \tag{6-1}$$

$$\vec{D}_t(x_{t+1}^k, y_{t+1}^k{:}\, g_x^k, g_y^k) = \max_{\theta,\lambda}\theta$$
$$\begin{aligned} s.t. \quad & \textstyle\sum_{k=1}^{K}\lambda^k x_t^k \le x_{t+1}^k - \theta g_x^k, \\ & \textstyle\sum_{k=1}^{K}\lambda^k y_t^k \ge y_{t+1}^k + \theta g_y^k, \\ & \textstyle\sum_{k=1}^{K}\lambda^k = 1, \\ & \lambda^k \ge 0, k=1,\dots,K \end{aligned} \tag{6-2}$$

Note that the positive sign of Luenberger productivity indicator means productivity improvement and negative values are consistent with productivity declines. Following Chambers et al. (1996a), the Luenberger productivity indicator can be decomposed into two components, i.e., efficiency change (EFFCH) and technical change (TECH).

$$\text{EFFCH} = \vec{D}_t(x_t^k, y_t^k{:}\, g_x, g_y) - \vec{D}_{t+1}(x_{t+1}^k, y_{t+1}^k{:}\, g_x, g_y) \tag{7-1}$$

$$\text{TECH} = \frac{1}{2}[\vec{D}_{t+1}(x_{t+1}^k, y_{t+1}^k: g_x, g_y) - \vec{D}_t(x_{t+1}^k, y_{t+1}^k: g_x, g_y) + \vec{D}_{t+1}(x_t^k, y_t^k: g_x, g_y) - \vec{D}_t(x_t^k, y_t^k: g_x, g_y)] \tag{7-2}$$

This decomposition provides an empirical framework to investigate the nature of productivity changes. This is because technical change component (TECH) and efficiency change component (EFFCH) represent different sources of productivity changes, i.e., technology and efficiency. We make use of this framework in our empirical analysis in the subsequent sections.

Ⅲ. DATA

The data used for this study are obtained from the Mining and Manufacturing Survey for the period of 1991-2001 conducted by Korea National Statistics Office. This survey provides rich information on individual firms in manufacturing industry. This enables us to conduct an empirical analysis of production technology in Korean manufacturing industry over time across space. However, unfortunately the geographical information of individual firms is not disclosed for public use. So, we are only able to use aggregated data at local government level. We include 221 local governments among the total of 234 local governments to construct a complete balanced panel data set, and hence the total number of observations for this study is 2,431 (221 local governments for 11 years).

Table 1 shows summary statistics on output and inputs. We use real value added of manufacturing industries of each local government as an output measure. Value added is derived by subtracting direct production costs from the value of gross output in the survey data.[10] As inputs, three factors are included; labor, land, and capital. For a labor input measure, we use total employment which consists of annual average number of employees, working proprietors and unpaid family workers who work more than one-third of the normal operating hours per week. The lot size occupied by each industry for production activities is used for land input. Real capital stock is used as capital input. Capital stock is measured as the beginning year capital stock, i.e., total value of tangible fixed assets.[11]

Table 2 provides a descriptive summary of average growth rates of output and input. During the sample period, the manufacturing industry in Korea demonstrated 4.98 percent annual average growth in real value added and 2.92 percent in land use. Real capital stock increased at the rate of 8.24 percent

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[10] Direct production costs include raw material cost, fuel, water, electricity, purchased services, and maintenance cost. By using value added as output measure, we can avoid the possibility that the extent of outsourcing and use of own industry intermediate inputs may vary systematically with the size of the region (Henderson et al., 2001).

[11] The values of assets under construction and land are excluded.

annually, while the number of workers in the manufacturing industry decreased at the rate of 1.54 percent. Note that capital-labor ratio increased during the study period except the period of 1999~2000.

