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The Comparative Study on Efficiency of the Large-sized Cities in Korea and China*

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This study measures the efficiency of the Korean and Chinese large-sized cities and then explores implications about two countries' cities efficiency. We apply two approaches to measure the efficiency, DEA (data envelopment analysis) and SFA (stochastic frontier analysis). Main finding facts of this paper are as follows. (i) Korean cities have IRS trends, but Chinese cities have DRS trend during the last 10 years. (ii) Beijing showed relatively lower efficiency in both DEA and SFA models. (iii) In Korea, also Seoul's efficiency values are relatively low in SFA method, but relatively high in DEA method. (iv) The efficiency of two Korean cities — Busan and Daegu — has been decreasing over time in DEA and SFA model.

JEL Classification: R11, R12, O18, O40
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1. INTRODUCTION

More than five decades ago, Korean economy stayed in the very underdeveloped state. By adopting export-led industrialization strategy, however, South Korea has achieved miraculously fast economic growth which has not been experienced ever before World War II in the world economic history. Despite the debate about the roles of exports in stimulating economic growth, there has been some consensus about the contributions of exports to economic growth among economists and practitioners. Due to the fast economic growth, Korean people's living standards have also been improved much faster than ever. Other Asian countries such as China and Thailand have followed the track of Korea.[1)] These countries have the common characteristics in that their governments have adopted the outward-looking and export-oriented development strategies and pursued the economic development through international trade.[2)] According to Wacziarg and Welch (2008), over the 1950-1998 periods, countries that liberalized their trade regimes experienced average annual growth rates that were about 1.5 percentage points higher than before liberalization.

In Asian countries, economic growth has been accompanied by rapid cities growth. There must be a close connection between economic growth and urbanization. Openness to trade and globalization strengthens the role of central cities as command-and-control posts in international networks of capital, services, and information trade. The easy access to resources such as labor, extensive business networks, and cutting-edge research performed at institutes of higher learning attracts both capital and entrepreneurs to urban

[1)] Japan was the first non-western country to achieve national richness. Four countries — Hong Kong, Singapore, South Korea and Taiwan have been success stories in the world economic history. All four countries were similar in terms of economic development and at the level of African countries as late as 1950s. About more explanation, see Paldam (2003).

[2)] According to Wacziarg and Welch (2008), just 22 percent of all countries, representing just 21 percent of the world's population, had outward-looking trade policies in 1960, but by 2000, some 73 percent of countries, representing 46 percent of world's population, adopted the those policies.

areas. Consequently, metro areas are often at the center of the development of many new technologies, like biotechnology. Metro areas also offer new industries crucial amenities, including a diverse and ample supply of labor, financial and physical capital, access to national and international markets, and a local base of technical knowledge.[3)]

Asian countries have liberalized and globalized their economies toward the world markets and also urbanized their rural economies very rapidly. They have reduced various city entry barriers in terms of economic and non-economic aspects and provided many incentives to live in the city. In particular, rapid growth of city's infrastructures has made large contributions to the decreasing transport costs in metro areas rather than rural areas. The efficient transportation and lower logistics cost have been based on the rapid economic growth of their national economy. Recently we have seen increasing number of academic articles about city growth and efficiency. In particular, East Asian countries' policy makers are interested in city growth and efficiency because of accelerating investments on the city's infrastructure, accompanied by rapid globalization in these areas. This study measures an efficiency of the Korea and China's large-sized cities at the first time by using DEA (data envelopment analysis) and SFA (stochastic frontier analysis). For several decades, many researchers have tried to find out the efficiency of production and cost, using one method such as DEA or SFA. But these empirical results have not given us some confidence of robust results, because different approaches have always the possibility to show different or inconsistent results. Recently, many researchers have tried to present more robust empirical results comparing one method's results with the others. Therefore, we apply two methods of efficiency measurement to China and Korea's cities and try to find out more robust results. Then we explore some implications about efficiency differences among the Korean and Chinese cities, using panel data from 1995 to 2006. The next section discusses the theoretical literature about efficiency

[3)] For the economic development of city areas, see Robert Cervero (2006).

measurement. Section 3 outlines research methodology related to this study. Section 4 presents data and empirical results. Section 5 draws some policy implications and concludes.

