

Productive Efficiency Differences among Chinese Cities: A Stochastic Frontier Approach

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Abstract

This paper treats the empirical issue related to the urban productive efficiency. First, we construct a model incorporating urban inefficiency term and estimate a stochastic frontier production function at urban level. Next, we compare technical efficiency across Chinese cities during 1997-2007 by using estimated results. The urban technical inefficiency effect is found to be significant in many cities. Then, in the way of constructing the specification of the technical inefficiency in terms of various capital explanatory variables, we analyze the determinants of technical inefficiency of individual cities, and explore how the urban technical inefficiency is influenced by capital density, FDI, the domestic investment, while the impact of technical inefficiency on capital variables is investigated. From the empirical results, FDI is able to reduce effectively the technical inefficiency. Capital intensive industry would be the engine of economic growth in the future.

Key words: technical inefficiency, urban productivity, stochastic frontier approach, chinese cities

1. Introduction

Different productivities are related to different technology efficiency levels of the production process, and also related to the different environment in which the production takes place. We can easily find regional economic disparities in Chinese regions in terms of labor productivity or total factor productivity (TFP). Since the economic reform in 1978 Chinese economy has continued high economic growth even after Lehman shock. Due to the different technology level and different local environment, the national productivity growth can't mean the productivity growth in all of regions. For example, the bimodal distribution of labor productivity shows the obvious regional productivity disparities across Chinese eastern region and western region (Xu, 2004)¹. The average value of TFP in Shandong Province reaches 0.632, while that in Qinghai Province is just 0.258 (Wu, 2006). Regional productivity differences attract interest of researchers, such as the productivity differences among provinces. However, there seems to be no established reason for explaining productivity differences

¹ It shows the probability density of labor productivity. Eastern provinces have higher value than western region. In statistics, a bimodal distribution is a continuous probability distribution with two different modes. These appear as distinct peaks (local maxima) in the probability density function. A bimodal distribution most commonly arises as a mixture of two different distributions.

among Chinese cities. This paper attempts to give the overall picture of productive efficiency differences among cities in China and explain why they exist.

There are many researches focusing on the differences in productive efficiency among different economic units and the improvement of productive efficiency in the production process. The issue to be addressed is whether output level is depended on investment level, worker force, or technical efficiency. It requires that the form of production function and the distributional assumptions for the error terms must be specified more exactly. The stochastic frontier approach (SFA) adopted in this paper allows this decomposition. In the SFA, there is particular functional form that defines the frontier, and deals with the statistical noise in the data. In addition, it is able to incorporate a regression model for technical inefficiency effects in terms of explanatory variables and an additive random error.

After proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and Broeck (1977), studies on the productive efficiency of different economic units begin to calculate the effectiveness and productivity level by applying the SFA. Then in the literature of technical inefficiency, the hybrid SFA approach has been preferred also (Battese and Coelli, 1993). Then more explicit model of technical inefficiency effect is formulated in Huang and Liu's paper (1994), the model combines a stochastic frontier regression and a truncated regression, which invests the factor influencing technical inefficiency effect and then identifies the sources of efficiency.

On the other hand, the empirical investigations for productive inefficiency of the firm's characteristics are produced. During the 1980's and 1990's, the concept of the technical inefficiency of firms is pivotal for the development of econometric models of frontier functions. In econometric frontier functions, the technical efficiency of a given firm is defined as the ratio of its mean production to the corresponding mean production if the firm utilized its levels of inputs most efficiently. Thus, in order to explain difference in technical efficiency, both of firm-specific effects and time effects are investigated in the model of technical inefficiency (such as Pitt and Lee, 1981; Battese and Coelli, 1993, 1995; Huang and Liu, 1994). Also Huang and Liu present empirical evidences for technical inefficiency effects of the firm's characteristics (such as the age of the firms, the export ratio, and the R&D expenditure).

Then, the discussion is expanded to the technical inefficiency of industry. Such as in the paper of Coelli and Battese (1996), some variables are considered in the model for the technical inefficiency effects of agriculture. More recently the empirical works is devoted to the determinants of regional productive inefficiencies (or productive efficiencies). They suggest that the capital is one of the important determinants in the regional efficiency improvement, according to the analysis of Chinese provincial productivity (Fu and Wu, 2006). In order to be more specific, some researches further investigate the determinants on technical inefficiency in more details, such as human capital or publish investment. (Galindo-Rueda and Haskel, 2005; Mastromarco and Woitek, 2006)

These detailed impacts of investment on productive inefficiency bring following questions. Could investments from different capital source affect technical inefficiency in different degrees? Furthermore, whether are there the interactions between cities' technical inefficiency and investment locations? The main object of this paper is

answering these questions in the SFA.

