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Regional Disparity of Productivity in China: A Stochastic Frontier Approach

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Abstract This paper analyzes temporal variations in the productivity performance of the Chinese economy at the regional level. Specifically, the focus is on regional disparity and regional temporal movement of productivity. It applies a stochastic frontier model to the Chinese provincial input-output panel data of 30 different regions over the period of 1993-2003. The empirical results confirm those of previous studies that Shanghai is the most productive economy in China and the eastern region is the best performer in productivity. Our analysis indicates that the gap between the eastern region and other regions(central, and western) is quite substantial, but the western region has made relative fast enough improvements of its efficiency to be able to narrow the gap with the eastern. This may have come about as a result of government investment in infrastructure and in social facilities such as education and health care, stimulating the performance of the less developed provinces.

Keywords Productivity, regional disparity, catch-

JEL Classification O18, D24

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1. Introduction

Since the launch of the economic reform in 1978, China has grown on average almost 10 percent per year, compared to the figure of 4 percent for other developing countries between 1978 and 2005 (He and Kuijs, 2007). Despite such impressive rates of growth, the regional development of the country remains largely unbalanced. By using the Gini coefficients of GDP per capita and GDP per worker to measure provincial income disparity from 1978 to 2000, Lin and Liu (2006) found that although regional disparities initially fell after the 1978 reforms, the Gini coefficients began to rise in the early 1990s. This implies that the benefits of rapid economic growth in China were distributed unevenly between rich and poor regions as the reform program pressed ahead.

In order to narrow these regional disparities, in the late 1990s the Chinese government began to divert more resources to the "backward" western provinces through budgetary payments and bank funds (Fan and Wang, 2004). However, as economic growth is generated not only by an increase in resource inputs but also by productivity improvement, the regional disparities currently observed may be caused either by differential amounts of input resources coming into each province or the productivity improvements that have been experienced by the corresponding regions. If the former is true, the government should focus more on formulating policies that will attract resources into the regions which lag behind, while in the latter situation it should place more emphasis on stimulating productivity in those areas. Clearly, if we are to formulate a balanced development policy there is a need to understand more about the productivity changes in regional China.

There have been only a handful previous studies on Chinese regional productivity [Fleisher and Chen, 1997; Ezaki and Sun 1999, Dong et al. 2006, Zheng and Hu, 2006; Chen et al. 2009]. They analyzed empirically the regional economic growth, especially focusing on the sources of economic growth (input factor driven versus productivity-driven) or the decomposition of total factor productivity (technology-driven versus efficiency driven). Fleisher and Chen (1997) attempted to understand the persistent income gap between coastal and inland provinces. They applied the Cobb-Douglas production function in the context of Solow growth model to investigate the total factor productivity (TFP) performance of all the provinces in China during the period 1979 to 1993. Their study found that TFP in the coastal provinces was twice as high as those in the inland provinces. Later, Ezaki and Sun (199) used the growth accounting method to calculate the regional TFP. As reported in Table 1, the coastal TFP grows faster than those of the inner regions. Dong et al. used a similar method to apply on a set of a more updated data with which they find that the TFP growth is higher in the inner region that that of the coastal. More recently, Zheng and Hu (2006) used data envelopment analysis approach to analyze regional productivity of the 29 provinces between the years 1979 and 2001. This method enables the separation of TFP growth into two components; efficiency change and technical progress. The former refers to the process of catching up to the frontier and the latter to movements of that frontier. Zheng and Hu's study showed that TFP growth in China has been achieved primarily through technical progress, which implies that there are large, unexploited opportunities to improve efficiency. They have reported separately the TFP growth rates of the coastal and inner regions. However, their estimates indicate that China has been experiencing a fall in the TFP growth rate from the 1980s to the 1990s. More recently, Chen et al. (2009) applied the generalized metafrontier MPI approach to conduct a provincial analysis. Their works reveal that the coastal region has a higher TFP growth rate that that of the inner region.

However, the previous studies investigated the regional economic growth and productivity of China by comparing average productivity growth rate, but were not particularly interested in the temporal movement of productivity. In an attempt to understand more about regional productivity performance in of China, our analysis extends the existing literature in the following directions. Firstly, although the literature has found that the eastern region is more developed and efficient than elsewhere (Fleisher and Chen, 1997; Zheng and Hu 2006), the temporal change in the Chinese regional productivity disparity in recent years has not been fully analyzed. Therefore, it may be of interest to analyze empirically how the wide productivity gap between regions found in Fleisher and Chen (1997) has changed in recent years.