[Table 1] Summary Statistics of Inputs and Output

Variables	Average	Standard Deviation	Minimum	Maximum
Value Added (Million Won)	689,719	1,213,831	2,051	10,900,000
Land (m^2)	2,041,601	3,383,018	528	57,600,000
Labor (person)	12,058	16,910	88	107,972
Capital (Million Won)	603,860	1,184,187	1,285	12,500,000

[Table 2] Average Growth Rate of Inputs and Output (%)

Year	Value Added	Land	Labor	Capital
1991/1992	3.03	3.92	-4.25	13.28
1992/1993	5.39	16.45	2.75	19.29
1993/1994	10.80	-7.31	1.17	3.78
1994/1995	10.13	2.83	-5.51	-1.42
1995/1996	3.22	6.23	-3.18	9.43
1996/1997	0.58	3.09	-6.41	11.16
1997/1998	-6.29	-4.47	-14.02	11.89
1998/1999	14.76	4.82	7.92	12.55
1999/2000	10.54	-1.83	6.00	0.78
2000/2001	-2.34	5.49	0.12	1.66
Annual Average	4.98	2.92	-1.54	8.24

Ⅳ. ESTIMATION RESULTS

1. Technical Efficiency across Region over Time

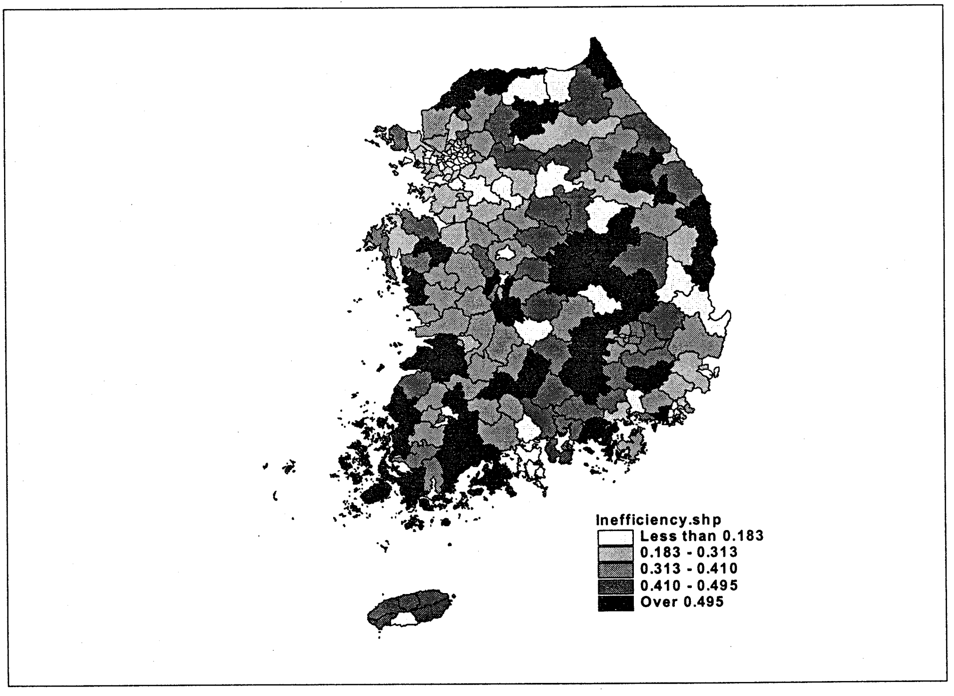
For solving the linear programming problems in equations (5), (6-1) and (6-2), we used each local government's observed inputs and outputs in that period as the direction, i.e., $g_x = x$ and $g_y = y$. Since the Luenberger productivity indicator is related to measures of technical efficiency, the mean inefficiency θ across regions over time is reported first in Table 3. Recall that the positive value of θ indicates the presence of technical inefficiency. The smaller the value of θ, the less inefficient, i.e., higher level of performance or productivity. Thus, the value of θ for an efficient firm should equal to zero. The overall mean of technical inefficiency measures for the manufacturing industry during the sample period is estimated as 0.3565. This indicates that on average, the netput of the manufacturing industry of local governments could have been increased by

0.3565 times of observed netput level if frontier technology were available.