The two-stage SFA approach is utilized. The first stage is constructing the urban stochastic frontier production function and calculating technical efficiency across cities in China. In order to explain the disparity of technical efficiency across Chinese regions, the second stage is involving the specification of the technical inefficiency in terms of capital explanatory variables.

Although our model mainly follows the proposition suggested by Coelli and Battese (1993), this paper has some different hypothesis from the suggestion of Coelli and Battese. We suppose that the technical inefficiency is not varying with time in stochastic frontier model, because the empirical data spans just 8 years.

In addition, there are other new lights on technical inefficiency effects in this paper. The specific impacts of domestic capital and foreign capital on technical inefficiency can be investigated to make sure the respective effects of capital from different capital sources in the productivity improvement process. The inducing effect of technical inefficiency on the investment from different capital sources are discussed also. Despite of previous researches referring to the regional growth using foreign capital as an independent variable of production function, in this paper, foreign capital is introduced into the determining function of technical inefficiency as one of capital variables. Then different from other analysts' suggestions for one province, the disparity of cities' productive efficiencies can be investigated from different perspectives.

The paper consists of the following four sections. Section 2 presents a literature review on stochastic frontier approach. Section 3 discusses the stochastic production frontier model. Section 4 provides the estimation including the relative data description and estimation results. Section 5 is the conclusion.

2. Review of Literature

Farrell (1957) suggests that the productive efficiency can be calculated by estimating the production frontier function. The definition of a production function holds that it gives the maximum possible output which can be produced from given quantities of a set of inputs. The word frontier may meaningfully be applied in each case because the function sets a limit to the range of possible observations. Thus one may observe points below the production frontier (firms producing less than maximal possible output) but no points can lie above the production frontier, similar comments apply to suitably defined cost and profit frontiers. From the basic understanding of production frontier, the measurement of productive efficiency is of interest to economists.

Based on Farrell's idea, the stochastic frontier production function is originally proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977). Stochastic frontier production functions have two error terms. One represents the effects of stochastic shocks to the production process (such as the effects of weather or luck) or noise in the variables measurement. The other represents the technical inefficiency in production and it is non-negative. It is assumed that both of the error terms are independent of explanatory variables and are uncorrelated with each other.

After the original identification of stochastic frontier production is proposed, technical inefficiency term of

stochastic frontier production function attracts more interest of researchers. The technical inefficiency effect for panel data become an important issue in the SFA studies. The stochastic frontier function for panel data is constructed in two ways. One is suggested by Battese and Coelli (1993 and 1995) et al. According to their suggestions, the stochastic frontier production function is defined for panel data, in which the non-negative technical inefficiency effects are assumed to be a function of firm-specific variables varying over time. The technical inefficiency effects are assumed to be independently distributed as truncations of normal distributions with constant variance, but means which are a linear function of observable firm-specific variables. The other is the stochastic frontier function with time-invariant technical inefficiency. The structure of production technology is assumed to be constant through time, which is similar to the cross-sectional production frontier model. There is just the addition of time subscripts to the output, to the inputs, and to statistical noise. It is also similar to a conventional panel data mode but without time effects. (Kumbhakar and Lovell, 2000)

On the other hand, since the 1990s there have been some studies that associate productive efficiency with a number of factors, such as agglomeration externality, publish infrastructure, or workforce characteristics et al. During the 2000s, some researchers give suggestions on the agglomeration externality in more detail. Tveteras and Battese (2006) separate the effects of agglomeration externalities on the production frontier and technical inefficiency. They suggest that agglomeration externalities influence both the best-practice productivity and technical inefficiency. Additionally Rueda and Haskel (2005) suggest that the association between workforce characteristics and firm-level productivity in the UK, and they propose that firms with higher proportions of more educated workers tend to be more productive.

Besides the analysis at the firm level, there are a number of literatures investigating the determinants of regional technical inefficiency. Mastromarco and Woitek (2006) suggest that as an important factor for convergence, the public capital is negatively related with technical inefficiency. In the work of Mastromarco and Woitek, the effect of public capital on productive efficiency is the composition of infrastructure and geographic disaggregation, and the impact of core-infrastructure investment on efficiency is always positive. Other factors influencing technical inefficiency (such as FDI) are proposed by Driffield and Munday (2001). Especially, there are many empirical studies regarding the regional productive efficiency of different countries. Some researchers give the empirical results that the differences of output across Chinese provinces might be the result of efficiency disparity. Yu (2009) examines the technical efficiency performance for the 28 provinces (including three municipalities, Beijing, Tianjin, and Shanghai) in the mainland China from 1970-2004. However, to the best of the author's knowledge, there are a few papers that focus on the studies of Chinese region for estimating urban productive efficiency in stochastic frontier approach.