The empirical comparison of temporal movements of technical efficiency between regions can be achieved by applying group-specific stochastic frontier models (Lee, 2010) to Chinese provincial input-output data. Earlier stochastic frontier production models, which estimate time-varying technical efficiency (Kumbhakar, 1990; Battese and Coelli, 1992; Lee and Schmidt, 1993), assume that all the constituent production units share the same temporal movement in productivity growth. The limitation of such an assumption is that the relative efficiency rankings of all the production units in the sample are assumed to be fixed throughout the sample period – the firm that is ranked n-th at the first period is always ranked n-th throughout the sample period[1]. The group-specific stochastic frontier method used in this paper extends this framework by separating production units into different groups, the technical efficiency of each of which can move at different rates over time. Therefore, production units in different groups may show different temporal variations in technical efficiency, but those in the same group are identical in this respect. As China shows a notable regional development disparity, we follow earlier studies, such as Tsui (1993) and Yang (1990), in dividing the country into three groups of provinces, namely the eastern, central, and western regions, so that each region is allowed to display different patterns of technical progress and efficiency improvement over time. As regional income disparity increasingly widens (Lin and Liu 2006), allowing each area to have different efficiency movements may

[1] For detail, see page 278 of Coelli et al. (2005).

increase the explanatory power of the model.

Furthermore, although Zheng and Hu (2006) found that provinces in China display different productivity growth rates, it is not possible for them to compare statistically whether or not the regional economies are displaying similar ability in catching up with the best-performing frontier economy. The adoption of group-specific stochastic frontier models, however, allows us not only to decompose TFP into the individual components of technical progress and efficiency improvement, but also to examine statistically whether regions in China show significantly different efficiency growth patterns.

Our paper will be arranged as follows. Section 2 discusses group-specific stochastic frontier models. Section 3 explains our specification of the production function and data. Section 4 presents the empirical results and finally, section 5 states our conclusions.

2. Stochastic Production Frontier Models

The general setting of stochastic frontier production models with panel setting is defined by

$$\ln y_{it} = \alpha_t + \ln x_{it}\beta + v_{it} - u_{it} = \ln x_{it}\beta + \alpha_{it} + v_{it}, \quad i = 1,...,N;\ t = 1,...,T, \qquad (1)$$

where x_{it} is $1 \times k$ vector of inputs, β is a $k \times 1$ vector of coefficients, u_{it} is the non-negative technical inefficiency term for firm *i* in period *t*, and ν_{it} is an *i.i.d.* N(0, σ^2). The time-varying parameter α_t is the frontier's intercept term at time *t* (no overall intercept is included in β). Accordingly, $\alpha_{it} = \alpha_t - u_{it}$ represents production unit *i*'s efficiency level at time *t*. Note that $u_{it} \geq 0$, so $\alpha_{it} \leq \alpha_t$, which is a standard setup of stochastic frontier models.

Since α_{it} (or, equivalently, u_{it}) is treated as a parameter in the fixed effects model, the number of unknown parameters in Eq. (1) is $NT+k$, which exceeds the number of observations NT. Hence, it is not possible to estimate Eq. (1) directly. In response to this problem, different time-varying models have been proposed so as to reduce the number of unknown parameters. Recently, Lee (2006a) has proposed a group-specific stochastic frontier model which attempts to solve this problem by combining production units into different groups. Under this model, each group has its own distinct temporal efficiency pattern, which is specified as $\alpha_{it} = \theta_{gt}\alpha_t$, where θ_{gt} denotes the temporal pattern parameter of group *g* at time *t* and is treated as a fixed parameter.[2] Using this group-specific temporal pattern for our study means that provinces from different regions are allowed to display different temporal technical efficiency patterns, but provinces from the same region are restricted to the same pattern.