2. A LITERATURE REVIEW

The previous literature about efficiency is not extensive compared with the literature about other infrastructure's efficiency. The efficiency can be expressed by the comparison of many inputs and many outputs. Generally, the DEA (data envelopment analysis) and SFA (stochastic frontier analysis) are utilized in measuring the efficiency among decision-making units (DMUs). These alternative methods are based on production or cost frontier models. In DEA method, two kinds of DEA method are utilized. The one is DEA-CCR model proposed by Charnes, Cooper and Rhodes (1978). The other is the DEA-BCC model by Banker, Charnes and Cooper (1984). Roll and Hayuth (1993) and Tongzon (2001) are using DEA-CCR model. Martinez *et al*. uses DEA-BCC model. Park and De (2004), Barros and Athanassiou (2004), Cullinane, Ji, and Wang (2005) are using both the DEA-CCR and DEA-BCC models. In SFA, there are two kinds of methods according to the assumed functional forms such as Cobb-Douglas functions and Translog functions. Cullinane, Song, and Gray (2002), and Tongzon and Heng (2005) assumes the Cobb-Douglas functions. Liu (1995), Coto *et al*. (2000) and Barros (2005) assume the Translog functions. Estasche *et al*. (2002) measures the efficiency using Cobb-Douglas and Translog functions. There are some authors using both DEA and SFA methods, who are Cullinane *et al*. (2006) and Lin and Tseng (2005).

3. METHODOLOGY

DEA can be roughly defined as a nonparametric method of measuring the efficiency of a Decision Making Unit (DMU) with multiple inputs and/or multiple outputs. This is achieved by constructing a single 'virtual' output to a single 'virtual' input without pre-defining a production functions. The DEA-CCR model was first proposed by Charnes *et al*. (1978), which assumes CRS (constant returns to scale). We call it DEA-CRS model. The DEA-CCR model was first proposed by Banker *et al*. (1984), which assumes VRS (variable returns to scale). We call it DEA-VRS model.

Let's assume that there are N cities (DMUs), each producing J different outputs employing I different inputs. Also, let's assume that x_i represents the amount of input employed and y_i represents the amount of output produced by the i-th cities. Thus, the data of all cities in the sample are represented by the $J \times N$ output matrix, Y, and $I \times N$ input matrix, X. Since there are N cities, the linear programming problem is solved N times, once for each city in the sample.

The DEA-CRS Technical Efficiency (DEA-CRS Model): To simplify the problem, let's consider that these N cities, operate under the CRS and employ three inputs $(X_j, j = 1, 2, 3)$ to produce single output (Y). The formal problem for the technical efficiency (TE) can conveniently be expressed in the following way:

$$\begin{aligned} &\text{Min}_{\ TE,\, w}\ TE_i \\ &\text{s.t.}\ \ Y \cdot w_i \geq y_i, \\ &\qquad X_j \cdot w_i \leq TE_i \cdot x_i,\ \ j = 1,\ 2,\ 3, \\ &\qquad w_i \geq 0, \end{aligned} \qquad (1)$$

where TE_i, is a scalar and represents the technical efficiency measure (index) for the i-th city. w_{ij} is the $1 \times N$ vector of intensity weights defining the linear combination of efficient cities to be compared with the i-th city. The inequality $(Y \cdot w_i \geq y_i)$ implies that the observed outputs must be less or equal to a linear combination of outputs of the cities forming the efficient frontier. The inequality $(X_j \cdot w_i \geq TE_i \cdot x_i)$ assures that the use of inputs at the linear combination of the efficient cities must be less or equal to the use of inputs of the *i*-th city. The formulation will show that $TE_i \leq 1$. According to the Farrel (1957), an index value of 1 refers to a point on the frontier and thus to a technically efficient city.

The VRS Technical Efficiency (DEA-VRD Model): The CRS assumption will be incorrect if all cities are not operating at an optimal scale. In this case, the CRS specification will bias the estimation of the technical efficiency by confounding scale effects. But, the substitution of the CRS with variable returns to scale (VRS) assumption brings about the estimation of the pure technical efficiency (PTE), i.e., *TE* devoid of the scale effects. This can be achieved by adding a convexity constraint $(N_1 \cdot w_i = 1)$ to (1) which allows VRS as demonstrated below:

$$\begin{aligned} &\text{Min}_{\ TE,\,w}\ TE_i \\ &\text{s.t. } Y \cdot w_i \geq y_i, \\ &\quad X_j \cdot w_i \leq TE_i \cdot x_i,\ \ j = 1,\ 2,\ 3, \\ &\quad N_1 \cdot w_i = 1, \\ &\quad w_i \geq 0, \end{aligned} \qquad (2)$$

where N_1 is an $1 \times N$ vector of ones. The VRS frontier obtained this way envelops the data more tightly than the CRS frontier and thus generates technical efficiency scores which are greater than or equal to those obtained from the CRS frontier.