3. Model

The frontier production models are developed by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977) for the case where the stochastic frontier models are designed for cross-sectional data. Then

Battese and Coelli (1995) extend their model by introducing technical inefficiency effects for panel data into the stochastic production frontier. The specification of stochastic production frontier is as follows:

$$Q_i = f(x_i; \beta) \cdot \exp\{v_i - u_i\} \quad (1)$$

In Eq. (1), Q is the observed output of the city. x is the input in the producing process. The function $f(x_i; \beta)$ represents theoretical maximum output. As the error terms, v represents random shocks, and u is technical inefficiency (which is for the given technology and levels of inputs, and the observed output falls short of its potential output).

The function $f(x_i; \beta)$ is a function that is related to input of production and other explanatory variables. The right side of Eq. (1) ($f(x_i; \beta) \exp\{v_i - u_i\}$) represents the stochastic frontier. The term $\exp\{v_i\}$ is assumed to be the random shocks on city output. Especially, $\{-u_i\}$ shows the technical efficiency (TE). i is city.

Depending on the stochastic frontier production function, the measurement of technical efficiency is derived from the basic specification as follows:

$$TE_i = \exp\{-u_i\} = \frac{Q_i}{f(x_i; \beta) \cdot \exp\{v_i\}} \quad (2)$$

Technical efficiency pertains to getting the most out of a set of input factors. When $TE < 1$, which provides a measure of shortfall of observed output to maximum feasible output in an environment characterized by $\exp\{v_i\}$ which is the random shock term in stochastic frontier function. The shortfall of observed output is partly due to technical inefficiency (u). It offers the key for understanding the disparity of technical efficiency in China, which is the further point clarified in the next section.

There are some further assumptions on the technical inefficiency term in stochastic frontier production for the panel data. Then due to a large sample size and a relative short sample period, the impact of time change on technical inefficiency would be ignored. Technical inefficiency could not change over time. The u is assumed to be a half-normal distribution with constant mean and variance, but uncorrected with the regression terms and with the v . There is no assumption on u 's distribution, only requiring u to be non-negative for representing the technical inefficiency.

Thus when $f(x_i; \beta)$ is Cobb-Douglas production function, the Cobb-Douglas production frontier with time-invariant technical inefficiency in random-effects model, which is including the input variables such as capital, labor and R&D capital, can be rewritten as:

$$\ln Q_{it} = \beta_0^* + \beta_1 \ln K_{it} + \beta_2 \ln L_{it} + \beta_3 \ln M_{it} + \beta_4 TIME_{it} + V_{it} - U_i^* \quad (3)$$

In Eq. (3), K is the capital. L is the labor. M represents the R&D capital. $TIME$ is the time trend for time changes. U_i^* is non-negative random disturbance that captures technical inefficiency with time-invariant,

which is not varying through time and uncollected with the independent variables of Eq. (3). The distribution of U_i^* follows half-normal distribution, with zero mean and variance α_u^2 . V is a symmetric random disturbance which captures the effect of statistical noise. The β -coefficients are unknown parameters.

It is necessary to deal with technical inefficiency term (U^*) carefully. To investigate the interaction of technical inefficiency and investment from different capital sources, the technical inefficiency term is seen as a function with kinds of capital variables. Different from Mastromarco's discussion on the impacts of private and public capital, this model puts emphases on the different impacts of foreign capital and domestic capital.

Furthermore, in spite of some suggestions on the externality variables estimated in both of production function and technical inefficiency function, this model focuses on the externality effect on technical inefficiency term rather than the total production. In the function of technical inefficiency effects, the interactions between technical inefficiency and foreign capital (or domestic capital) can be discussed.

U^* is assumed to be not varying over the sample period, the variables of U^* are uncollected with time change. In the model with time-invariant, U^* is defined as follows:

$$U_i^* = f(s_i; \delta) \quad (4)$$

The δ -coefficients are unknown parameters to be estimated, together with the variance parameters which are expressed.