Further restrictions can be imposed on the temporal pattern parameter θ_{gt}. On this point, we follow Lee (2009) in using Battese and Coelli's (1992) parametric specifications for modeling the efficiency change of each group, namely $\theta_{gt} = \exp(\eta_g(t-1))$, where η_g is assumed to be constant for each group *g*. Instead of assuming all the production units share the same TE temporal pattern, as in the case of Battese and Coelli's (1992) model, the present model assumes that each group of production units can have its own. The use of this restriction smoothes the temporal variation in TE and reduces the number of unknown parameters of θ_{gt} in each group from *T*-1 to one. One consequence of this smoothing procedure is that the change of TE in each group remains constant over time. However, since our interest is not in the temporal variation of TE of each specific year but in the overall temporal trend of TE, the smoothing effect of the parametric specification assumption suits the purpose of our study.

For conducting the estimation, Lee (2009) suggests using a concentrated least square

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[2] For a given group *g*, the number of unknown parameters relating to the vector (θ_{g1},., θ_{gt},., θ_{gT}) is *T*-1 since θ_{g1} can be normalized equal to 1.

method that requires iteration techniques for minimizing a likelihood function. Furthermore, in order to combine production units into groups, Lee (2009) has applied a generalized likelihood ratio (LR) test for checking if production units can be combined into a group. More specifically, if the null hypothesis of $\eta_g = \eta_h$ ($g \neq h$, $\forall g$, h = 1, …, G, where G stands for the total number of the groups in the dataset) is not rejected, this will imply that the two production units *g* and *h* can be merged into one group. In addition, for a dataset that is separated into *G* groups, the null hypothesis of $\eta_1 = \eta_2 = ... = \eta_G$ would reduce the model to the one developed by Battese and Coelli (1992) in the case that the null is not rejected.

For the measurement of technical efficiency, the separation of $\hat{u}_{it}$ from $\hat{\alpha}_{it}$ follows the conventional method, which has been used by Schmidt and Sickles (1984), Cornwell, Schmidt and Sickles (1990), Lee and Schmidt (1993), and Lee (2006 & 2009), as follows:

$$\hat{\alpha}_t = \max_i \theta_t(\hat{\eta}_g)\hat{\alpha}_i \ , \tag{2}$$

where $\hat{\alpha}_i = [\theta(\hat{\eta}_g)'\theta(\hat{\eta}_g)]^{-1}\theta(\hat{\eta}_g)' e_i(\hat{\beta})$. Based on (2), the technical efficiency of each production unit can be estimated as:

$$\hat{u}_{it} = \hat{\alpha}_t - \theta_t(\hat{\eta}_g)\hat{\alpha}_i, \ \ \forall i \in Group \ g \, ; \tag{3}$$

$$T\hat{E}_{it} = \exp(-\hat{u}_{it}) = \exp[-(\hat{\alpha}_t - \theta_t(\hat{\eta}_g)\hat{\alpha}_i)], \tag{4}$$

where $T\hat{E}_{it}$ stands for the estimated technical efficiency score. Note that the technical efficiency as defined here is a relative concept in the sense that an increase in the average score implies a fall in the variation of the technical efficiency among the sample production units.

3. Specification Model and Data

The translog production function is generally defined as:

$$\ln y_{it} = \alpha_t + \sum_j \beta_j \ln x_{jit} + \beta_t t + (1/2) \sum_j \sum_k \beta_{jk} \ln x_{jit} \ln x_{kit} + (1/2) \beta_{tt} t^2 + \sum_j \beta_{jt} \ln x_{jit} t - u_{it} + v_{it} , \quad (5)$$

where j = L, K; i = 1, …, N; t = 1, …, T. As we do not have a large sample size, we have chosen to conserve degrees of freedom by imposing the constant returns to scale (CRTS) condition on Eq. (5). The translog production function with CRTS for our estimation is:

$$\ln(y_{it}/L_{it}) = \alpha_t + \beta_K \ln(K_{it}/L_{it}) + \beta_t t + (1/2)[\ln(K_{it}/L_{it})]^2 + (1/2)\beta_{tt} t^2 + \beta_{Kt} \ln(K_{it}/L_{it}) t - u_{it} + v_{it}. \quad (6)$$

In deriving Eq. (6) the following restrictions have been imposed on Eq. (5): $\beta_L = 1 - \beta_K$, $\beta_{LL} = \beta_{KK} = -2\beta_{LK}$, $\beta_{Lt} = -\beta_{Kt}$. Note that the translog production function with CRTS will reduce to a Cobb-Douglas production function with CRTS when $\beta_{KK} = \beta_{tt} = \beta_{Kt} = 0$.