The Scale Efficiency: If there is a difference between the CRS technical efficiency (*CRSTE*) and the technical efficiency (*VRSTE*) for a specific city, then this means that the city has scale inefficiency. The scale inefficiency (*SE*) for the city, thus, can be computed from the difference between the *CRSTE* and the *VRSTE*. Since, *CRSTE* = *VRSTE***SE*, then, *SE* = *CRSTE* / *VRSTE*. We use the software DEAP 2.1 to measure DEA's efficiency.[4)]

[4)] This software can be freely downloaded from the website http://www.uq.edu.au/economics/

The Stochastic Frontier Analysis Model: In order to estimate the technical efficiency of city production by Stochastic Frontier Analysis (SFA), we assume translog production frontier function, which is estimated by using Maximum likelihood techniques to examine factors influencing the output of city production. The stochastic translog production frontier can be written as

$$\ln(Y_i) = \beta_0 + \sum_i \beta_i \ln X_i + \sum_i \sum_j \beta_{ij} \ln X_i \ln X_j + \varepsilon_i, \qquad (3)$$

where Y_i is output of the DMU_i, X_{ij} is the *j* input used by DMU_i. The essential idea behind the stochastic frontier model is that ε_i is a "composed" error term. The error term (ε_i) is now defined as

$$\varepsilon_i = v_i - u_i, \qquad (4)$$
$$i = 1, \ ..., \ N, \ \ N = 84,$$

where v_i is a two-sided $(-\infty < v < \infty)$ normally distributed random error $(v \sim N[0, \ \sigma v^2])$ that captures the stochastic effects outside the cities' control (e.g., business cycles, cities' physical conditions, and government policy changes), measurement errors, and other statistical noise. The term u_i is a one-sided $(u \geq 0)$ efficiency component that captures the technical inefficiency of the city. In other words, u_i measures the shortfall in output Y_i from its maximum value given by the stochastic frontier $\ln(Y_i) = \beta_0 + \sum_i \beta_i \ln X_i + \sum_i \sum_j \beta_{ij} \ln X_i \ln X_j + v_i$. This one-sided term can follow such distributions as half-normal, exponential, and gamma.

In this study, it is assumed that u_i follows a half-normal distribution $(u \sim N[0, \ \sigma v^2])$ as it is typically done in the applied stochastic frontier literature. The two components v_i and u_i are also assumed to be independent each other. The maximum likelihood estimation of equation

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cepa/deap.htm

(4) yields consistent estimators for β, λ, and σv^2, where β is a vector of unknown parameters, $\lambda = \sigma u / \sigma v$, and $\sigma u = \sigma u^2 + \sigma v$.

Cities' specific technical efficiency will be obtained by using the relationship:

$$TE_i = \exp(\hat{u}_i / \sum_i \beta_i) = \exp(-E(u_i / \sum_i B_i). \qquad (5)$$

In this equation, we can assume constant returns to scale (SFA-CRS Model) or various returns to scale (SFA-VRS Model) according to the assumption that $\sum \beta_i$ *equals to* 1 *or not*. We derive the estimates for v and u by replacing ε, σ^*, and λ in equations (3) and (4). Subtracting v from both sides of equation (3) yields the stochastic production frontier.

$$\ln(Y_i^*) = \beta_0 + \sum_i \beta_i \ln X_{ij} + \sum_i \sum_j \beta_{ij} \ln X_i \ln X_j - u_i = \ln(Y_i) - v_i, \qquad (6)$$

where $\ln(Y_i^*)$ is defined as the farm's observed output adjusted for the statistical noise contained in v_i.

Given the specifications of the stochastic frontier production function, defined by equation (6), the null hypothesis, that technical inefficiency is not present in the model, is expressed by H_0: $\gamma = 0$, where γ is the variance ratio, explaining the total variation in output from the frontier level of output attributed to technical efficiencies and defined by $\gamma = \sigma_u^2 / (\sigma_v^2 + \sigma_u^2)$. This is done with the calculation of the maximum likelihood estimates for the parameters of the stochastic frontier model by using the computer program FRONTIER Version 4.1 (Coelli, 1996).[5)] The parameter γ must lie between 0 and 1. If the null hypothesis is accepted, this would indicate that σ_u^2 is zero and hence that the U_{it} term should be removed from the model, leaving a specification with parameters that can be consistently estimated

[5)] This software can be freely downloaded from the website http://www.uq.edu.au/economics/cepa/frontier.htm. For the manual, see Coelli (1996).

using ordinary least squares. These hypotheses are tested using the generalized likelihood ratio test and the generalized likelihood ratio statistic, λ is defined by $\lambda = -2\ln[L(H_0)/L(H_1)]$, where H_0 and H_1 are the null and alternative hypotheses involved. If the null hypothesis, H_0, is true, then λ is asymptotically distributed as a Chi-square (or mixed Chi-square) random variable. If the null hypothesis involves $\gamma = 0$, then λ has mixed Chi-square distribution (see Coelli, 1995 and 1996) because $\gamma = 0$ is a value on the boundary of the parameter space for γ.