The s shows the time-invariant variables which could influence technical inefficiency, such as foreign capital and the variables of urban economy. Considering the interaction of technology improvement and kinds of capital, in the estimation process, the technical inefficiency simultaneity functions are defined as follows:

$$U_i^* = f(CL_i, FC_i, DC_i, Location_i, TIME_i) \quad (5)$$

$$FC_i = f(U_i^*, CL_i) \quad (6)$$

$$DC_i = f(U_i^*, CL_i) \quad (7)$$

In this simultaneity functions Eq. (5)-(7), the time varying is ignored. Taking into consideration the interrelation of investment location and technical changes, it suggests that the functions are linear functions. CL is the capital density variable. FC shows the effect of foreign capital on technical inefficiency. DC shows the impacts of domestic capital on technical inefficiency, and Dummy variable ($Location$) equal 1 when the sample city is in the policy-preference region². The definitions of all variables are summarized in Table 1. Whether

² Although all of Chinese cities have implications for policy aimed at urban economic development, considering difference in the establishment of effective development policy across regions, the eastern region has been seen as the policy-preference region. It is including the provinces of Beijing, Tianjin, Hebei, Liaoning, Heilongjiang, Jilin, Shandong, Hainan, Zhejiang, Jiangsu, Fujian, Guangdong and Shanghai.

foreign companies are able to more effectively decrease technical inefficiency than domestic enterprises in the producing process? Whether the levels of technical inefficiencies in different cities influence the investment location in different regions? Such questions are answered by investigating the different effects of foreign capital and domestic capital in the technical inefficiency effect model.

4. Estimation

We consider a set of panel data on 286 Chinese cities to estimate the parameters of a stochastic frontier production function for which the technical inefficiencies of individual cities are assumed to be time invariant as specified by Eq. (3)-(4) in section 3, by Maximum Likelihood Estimation (MLE). Then the technical efficiencies of cities are calculated according to Eq. (2). Finally, in order to further explore the determinants of technical inefficiency, Eq. (5)-(7) is estimated by 3SLS.

4.1. Data Description

It is helpful to describe data set before the estimation. The explanation of the data on the different variables in the frontier production function is summarized in Table 1. The data exclusively is drawn from Chinese urban data set. It complies with *Chinese Urban Statistic Yearbook*. The data is concerning 286 cities covering the years of 2000-2007. The sample cities are distributed across three main regions of China³. Though the Chinese cities are divided into urban area and county area, in order to study the urban economy exactly, in the estimation process the urban area data is utilized. In the 3SLS estimation, besides the independent variables ranked again in the instrumental variables list, there are some related data used as instrument variables, such as population and FDI of total cities.

Table 1 Data and variables

Dependent variable	
<i>y</i>	Gross Domestic Product: gross value added as defined in the Yearbook of Urban Statistic
Independent variables	
<i>K</i>	Capital stock
<i>L</i>	Employment
<i>M</i>	Government expenditure for R&D
Efficiency parameters	
CL	Capital density that is accounted for by the capital-labor ratio
FC	FDI
DC	Domestic enterprise variable, accounted for by output of large state-owned industrial enterprises
Location	Regional category dummy variable
Common variable	
Time	Time trend variable (expressed in terms of 1, 2, ..., 8)

3 China is divided into the eastern, middle, and western regions. The eastern region is including the provinces of Beijing, Tianjin, Hebei, Liaoning, Heilongjiang, Jilin, Shandong, Hainan, Zhejiang, Jiangsu, Fujian, Guangdong and Shanghai; the central region is including the provinces of Henan, Hunan, Hubei, Anhui, Shanxi, Jiangxi, Neimenggu; the western region is including provinces of Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shanxi, Gansu, Ningxia and Xijiang.

4.2. Estimation Results

4.2.1. Production Function

As the first step of the estimation process, the MLE estimators of the parameters in the stochastic frontier are obtained. The results are summarized in Table 2. The signs of the β -estimates of parameters are positive as expected. Capital, labor and R&D variables have significant positive signs in the urban production function. The positive sign on the time trend variable shows that urban production is increasing through time. Evenly all coefficients are statistically significant.

4.2.2. Difference of Technical Efficiency across Cities

The urban technical efficiencies (covering the period from 2000 to 2007) are calculated by using estimated coefficients. This section reports on an analysis of technical efficiencies in Chinese regions (provinces and cities) both in a longitudinal way (over time) and a horizontal way (across regions).

First, the discussion on the variance of technical efficiency over time is given. It is the analysis on the changes of urban technical efficiency in Eastern Region, Central Region and Western Region at four time point (the year of 2001, 2003, 2005, and 2007)⁴. It investigates the tendency of the changes of TE value in recent years. The TE value of each region is the mean of TE values of all cities in one region. The average TE values of three regions are shown in Table 3, as well as the average TE value of the total sample cities. From the results in Table 3 it seems that the technical efficiencies of individual regions vary widely during the investigated years. Regions get high TE values in some years, and get low TE values in other years. The TE values of each region decline in at least one year between 2001 and 2007. Although regional technical efficiencies generally increase over the sample period, no region appears with continuously increasing TE values for all investigated years.