The dynamics of technical efficiency measure is of interest in many aspects. In particular, this enables us to analyze the path of adjustments that manufacturing firms took in order to cope with the changes in economic environment. Even though there are some fluctuations (spikes or peaks), it seems that technical inefficiency has an increasing trend until the economic crisis, the IMF bail-out starting at the end of 1997. The mean technical inefficiency after the crisis, however, dropped to the level which is much lower than that of the early 1990s. This suggests that on average, the financial crisis might stimulate firms to improve production efficiency for their survival.

Table 3 also shows the regional variations of technical inefficiency. The manufacturing firms located in large metro-cities and in capital region generally performed better than those in other areas. Ulsan demonstrated the lowest technical inefficiency followed by Seoul, Incheon, Kyonggi, and Busan. Northen Jeolla province recorded the highest inefficiency followed by Northern and Southern Kyongsang province, Daejun and Northern Choongchung province, and Southern Jeolla province. Regional variations of inefficiency across space at the local level are summarized in Figure 1. It shows the geographical distribution of mean inefficiency measure for the whole sample period for 221 local governments.

[Figure 1] Mean Inefficiency of Local Manufacturing Industry



[Table 3] Technical Inefficiency across Region over Time

Region	N	Mean	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Seoul	242	0.1848	0.1919	0.1758	0.1621	0.2071	0.1746	0.1759	0.2438	0.1781	0.1477	0.2046	0.1713
Busan	132	0.3115	0.1911	0.2819	0.2664	0.3612	0.3294	0.3358	0.4275	0.2965	0.3032	0.3434	0.2895
Daegu	88	0.3549	0.2888	0.3485	0.3327	0.3851	0.4081	0.4037	0.3645	0.3301	0.2979	0.4073	0.3378
Incheon	77	0.2841	0.1932	0.2195	0.2486	0.3679	0.4197	0.3192	0.2470	0.2250	0.2860	0.3334	0.2657
Kwangju	44	0.3650	0.2770	0.3287	0.3173	0.3676	0.4277	0.4101	0.4747	0.4324	0.3435	0.3721	0.2640
Daejun	55	0.4122	0.3734	0.4236	0.4108	0.4962	0.4408	0.4542	0.4703	0.4032	0.3290	0.3818	0.3512
Ulsan	44	0.1508	0.0737	0.0630	0.1417	0.1894	0.2566	0.1980	0.1883	0.1027	0.1669	0.1755	0.1035
Kyonggi	341	0.2844	0.2346	0.2831	0.2578	0.3101	0.3767	0.3269	0.3109	0.2617	0.2527	0.2813	0.2328
Kangwon	198	0.3843	0.3421	0.3676	0.3902	0.4150	0.4049	0.4089	0.4398	0.4282	0.3465	0.3626	0.3210
N. Choongchung	132	0.3601	0.3307	0.3640	0.3447	0.3584	0.4656	0.4019	0.3842	0.3923	0.3001	0.3244	0.2946
S. Choongchung	176	0.4006	0.4712	0.4474	0.4221	0.4015	0.4453	0.4121	0.3893	0.4069	0.3474	0.3484	0.3153
N. Jeolla	154	0.3973	0.4350	0.4021	0.3958	0.3689	0.4220	0.3989	0.4234	0.4442	0.3345	0.3800	0.3659
S. Jeolla	242	0.4637	0.4713	0.4879	0.4922	0.4727	0.4758	0.4524	0.4954	0.4948	0.4135	0.4346	0.4103
N. Kyongsang	242	0.4348	0.4327	0.4645	0.4503	0.4496	0.5315	0.4860	0.4472	0.4441	0.3743	0.3632	0.3400
S. Kyongsang	220	0.4331	0.4460	0.4584	0.4743	0.4592	0.4947	0.4552	0.4204	0.4398	0.3578	0.3964	0.3534
Jeju	44	0.3812	0.4833	0.4860	0.3793	0.3976	0.4268	0.4230	0.3758	0.3435	0.2492	0.3138	0.3152
Mean	2431	0.3565 (0.1802)	0.3403 (0.1969)	0.3614 (0.1956)	0.3540 (0.1870)	0.3769 (0.1687)	0.4085 (0.1769)	0.3801 (0.1701)	0.3878 (0.1862)	0.3617 (0.1995)	0.3092 (0.1627)	0.3397 (0.1494)	0.3012 (0.1558)

Note : The numbers in the parenthesis are standard deviations.