4. EMPIRICAL RESULTS

4.1. The Data

In this paper we assume three inputs and single output. Output is y_1 (= gross regional product (*GRP*), and Inputs are x_1 (= capital (*K*)), x_2 (= labor (*L*)), and x_3 (= city government expenditure (*G*)). We selected seven largest cities in Korea and China, which are Seoul, Busan, Daegu, and Incheon in Korea and Beijing, Tianjin and Shanghai in China. Chongqing city is excluded because it was separated from Sichuan Province in 1997, and has no adequate serial data of fixed capital formation. We use the cities' annual panel data, for the years 1995 to 2006.[6)]

We collected the all data from the statistical yearbooks of two countries except capital, such as Gross Regional Domestic Product and Expenditure (each year) of Korea Statistical Office, China Compendium of Statistics 1949-2004 of China Statistics Press (2005), and China Statistical Yearbook of China Statistics Press.

[6)] DEA literature distinguishes between three types of frontiers, the contemporaneous, sequential and intertemporal frontiers. Our study adopted the intertemporal frontiers, in which a DMU in a one period and the same DMU in different periods are treated as different DMUs. In these frontiers an efficiency gain or loss over time can be interpreted as technical progress or regress. For more detail, see Los and Timmer (2005).

Table 1 Current Situations of Selected Cities (2006)

Cities	Population (1,000 Persons)	Per GRP (Yuan)	Area (Km^2)
Seoul	10,181	134,115	606
Busan	3,612	97,350	760
Daegu	2,496	79,441	885
Incheon	2,620	111,991	993
Beijing	15,810	50,467	16,800
Tianjin	10,750	41,163	11,000
Shanghai	18,150	57,695	6,350

Table 2 Summary of the Input and Output Variables

Variable	Description	Unit	Average	Min.	Max.	C.V.
Y (GRP)	Gross Regional Product	Billion Yuan	394.6	94.5	1,365.5	0.83
x_1 (C)	Capital	Billion	12,444	69.7	666,017	1.35
x_2 (L)	Labor	Million	0.98	10.8	4.17	0.68
x_3 (G)	Local Gov't Expenditure	Billion	0.5	1.6	0.09	0.74

Note: C.V. means coefficient of variation.

We use labor as total number of employed person in each city. Capital data are calculated by using the formula $K_t = (1-d)K_{t-1} + I_t$, where d denotes a constant percentage rate of depreciation and I_t denotes total investment in fixed assets at each city during period t. We assume that d is 0.01.[7)]

[7)] There are many different opinions on the depreciation rate of capital assets among economist, but, in here, we simply assume that new capital assets have maintained for 10

Summary information on the input and output variables is shown in table 2. All money values are transformed into the constant values of the year 2000 applying Chinese currency exchange rate to Korean currency.

4.2. DEA and SFA Results

Table 3 and figure 1 shows the efficiency levels which are measured from the assumptions of CRS and VRS by using input-oriented DEA methods. The average efficiency of DMU6 (Tianjin) are highest in both CRS and VRS model. DMU1 (Seoul) is second highest in both models.

Table 3 The efficiency Levels of Input-oriented DEA CRS and DEA VRS Models

	DMU1		DMU2		DMU3		DMU4		DMU5		DMU6		DMU7	
	CRS	VRS	CRS	VRS	CRS	VRS	CRS	VRS	CRS	VRS	CRS	VRS	CRS	VRS
1995	1.000	1.000	0.801	0.882	0.895	1.000	1.000	1.000	0.905	0.925	1.000	1.000	0.989	1.000
1996	0.963	0.963	0.760	0.836	0.831	0.991	0.916	0.952	0.890	0.894	1.000	1.000	0.928	0.959
1997	0.930	0.935	0.634	0.811	0.672	1.000	0.782	1.000	0.824	0.826	1.000	1.000	0.884	0.927
1998	0.980	0.986	0.635	0.823	0.719	1.000	0.677	1.000	0.798	0.799	0.994	0.998	0.881	0.938
1999	1.000	1.000	0.731	0.827	0.786	1.000	0.721	0.983	0.692	0.744	0.974	0.982	0.863	0.940
2000	0.935	0.940	0.677	0.849	0.683	0.955	0.771	1.000	0.732	0.739	1.000	1.000	0.903	0.992
2001	0.896	0.903	0.670	0.839	0.638	0.905	0.689	0.950	0.728	0.739	1.000	1.000	0.934	0.943
2002	0.926	0.929	0.677	0.777	0.673	0.927	0.724	0.945	0.701	0.705	0.975	0.976	0.936	0.940
2003	0.909	0.912	0.706	0.823	0.667	0.904	0.720	0.933	0.677	0.680	0.958	0.959	0.963	0.966
2004	0.950	0.951	0.716	0.798	0.717	0.875	0.771	0.893	0.667	0.668	0.934	0.937	0.959	0.964
2005	0.953	0.954	0.723	0.799	0.727	0.859	0.796	0.886	0.936	1.000	1.000	1.000	1.000	1.000
2006	1.000	1.000	0.779	0.845	0.735	0.849	0.825	0.885	0.928	0.983	1.000	1.000	1.000	1.000
Mean	0.954	0.956	0.709	0.826	0.729	0.939	0.783	0.952	0.790	0.809	0.986	0.988	0.937	0.964