Having gotten the above results, it is turn to the horizontal analysis that explores differences in technical efficiencies across regions in 2007, the most recent year data are available. The disparity of technical efficiency across regions is considered from three perspectives. First, it is concerning whether there are significant

Table 2 MLE for parameters of stochastic frontier production functions

Variable	Parameter	Estimate Value	
Constant	β_0	5.063***	(25.22)
Capital	β_1	0.514***	(28.75)
Labor	β_2	0.453***	(23.67)
R&D	β_3	0.140***	(14.03)
TIME	β_4	0.380***	(24.05)
	σ^2	0.302***	(14.10)
	γ	0.544***	(8.82)
Log likelihood		-1297.92	

Notes: Significance levels: *** is 1%. t values are given in parentheses to two significant digits.

$$\sigma^2 = \sigma_v^2 + \sigma_u^2, \quad N = \sigma_u^2 / (\sigma_v^2 + \sigma_u^2)$$

4 The definition of three regions refers to the section 4.2.1 for the detailed district classification. The average TE value of all sample cities is shown in Table 3 as well.

differences of technical efficiencies across the Eastern, Central and Western Regions. Next, it is relating to the internal differences of technical efficiency within one region (the difference of technical efficiencies among provinces of one region). Then, the discussion on the disparity of technical efficiency in one province (the differences of technical efficiencies among cities of one province) is given. The details are as follows.

First, the differences of technical efficiency across three relatively large areas (the Eastern, Central and Western Regions in China, which are defined in Section 4.1) are shown in Table 3. In addition, Figure 1 provides a map showing TE values for 286 cities of China with different levels of black (the darker the color of one city, the higher the value of its urban TE). In Figure 1, it seems to be that high efficient cities are scattered all over the country. Cities with high TE values (in the level of 0.912-0.950) are not concentrating in one region. Also in Table 3, the difference in the average TE values among the Eastern, Central and Western Regions is not obvious. The average TE value of the Eastern Region is just slightly higher than those of the Middle and Western Regions. The TE differences among these three regions are not as obvious as GRP differences among these regions. There is no significant gap between each regional average TE value and the average TE value of all sample cities (the specific values shown in Table 3).

Then, the differences of TE across provinces are examined in more details. The top 40 cities in the rank of TE (shown in Table 4) are scattered in the three large regions. However, to a lesser extent, the TE difference

Table 3 Average Urban Technical Efficiencies across Regions during 2001-2007

	2001	2003	2005	2007
Eastern Cities	0.818	0.808	0.845	0.847
Middle Cities	0.807	0.803	0.839	0.840
Western Cities	0.811	0.783	0.834	0.837
Total Cities	0.813	0.800	0.840	0.842

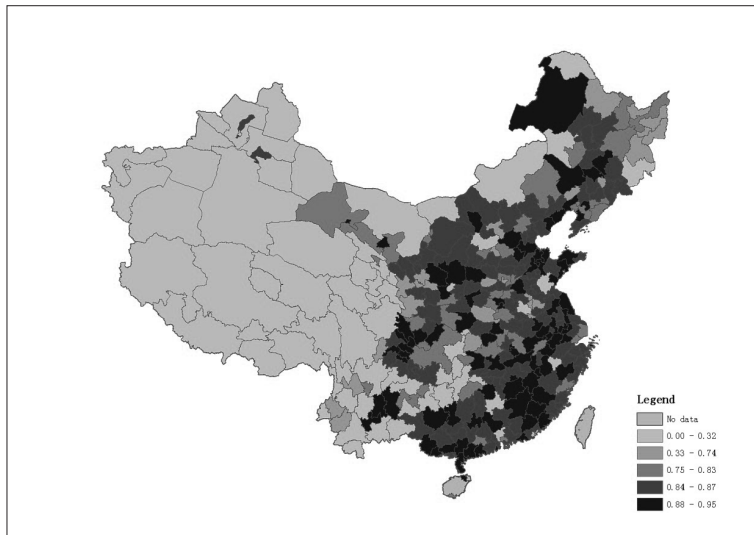


Figure 1 Technical Efficiencies across Cities in 2007

across provinces is manifest. The calculated result of TE value supports the view that if one province completed the efficient integration of production, the overall technical efficiency of this province is able to become higher than those of other provinces. For example, according to the cities' absolute number of each province in the top rank shown in Table 4, Guangdong Province, the province with the highest level of industrialization, has most cities which are in the top rank of technical efficiency. Guangdong Province shows the best performance in accelerating industry upgrade and attracting FDI inflow. These efforts play a role in the provincial productive efficiency improvement. The technology spillover and effective investment give the positive impact to the