2. Productivity Change and Its Decomposition

Table 4 summarizes the productivity change as well as its decomposition into efficiency change component and technical change component for each adjacent pair of years between 1991~2001. Note that the positive value of productivity change and its components denotes improvement, whereas the negative value represents regress or deterioration. Looking first at the bottom of Table 4, it is seen that the productivity increased with an average rate of 1.17 percent per year over the sample period. This productivity increase can be attributed to both technical progress (0.78%) and efficiency improvement (0.39%).

Next, in order to investigate the impacts of the economic crisis on the performance of local manufacturing firms, we compare the productivity change and its decomposition between two periods, before and after the economic crisis. Table 4 shows that the productivity growth rates in the year 1997 (0.4%) and 1998 (0.51%) are relatively low. In addition, the annual average productivity growth rate after the IMF bail-out is estimated as 1.06 percent per annum, which is lower than that of the period of 1991~1997 (1.25%). Relatively low productivity growth rate after the year of 1997 indicates that the economic crisis has negative impacts on the productivity of manufacturing industry. This provides empirical evidence that the performance of local manufacturing industry is closely related to the economic crisis. Table 4 also shows that the main source of productivity growth is switched between two periods; before the IMF bail-out (1991-1997), the main source of productivity growth (1.25%) is technical change (2.04%) whereas after the economic crisis, the productivity growth is mostly attributed to efficiency improvement (2.17%). Note also that efficiency growth rate is estimated as negative during 1991-1997. On the contrary, technical change is estimated as negative after the economic crisis (1998-2001). This suggests that on average, the adjustment path of local manufacturing firms confronting the economic crisis can be characterized by "efficiency improvement" rather than technical improvement. This finding is consistent with the decrease of firms' investment for technology improvement evidenced by a large decline of the growth of R&D (research and development) investment and the number of researchers during the economic crisis (Korea Institute of Science and Technology Evaluation and Planning, 2002).

Our next question concerns the regional variations of the dynamics of productivity change and its decomposition. Table 5 provides the annual average productivity growth rates and its decomposition across space over time and Figure 2 shows the geographical distribution of annual average productivity growth rates for 221 local governments. During the overall sample period, Jeju province and Southern Choongchung province recorded the highest productivity growth rate (2.5 percent per annum) followed by Northern Choongchung (1.84%), Northern Kyongsang (1.76%), Seoul (1.64%), and Ulsan (1.61%). In Jeju and Southern Choongchung, efficiency change is the main contributing

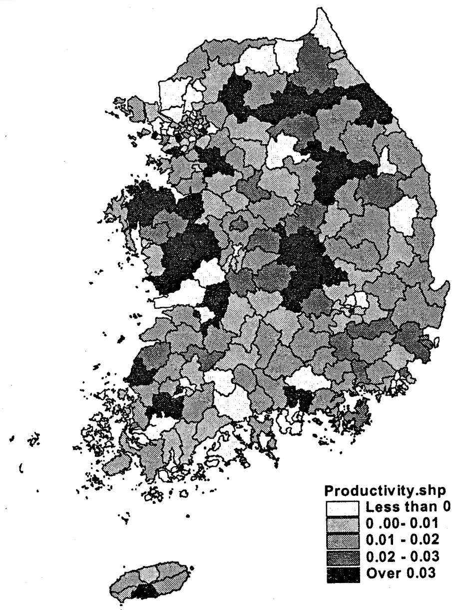
[Table 4] Productivity Change, Efficiency Change and Technical Change