Note: DMU1=Seoul, DMU2=Busan, DMU3=Daegu, DMU4=Incheon, DMU5=Beijing, DMU6=Tianjin, and DMU7=Shanghai.

years. Capital stock of each city in 1995 is accumulated value for 10 years from 1985 by using formula of $K_t = (1-d)K_{t-1} + I_t$. However, data of total investment in fixed assets of South Korea is only available from 1995. Therefore, we estimate average rate of investment of each city from 1995 to 1998 and use that estimated rate to the national total investment in fixed assets to get the capital stock data.

Figure 1 DEA-CRS Efficiency Level Trends of Seven Cities

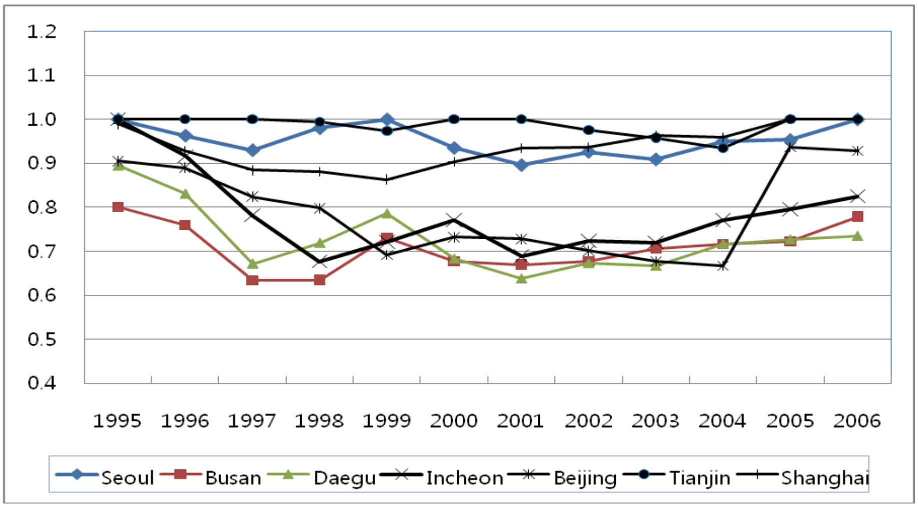
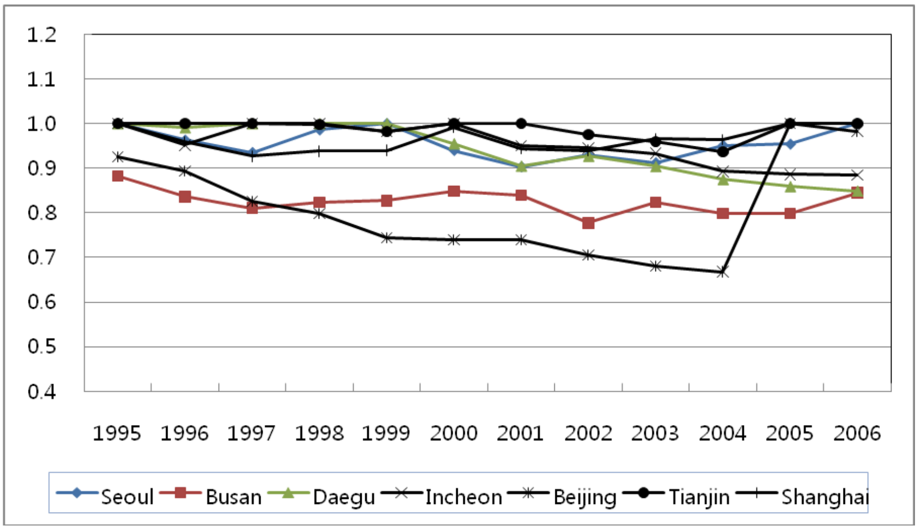


Figure 2 DEA-VRS Efficiency Level Trends of Seven Cities



The average efficiency of DMU2 (Busan) and DMU5 (Beijing) are relatively lower in both models. In DMU2 (Busan) and DMU3 (Daegu), the difference between CRS and VRS model are relatively large and show