Table 4 Technical Efficiency of Top 40 Cities of in 2007

Rank	City	Province	TE
1	Yanan	Shanxi	0.950
2	Yingtian	Jiangxi	0.939
3	Maoming	Guangdong	0.932
4	Jinchang	Gansu	0.932
5	Tongliao	Neimenggu	0.925
6	Yuxi	Yunnan	0.922
7	Fangchenggang	Guangxi	0.920
8	Fuzhou	Jiangxi	0.917
9	Ziyang	Sichuan	0.916
10	Nanchong	Sichuan	0.914
11	Qingyuan	Guangdong	0.913
12	Qujing	Yunnan	0.911
13	Taizhou	Jiangsu	0.910
14	Meizhou	Guangdong	0.909
15	Ganzhou	Jiangxi	0.908
16	Luohe	Henan	0.907
17	Jinzhou	Liaoning	0.906
18	Zhanjiang	Guangdong	0.906
19	Qingyang	Gansu	0.905
20	Huangshan	Anhui	0.905
21	Dazhou	Sichuan	0.904
22	Linfen	Shanxi	0.901
23	Bayanzhuobu	Neimenggu	0.900
24	Jiayuguan	Gansu	0.898
25	Yueyang	Hunan	0.898
26	Qin Zhou	Guangxi	0.898
27	Jinmen	Hubei	0.898
28	Tongling	Anhui	0.898
29	Huhehaote	Neimenggu	0.897
30	Huzhou	Zhejiang	0.897
31	Changchun	Jilin	0.896
32	Yangjiang	Guangdong	0.896
33	Changde	Hunan	0.895
34	Xinyu	Jiangxi	0.895
35	Hezhou	Guangxi	0.894
36	Lishui	Zhejiang	0.894
37	Liuzhou	Guangxi	0.893
38	Yantai	Shandong	0.893
39	Xuancheng	Anhui	0.892
40	Zhangzhou	Fujian	0.892

improvement of productive efficiency as well. Then cities in Guangdong Province are able to achieve high technical efficiency. Further, it is worth noting that in Chinese province, the city with the highest TE value is not its largest city. To some extent, it reflects that the population sizes of major Chinese cities are not optimal for productive efficiency at least. In normal view, the larger production scales, the higher technical efficiency. However from this result, the blind pursuit of increased production, however, is not helpful to achieve high technical efficiency. High productive efficiency should be based on an adequate scale of local production to optimize resource allocation in product unit. This result brings the necessary of analysis on technical efficiency in a single city.