Period	Productivity Change	Efficiency Change	Technical Change
1991~1992	0.0111	-0.0211	0.0322
1992~1993	0.0113	0.0074	0.0039
1993~1994	0.0175	-0.0229	0.0404
1994~1995	0.0186	-0.0317	0.0502
1995~1996	0.0124	0.0284	-0.0160
1996~1997	0.0040	-0.0077	0.0118
1997~1998	0.0051	0.0262	-0.0210
1998~1999	0.0179	0.0524	-0.0345
1999~2000	0.0226	-0.0304	0.0530
2000~2001	-0.0032	0.0386	-0.0418
Annual Average : 1991~1997	0.125	-0.0079	0.0204
Annual Average: 1997~2001	0.0106	0.0217	-0.0111
Annual Average : 1991~2001	0.0117	0.0039	0.0078

factor for productivity growth, while in Seoul, Kwangju, Ulsan, Kyonggi, and Northern Choongchung, technical change is largely attributable to their productivity growth. Before the IMF bail-out, Jeju recorded the highest productivity growth rate (3.95%) followed by Southern Choongchung (3.69), Ulsan (2.22), and Seoul (1.73), whereas Busan (-0.93), Kwangju (-0.98), Daejun (-0.29), and Kangwon (-0.1) suffered from a productivity decline. During this period, it appears that manufacturing firms in Jeju, Southern Choongchung and Northern Jeolla provinces were successful in improving technical efficiency, while other regions ended up with an efficiency decline. On the contrary, all regions recorded technical progress during this period.

During the 2nd period (1998-2001), efficiency improvements were identified as the major source of productivity growth in all regions except Incheon. Kwangju recorded the highest productivity growth rate (5.4%) followed by Kangwon (2.37), Northern Kyongsang (2.03), Northern Choongchung (1.87), Daejun and Southern Kyonsang (1.66). Productivity was estimated to be decreasing in Daegu, Inceon and Kyonggi province. Among them, Incheon has experienced both efficiency deterioration and technical regress. All regions except Kwangju suffered from technical regress during this period. In general, the regions with large improvement in production efficiency recorded higher productivity growth. It is also notable that Kwangju and Kangwon, where benefits from industrialization and economic development were believed to be relatively small, demonstrated the highest productivity growth after the economic crisis (1998-2001). Interestingly, efficiency improvement is identified as the major source of this productivity growth during this period. Recall that, in contrast, technical progress seemed to be the major contributing factor for productivity growth before the economic crisis (1991-1997).

[Figure 2] Annual Average Productivity Growth Rates of Local Manufacturing Industry



3. The Dynamics of Two Productivity Components

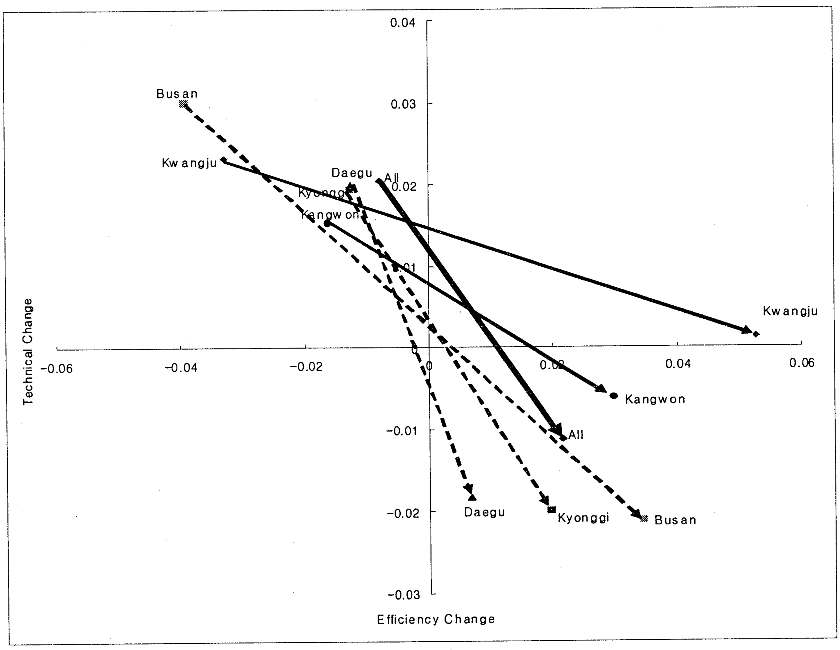
While the dynamics of productivity changes look very similar across regions, there exist significant differentials in the dynamics of the changes in two productivity components (efficiency and technology change) across regions. Figure 3 summarizes the dynamics of productivity changes between two periods (before and after the IMF bail-out), especially focusing on the relative changes in two components. The vertical axis represents technical change and the horizontal axis represents efficiency change. For example, the regions in the first quadrant represent regions with technical progress (+) and efficiency improvement (+), while the regions in the second quadrant records technical progress (+) and efficiency deterioration (-). Before the economic crisis, productivity growth can be characterized by technical progress and efficiency deterioration, because during this period, technical change has a positive value and efficiency change is associated with a negative value. The point labeled as "All" in the second quadrant represents the mean values of technical change and efficiency change components. On the contrary, during the 2nd period (after the IMF bail-out), the efficiency improvement is identified as a major component of productivity growth. This is represented by the point labeled as "All" in the fourth quadrant. The slope of the line connecting two points indicates the ratio of technical change to efficiency change, measuring the dynamics of relative changes in two