Table 4 The Efficiency Levels of SFA's Translog Models

Independent Variables	SFA Translog Dependent Variables Log (*GRP*)	
Constant	0.178***	(3.131)
log(*K*)	0.626***	(16.211)
log(*L*)	1.068***	(7.854)
log(*G*)	–0.054	(–0.488)
log(*K*)log(*L*)	0.238***	(5.299)
log(*K*)log(*G*)	–0.232***	(–7.026)
log(*L*)log(*G*)	–0.621***	(4.159)
log(*K*)log(*K*)	0.099***	(13.357)
log(*L*)log(*L*)	0.644***	(5.801)
log(*G*)log(*G*)	0.125**	(2.085)
σ^2	0.029***	(5.201)
γ	0.986***	(12.558)
Log Likelihood	79.578	
LR	5.873	

Note: ***, **, * = significance at 1%, 5%, 10% level.

decreasing trends over time. DMU1 and DMU6 show relatively similar results in the CRS and VRS model.

The efficiency measures of VRS are higher than those of CRS, which can be evident from the definition of VRS. The efficiency of DMU1 has been rapidly increasing over time.

Table 4 shows maximum likelihood estimation (MLE) results from SFA methods. We estimated parameters using FRONTIER 4.1. which is considering half-normal and truncated-normal distributions about u_i's. We use half-normal distributions. All coefficients except log(*G*) are significant at the 1% or 5% significance level of *t* distribution. The coefficients of log(*K*) and log(*L*) are positive, which means output-increasing effects of factors, which is consistent with economic theory.

But the coefficient of log(G) is negative and statistically insignificant. It seems that the impact of government expenditure on cities' GRP is limited and not significant. The LR values of SFA are 5.873, which is larger than the critical value 5.02 of χ^2 distribution at the 5% two-sided hypothesis test. It means that $H_0: \gamma = 0$ is rejected. So there exists some technical inefficiency effect. Therefore, we can measure the efficiency of translog model using stochastic frontier analysis.

Table 5 shows the results of measurement. Similar to the DEA model, DMU5's (Beijing) average efficiency are lowest. In contrast to DEA model, the averages of VRS's efficiency of DMU2 (Busan) and DMU3 (Daegu) are higher compared with other DMUs.

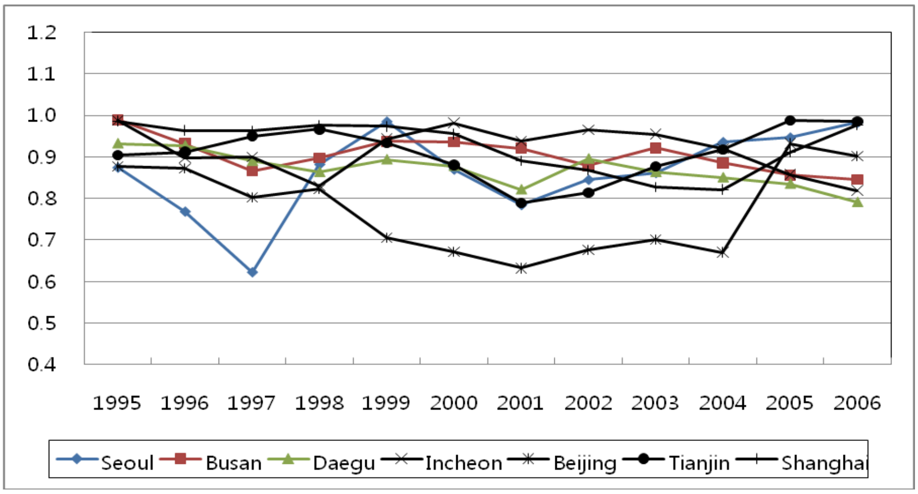
Three cities, DMU2, DMU3 and DMU5, have the decreasing trends over time.

Table 5 The Efficiency Levels of SFA's Translog Models

	DMU1	DMU2	DMU3	DMU4	DMU5	DMU6	DMU7
1995	0.873	0.989	0.931	0.987	0.877	0.904	0.986
1996	0.768	0.932	0.926	0.897	0.872	0.911	0.963
1997	0.621	0.865	0.889	0.899	0.802	0.950	0.962
1998	0.881	0.897	0.862	0.830	0.822	0.966	0.976
1999	0.985	0.937	0.893	0.943	0.705	0.933	0.973
2000	0.869	0.935	0.877	0.981	0.671	0.880	0.955
2001	0.783	0.920	0.821	0.938	0.632	0.789	0.890
2002	0.844	0.878	0.895	0.965	0.676	0.814	0.868
2003	0.861	0.921	0.863	0.954	0.700	0.876	0.827
2004	0.935	0.885	0.850	0.919	0.670	0.918	0.821
2005	0.946	0.855	0.835	0.857	0.932	0.987	0.911
2006	0.982	0.845	0.790	0.819	0.902	0.985	0.977
Mean	0.862	0.905	0.869	0.916	0.772	0.909	0.926

Note: DMU1=Seoul, DMU2=Busan, DMU3=Daegu, DMU4=Incheon, DMU5=Beijing, DMU6=Tianjin, and DMU7=Shanghai.