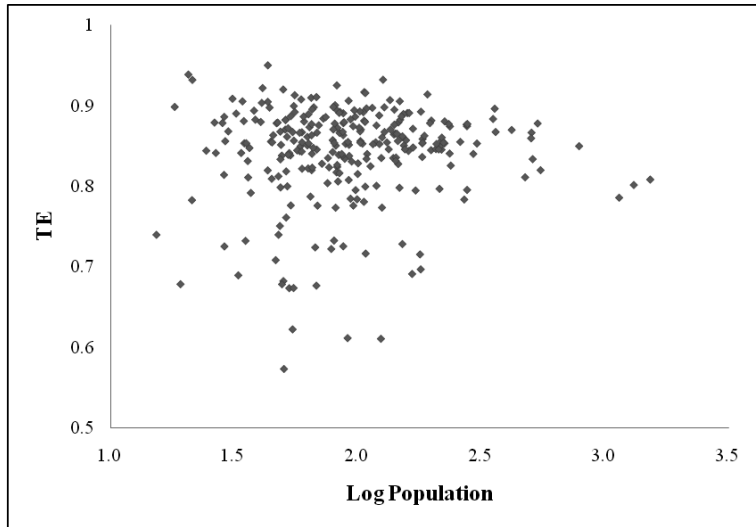


Figure 2 Relationships between Population and Technical Efficiency in 2007

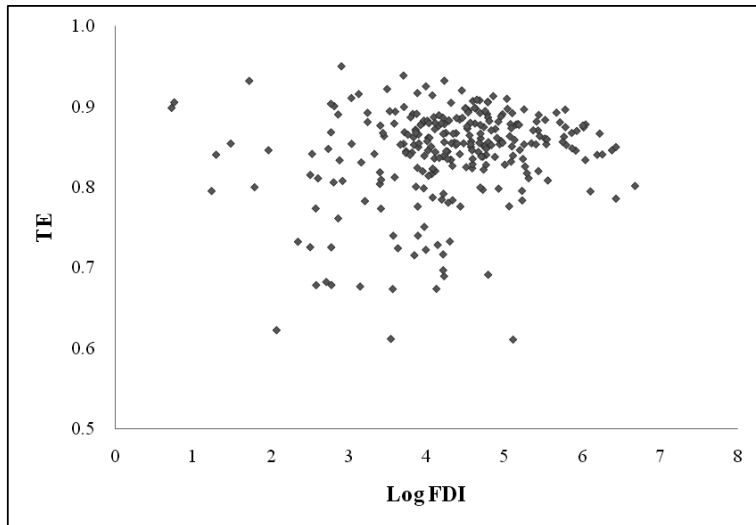


Figure 3 Relationships between Technical Efficiency and FDI Stock in 2007

Then, there are some suggestions on technical efficiency in individual city. There are surprising results in the rank table (the specific rank shown in Table 4 and Table 5). The first important point is that some cities have high technical efficiency in production process, other cities, however, have low technical efficiency. TE values of cities are varying from 0.6 to 1. Even more important is that the large population size is not necessary to achieve

Table 5 Technical Efficiency of Bottom 40 Cities of in 2007

Rank	City	Province	TE
1	Guyuan	Ningxia	0.574
2	Yihang	Hubei	0.611
3	Jixi	Heilongjiang	0.612
4	Longnan	Gansu	0.623
5	Qitaihe	Heilongjiang	0.674
6	Hebi	Henan	0.674
7	Hegang	Heilongjiang	0.677
8	Pingliang	Gansu	0.679
9	Heihe	Heilongjiang	0.679
10	Shuangyashan	Heilongjiang	0.683
11	Jincheng	Shanxi	0.690
12	Huainan	Anhui	0.691
13	Nanyang	Henan	0.697
14	Dingxi	Gansu	0.709
15	Suzhou	Anhui	0.716
16	Huaibei	Anhui	0.717
17	Fuxin	Liaoning	0.722
18	Yangquan	Shanxi	0.724
19	Lincang	Yunnan	0.726
20	Baoshan	Yunnan	0.726
21	Datong	Shanxi	0.728
22	Yaan	Sichuan	0.732
23	Mudanjiang	Heilongjiang	0.733
24	Lijiang	Yunnan	0.740
25	Liaoyuan	Jilin	0.740
26	Zhangjiajie	Hunan	0.751
27	Zhangye	Gansu	0.761
28	Yichun	Heilongjiang	0.774
29	Guangan	Sichuan	0.774
30	Benxi	Liaoning	0.776
31	Panzhihua	Sichuan	0.776
32	Sanya	Hainan	0.776
33	Anyang	Henan	0.781
34	Simao	Yunnan	0.783
35	Zhengzhou	Henan	0.784
36	Pingdingshan	Henan	0.784
37	Xiaogan	Hubei	0.785
38	Beijing	Beijing	0.786
39	Puyang	Henan	0.787
40	Huanggang	Hubei	0.792

the high TE value. The fact can be seen from the rank of TE value in 2007 that most of large metropolitans have normal or low TE values. For example, Beijing is the 39th city in the bottom rank of all cities in 2007. However there are more medium and small cities in the top rank of TE value (shown in table 4) than large cities. It seems to say that it is easier for medium-small cities to reach higher technical efficiency than large cities during the sample period. In the normal view, small cities are at the disadvantage in the process of technical efficiency optimization, however, in China, the size advantages of large cities in terms of technical efficiency are not reflected as well. Most important of all is that there seem to be no significant impact of policy variable on the urban productive efficiency. Cities ranking in the top 10 are not the coastal cities in Eastern Region as expected, but those cities in the inland areas. It should be noted that most of the top 40 cities in the rank of TE value are cities which have rich natural resource and small city sizes, while those cities, which take high share of industry in urban production could not reach a high level of technical efficiency. To some extent, this also shows that in spite of Chinese cities' substantial output, it could be a pity that there is low overall productive efficiency and weak capability of technological innovation in Chinese cities. There is no the establishment of the effective utilization of labor and capital. Technical efficiency has a connection with effective utilization of kinds of economic capital, not only the input scales. Then large cities would lose the scale advantage in the process of technology improvement. It results from that the enterprises gain production profit still with abundant resource and cheap labor, but not with better technology and management method.

There are different TE values across cities which have same city size (Figure 2). It suggests that except population, there may be more important determinants of cities' technical inefficiency. It is discussed in the next section.

4.2.3. Technical Inefficiency Function

After calculating TE values, next question is that what is the result of technical inefficiency in the production process? By estimating the simultaneity model of technical inefficiency, some suggestions about the determinants of technical inefficiency are given as follows. The coefficients of the independent variables in the technical inefficiency simultaneity function are shown in Table 6.