[Table 5] Annual Average Productivity Change and Its Decomposition by Region by Period

Region	1991~2001			1991~1997			1997~2001		
	Productivity Change	Efficiency Change	Technical Change	Productivity Change	Efficiency Change	Technical Change	Productivity Change	Efficiency Change	Technical Change
Seoul	0.0164	0.0021	0.0143	0.0173	-0.0086	0.0259	0.0150	0.0183	-0.0034
Busan	-0.0002	-0.0098	0.0098	-0.0093	-0.0394	0.0301	0.0135	0.0345	-0.0210
Daegu	-0.0002	-0.0049	0.0047	0.0074	-0.0126	0.0200	-0.0116	0.0067	-0.0183
Incheon	0.0015	-0.0072	0.0087	0.0078	-0.0090	0.0167	-0.0080	-0.0047	0.0033
Kwangju	0.0158	0.0013	0.0145	-0.0098	-0.0330	0.0232	0.0540	0.0527	0.0014
Daejun	0.0049	0.0022	0.0027	-0.0029	-0.0161	0.0132	0.0166	0.0298	-0.0132
Ulsan	0.0161	-0.003	0.0191	0.0222	-0.0191	0.0413	0.0070	0.0212	-0.0142
Kyonggi	0.0039	0.0002	0.0037	0.0067	-0.0127	0.0194	-0.0003	0.0195	-0.0199
Kangwon	0.0089	0.0021	0.0068	-0.0010	-0.0163	0.0153	0.0237	0.0297	-0.0060
N. Choongchung	0.0184	0.0036	0.0148	0.0182	-0.0089	0.0271	0.0187	0.0224	-0.0037
S. Choongchung	0.0250	0.0156	0.0094	0.0369	0.0136	0.0232	0.0072	0.0185	-0.0113
N. Jeolla	0.0121	0.0069	0.0052	0.0146	0.0019	0.0127	0.0084	0.0144	-0.0060
S. Jeolla	0.0104	0.0061	0.0043	0.0153	-0.0040	0.0193	0.0031	0.0213	-0.0182
N. Kyongsang	0.0176	0.0093	0.0083	0.0158	-0.0024	0.0182	0.0203	0.0268	-0.0066
S. Kyongsang	0.0143	0.0092	0.0051	0.0129	-0.0007	0.0136	0.0166	0.0242	-0.0077
Jeju	0.0252	0.0168	0.0083	0.0395	0.0179	0.0216	0.0036	0.0151	-0.0115

productivity components. Note that a region represented by a steep (flat) and downward slope can be seen as one experiencing large (small) "trade-offs" between technical change and efficiency change. In other words, when the slope of a line connecting two points (before and after the economic crisis) is negative and steep, it can be interpreted as achieving relatively small efficiency improvement with a cost of large decrease in technical progress.