Figure 3 SFA Efficiency Level Trends of Seven Cities



The differences among cities in SFA model are relatively smaller than in the DEA models. Because econometric method permits error terms, it can exclude some irregular fluctuation from dependent variable. So the difference of SFA model seems to be smaller than those of DEA models.

From these results of DEA and SFA, we can calculate the correlation between two methods. The correlation between DEA-CRS and DEA-VRS efficiency levels is 0.64. The correlation between DEA-CRS and SFA efficiency levels is 0.30 and the correlation between DEA-VRS and SFA efficiency levels is 0.60. Therefore, DEA-VRS has relatively higher correlations with other methods and SFA method has closer similarity with DEA-VRS methods.

4.3. Scale Efficiency and Returns to Scale

Table 6 shows that scale efficiency (*SE*) and returns to scale (*RTS*). In terms of scale efficiency, DMU2's, DMU3's and DMU4's average values are lower than other DMUs' values. This phenomenon is related to the city size. Compared with Chinese cities, Korean cities' population sizes are smaller except Seoul.

Table 6 Scale Efficiency (*SE*) of DEA Model

	DMU1	DMU2	DMU3	DMU4	DMU5	DMU6	DMU7
1995	1.000	0.908	0.895	1.000	0.978	1.000	0.989
1996	0.999	0.908	0.838	0.962	0.995	1.000	0.967
1997	0.994	0.782	0.672	0.782	0.997	1.000	0.953
1998	0.995	0.771	0.719	0.677	0.999	0.997	0.939
1999	1.000	0.883	0.786	0.733	0.930	0.991	0.918
2000	0.994	0.797	0.716	0.771	0.991	1.000	0.910
2001	0.993	0.798	0.706	0.725	0.985	1.000	0.990
2002	0.996	0.871	0.726	0.766	0.994	0.999	0.996
2003	0.997	0.858	0.738	0.771	0.996	0.999	0.997
2004	0.998	0.898	0.820	0.863	0.998	0.997	0.994
2005	0.999	0.904	0.846	0.898	0.936	1.000	1.000
2006	1.000	0.922	0.866	0.932	0.943	1.000	1.000
Mean	0.997	0.858	0.777	0.823	0.976	0.999	0.971

Note: DMU1=Seoul, DMU2=Busan, DMU3=Daegu, DMU4=Incheon, DMU5=Beijing, DMU6=Tianjin, and DMU7=Shanghai.