There are two positive coefficients of explanatory variables for technical inefficiency, domestic enterprise variable and time variable. During the sample period, the technical inefficiency is increasing annually, and the domestic enterprise variable increases the technical inefficiency. It supports the suggestion mentioned in the previous part that the technical efficiencies of individual regions vary over years and connect with not only the scales of input factors, but also the utilization ratio of input factors. Thus the domestic production units lose their size advantage and cannot accelerate the technical efficiency improvement as well as foreign capital does.

There are other three explanatory variables which could reduce the technical inefficiency significantly. Two of them, capital density and foreign industry ratio, are the variables related to high capital-labor ratio. The high capital density means high capital-labor ratio directly, and its negative coefficient for technical inefficient shows the great positive influence of capital-labor ratio on the improvement of technical efficiency.

The coefficient of FDI shows the reducing impact on technical inefficiency as well. For one thing, FDI is

available for upgrading existing local production system. Depending on the advanced production technology and management method, FDI plays a certain role in productivity promotion and in effective reduction of technical inefficiency. The spillover effects of foreign capital also promote the improvement of local technology and labor productivity. For another, foreign enterprises conduct import and export activities more often than domestic enterprises. They optimize the structure of international trade. The FDI location contributes shaping the global division of labor in technologically advanced industries, and enhancing the structure of import and export commodities. It supports results of previous studies which suggest the link between FDI and industrial development. For example, industries that benefit from the FDI inflow include sectors that are more capital-intensive, such as chemical, petroleum and nonferrous metal processing, transportation, and electronics (Ran and Voon, 2007).

Another factor reducing technical inefficiency is the location variable. The cities' location variables show a little improvement on the reduction of technical inefficiency. Its impact is not as significant as those of FDI and capital density variables. As discussed in the section 4.2.2, though differences of technical efficiency are reflected across cities, it can be found that the costal cities' average TE value is not much larger than those in other regions. As the cities with high TE value are scattered all over the large regions, the TE values have little correlation with their locations. The location variable could affect the technical inefficiency, mainly on the grounds that the eastern cities have more FDI inflow than other cities by preferential policies. The location variable would give effect on technical efficiency with FDI together.

On the other hand, the interaction of technical inefficiency and kinds of capital are concerned in the determining function of technical inefficiency. There are not just the opposite effects of the foreign and domestic industry variables given on technical inefficiency, but also the different influence of technical inefficiency on kinds of capital. That is, the technical efficiency level could induce the foreign investment inflow, but could not affect the large domestic enterprises location. If the technical inefficiencies of some cities are higher, it means that there are high losses in production process. Thus from the economic point of view, the foreign enterprises would not consider these cities as the best location of investment. In the decision-making process, foreign enterprises make the investment decision depending on the economic situation. On the contrary, the investment decisions of domestic large enterprises in China, for various reasons, are influenced by many factors as well as economic factors, and the local production efficiency is often overlooked.

Table 6 Parameters of Simultaneity Function of Technical Inefficiency

	Technical Inefficiency	Foreign Industry Ratio	Domestic Industry Ratio
Technical Inefficiency		-5.205*** (-3.67)	3.193*** (11.17)
Capital Density	-0.133** (-2.343)	-2.226*** (-4.10)	0.134 (-1.12)
FDI	-0.040*** (-4.28)		
Domestic Industry Ratio	0.220*** (6.55)		
Location	-0.053 (-0.50)		
Time	0.544** (3.10)	8.953*** (5.97)	-0.567* (-1.87)

Note: Significant levels: * is 10%, ** is 5%, *** is 1%

t values are given in parentheses to two significant digits.

5. Conclusions

From what has been discussed above, it can be concluded as follows. Firstly, cities' production is keeping growth during the sample period. Capital, labor and R&D variables have significant contributions to urban production as expected.

Secondly, technical efficiency has not been improving annually. In addition there are differences in technical efficiencies across regions.

Thirdly, FDI distribution across cities brings the decrease of technical inefficiency in different degrees. It is able to reduce technical inefficiency in production process by utilizing the advanced technology and effective management method. Oppositely the domestic enterprises show a negative effect on the improvement of technical efficiency.

Fourthly, cities can get more FDI and decrease the cost in the regional producing because of their lower technical inefficiency. The location variable would give the positive effect on the growth of technical efficiency with FDI inflow together. Depending on the less help from domestic capital for technical efficiency changes, the eastern coastal region's high TE values seem to mainly result from much FDI inflow.

The different interaction between technical inefficiency and investment from different capital sources should be noticed. Foreign companies are able to greatly decrease technical inefficiency in the production process, while domestic enterprises could not do it as well as foreign companies. The disparity of productivity efficiencies across different cities brings the different FDI inflow into cities. This fact would not change in a short period. However, technical inefficiency is not a powerful factor influencing the location of large-size domestic enterprises.

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