[Figure 3] The Dynamics of Productivity Change and Its Components



Many regions can be represented by a downward slope (from the second quadrant to the fourth quadrant). Figure 3 shows the dynamics of two components of six representative regions; Daegu, Busan, Kyonggi, Kangwon, and Kwangju. It indicates that the type of productivity changes in Kwangju and Kangwon is quite different from that of Daegu, Busan, and Kyonggi. In these two regions, production efficiency is estimated to increase faster at a cost of relatively small technical regress, i.e., small trade-offs. This small trade-off between efficiency improvement and technical regress might have implications beyond economic factors. Admittedly, in the past, these regions were considered to enjoy less benefits from economic growth compared to the east side of Korean peninsular, e.g., Kyongsang province. Considering new political leadership of Kim Dae-Jung administration started from 1998, this observation might reveal favorable evidence on the unbalanced regional development hypothesis. This argument is consistent with the fact that relatively large trade-offs reflected by a steeper line in Daegu and Busan are reported in Figure 3. Our analysis indicates that changes in political environments in the late 1990s might have non-negligible effects on the performance of regional industry.

V. CONCLUDING REMARKS

Using the panel data obtained from the Mining and Manufacturing Survey for the period of 1991-2001, this analysis has investigated the performance of Korean manufacturing industry across region over time, especially focusing on the dynamics of productivity changes between pre- and post-economic crisis. We used a frontier production function approach. Specifically, we modeled production technology using a directional distance function approach, a version of Luenberger shortage function. The estimated productivity changes are then decomposed into efficiency changes and technical changes.

The findings of our analysis are as follows. First, the overall mean technical inefficiency measure for manufacturing industry during the sample period is estimated to be 0.3565, suggesting that the netput of manufacturing industry of local governments could have been increased by 0.3565 times of observed netput level. Technical inefficiency appears to increase until the economic crisis and dropped significantly during the crisis. This implies that the financial crisis may have significant impacts on firms' performance in a way that it tends to improve production efficiency. Second, manufacturing firms located in large metro-cities and in capital region generally perform better than those in other areas. Third, productivity increased with an average rate of 1.17 percent per annum over the sample period, which is largely attributable to technical progress (0.78 percent) compared to efficiency improvement (0.39 percent). Relatively low productivity growth rates in 1997 and 1998 represent that the economic crisis has negative impacts on the performance of manufacturing industry. Before the IMF bail-out, the major source of productivity growth is technical change. In contrast, post-economic crisis period, productivity growth can mostly be explained by efficiency improvement. Next, we found that during pre-economic crisis period, Southern Choongchung and Northern Jeolla improved its technical efficiency, while other regions suffered from efficiency decline. During post-economic crisis period, efficiency improvements were attributable to productivity growth in all regions except Incheon. It is notable that Kwangju recorded the highest productivity growth rate followed by Kangwon, Northern Kyongsang, Northern Choongchung, Daejun and Southern Kyonsang.

Finally, we attempted to categorize the dynamics of the changes in two productivity components (efficiency and technology) across regions. We found that the dynamics of changes in two components in Kwangju and Kangwon is quite different from that of Daegu, Busan, Kyonggi, and S. Choongchung. Our results show that manufacturing firms in Kwangju and Kangwon (where the benefits from economic growth are believed to have been small) demonstrated relatively "small trade-offs" between efficiency and technical change. This provides indirect evidence of non-negligible effects of the changes in political environments in the late 1990s on the performance of regional industry.

This study could be extended in several ways. Identifying the determinants of the technical inefficiency and productivity change estimated in this study is of interest in the sense that it will allow us to test econometrically unbalanced regional development hypothesis. Secondly, if one uses more micro-level manufacturing industry data, it might provide richer information in analyzing the manufacturing industry at the disaggregated level such as two or three digits.

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