Figure 4 Scale Efficiency Level Trends of Seven Cities

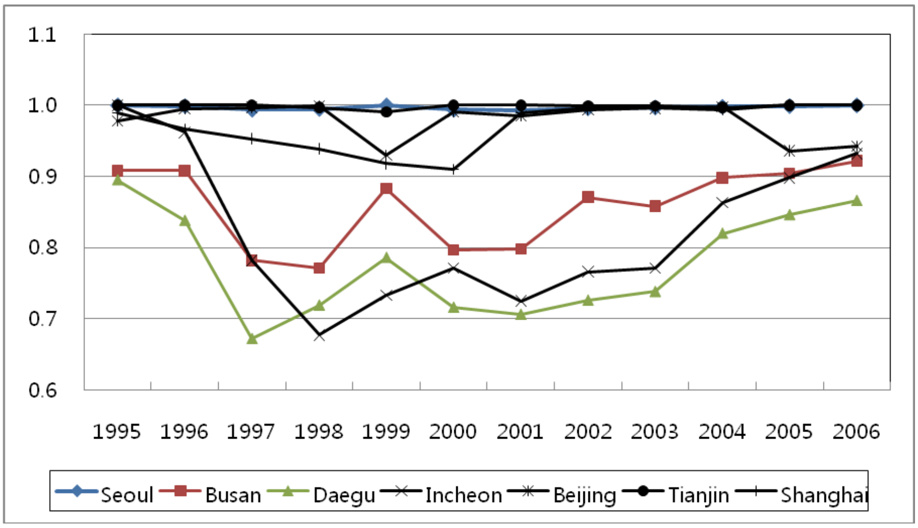


Table 7 The Measurement of Returns to Scale from DEA Model

	DMU1	DMU2	DMU3	DMU4	DMU5	DMU6	DMU7
1995	CRS	IRS	IRS	CRS	DRS	CRS	DRS
1996	IRS	IRS	IRS	IRS	DRS	CRS	DRS
1997	IRS	IRS	IRS	IRS	DRS	CRS	DRS
1998	IRS	IRS	IRS	IRS	DRS	IRS	DRS
1999	CRS	IRS	IRS	IRS	IRS	IRS	DRS
2000	IRS	IRS	IRS	IRS	IRS	CRS	DRS
2001	IRS	IRS	IRS	IRS	IRS	CRS	DRS
2002	IRS	IRS	IRS	IRS	IRS	IRS	DRS
2003	IRS	IRS	IRS	IRS	IRS	DRS	IRS
2004	IRS	IRS	IRS	IRS	DRS	DRS	IRS
2005	IRS	IRS	IRS	IRS	DRS	CRS	CRS
2006	CRS	IRS	IRS	IRS	DRS	CRS	CRS

Note: DMU1=Seoul, DMU2=Busan, DMU3=Daegu, DMU4=Incheon, DMU5=Beijing, DMU6=Tianjin, and DMU7=Shanghai.

Table 7 shows the measurement of returns to scale derived from DEA model.

Roughly, Korean cities have shown IRS trends but Chinese cities have shown CRS and DRS trends.[8)] This finding appears to be related to the city size, as already mentioned. This shows that Korean smaller-sized cities have the IRS characteristics compared with larger Chinese cities.

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8) These phenomena have some relationships with DEA methods, which can measure the relative efficiency among different DMUs. For example, if we measure the Korean small and large cities, also we will find out the tendency that Korean small cities show DRS and Korean large cities show IRS. Theoretically, the slope of small DMUs' production frontiers is steeper than that of large DMUs' production frontiers. Therefore, when we use the DEA method, we always will experience the package small-IRS and large-DRS. So this result can not be interpreted as high efficiency phenomena of small cities, because we cannot know absolute efficiency levels and only we can know the relative efficiency levels.

5. CONCLUSION

DEA is very easy and useful tool to measure the relative efficiency even if there are some shortcomings by excluding the statistical errors. SFA is a powerful method to measure to DMUs' relative efficiencies in considering the statistical errors, but there are many research barriers to overcome in this method. For instance, there are several problems such as multicolinearity, the lack of sample data, autocorrelations and the selection of functional forms in using stochastic approaches. There should be much trade-offs between DEA and SFA. In this paper, we apply two methods to Korean and Chinese large-sized cities and compare the results. Important implications are presented in the following. First, Korean cities have IRS trends, but Chinese cities have DRS during the last 10 years. So we can think that this phenomenon is related to the fact that Korean cities' population sizes are smaller than those of Chinese cities. Second, Beijing showed relatively lower efficiency in both DEA and SFA models. This phenomenon can be related to the inefficiency of capital city. Chinese capital city's inputs such as labor, infrastructure and government expenditure are over-employed for the last decade compared with other cities to hosting Asian game, WTO Summit, Olympic etc. Beijing also has possibility to show lower productivity because of bureaucratic or institutional inefficiency of capital city. Third, in Korea, efficiency values of Seoul are also relatively lower in SFA method, like Beijing. Korean government has put a lot of investments in Seoul disproportionately to support one fourth of the nation's population for a more than three decades. In addition, Seoul also has possibility to show lower productivity because of bureaucratic or institutional inefficiency of capital city. But in terms of DEA method, Seoul does not show consistent results. The reason is that DEA approaches are different methods from SFA approaches. DEA methods don't permit any randomness of variables and measurement errors, while SFA methods are econometric methods to measure the efficiency levels permitting some errors. Furthermore, we may also need more time series data of each city to fine more accurate reasons of this difference. Fourth, the efficiency of two Korean cities, Busan and Daegu, has been decreasing over time in DEA and SFA model. This phenomenon may be closely related to the situation that most of economic activities in Korea are continued to concentrate on the capital area where the Seoul and Incheon are belonged.

Our models are necessary to improve in terms of the changes of multi-output and multi- input models through more data collection, the selection of other functional forms such as generalized Leontief functions, and the usage of the other methods such distance function approaches or Luenberger index approaches. More data and researches will be helpful to understand the city production phenomena, especially in Asian highly growing areas. Sometimes we have perceived serious problems of the overinvestment about some metro areas in Korea and China. Hence, optimal allocation of resources will lead to the higher living standards in our future. It is very timely to consider seriously optimal investment of developing areas in the world. Depression periods will make overinvestment problems more prominent and serious in the future.

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