Technical progress (TP), and TFP growth rate and elasticity of inputs are calculated as:

$$TP_{it} = \frac{\partial \ln y_{it}}{\partial t} = (\alpha_t - \alpha_{t-1}) + \beta_t + \beta_{tt} t + \beta_{Kt} \ln(K_{it}/L_{it}), \quad (7)$$

$$TFP_{it} = TP_{it} - \Delta u_{it}, \quad (8)$$

$$\varepsilon_{Lit} = \frac{\partial \ln y_{it}}{\partial \ln L_{it}} = \beta_L + \beta_{LL} \ln L_{it} + (1/2)\beta_{LK} \ln K_{it} + \beta_{Lt} t. \quad (9)$$

To estimate the regional productivity of China, we have used GDP to represent output, and capital and labor to represent inputs. At the regional level, the country is administratively divided into 22 provinces, 5 autonomous regions, and 4 municipalities. For the purposes of our analysis, they are grouped into three regions; eastern, central, and western.[3] The sample period of our data spans the years 1993 to 2003. The data for provincial GDP and labor employment level have been collected from various issues of the

[3] The coastal region includes Liaoning, Hebei, Beijing, Shandong, Tianjin, Shanghai, Jiangsu, Zhejiang, Fujian, Guangdong, Guangxi, and Hainan. The central region encompasses Heilongjiang, Jilin, Inner Mongolia, Shanxi, Henan, Anhui, Hubei, Hunan, and Jiangxi. The remaining provinces belong to the western region.

Statistical Yearbook of China, while the regional capital data are taken from He et al. (2006). More specifically, Dong et al. (2006) take the 1992 capital stock in Li (2003) as the starting value and then apply the formula $K_t = K_{t-1} + RNI_t$, where K_t denotes real capital stock and RNI_t the real net investment (real gross investment minus real depreciation), to calculate the capital stock at year t. Real net investment is computed by $RNI_t = (GCF_t – D_t)/P_t$, where GCF denotes the gross investment, D the nominal depreciation of capital stock and P the deflator. All of these data are available in the official statistics.

Table 2 presents the growth rates of GDP and factor inputs for the whole country. However, in order to compare the performance of the three regions in China, their output and input statistics have also been tabulated. Over the sample period, the country experienced an economic growth rate of 10.49 percent. The annual GDP growth rate was highest in the eastern region, while the lowest was in the western. However, during the same period, the eastern region recorded the largest growth rate in capital input, while the central region saw the lowest. Finally, for labor input, the western region witnessed the fastest growth rate, while the central region experienced the smallest.

With respect to national incomes, the average GDP of the eastern province was 144.3 billion Renminbi measured at the 1980 constant price, while those of the central and western regions were at smaller levels, that is 83.1 and 40.0 billion Renminbi respectively. The same pattern of regional gaps is observed in capital stock, but not in labor. On average, provinces in the central region had the largest number of workers at 22.8 million, followed by the eastern and western regions which had 21.8 and 17.0 million respectively.

4. Empirical results

By applying the group-specific stochastic frontier model to Chinese provincial data it is possible to study temporal productivity patterns at the regional level. As a first step, we have compared the performance of the translog and Cobb-Douglas production function with CRTS in modeling the data. The estimation results are reported in Table 3. The LR statistic for testing the hypothesis $\beta_{KK} = \beta_{tt} = \beta_{Kt} = 0$ is 93.381, which is rejected at the 1 percent significance level, thereby implying that the translog function is more appropriate for modeling Chinese provincial production data.

The next step is to check which regions share similar temporal efficiency trends so that they can be grouped. This can be done by conducting hypothesis testing on various combinations. The first hypothesis we have applied is to check whether there is an identical temporal pattern of technical inefficiency across all the three regions (H_0: $\eta_1 = \eta_2 = \eta_3$). If the null hypothesis is not rejected, then the model will reduce to the one developed by Battese and Coelli (1992). As reported in Table 4, the LR statistic, which follows a Chi-squared distribution with 2 degrees of freedom, is 57.517, thereby rejecting the null hypothesis at the 1 percent level. Hence, this empirical test shows that at least one of the three regions displays a distinct temporal pattern of technical efficiency.

To identify which grouping best fits the data, we have tested three hypotheses, referenced as 2, 3, and 4 in Table 4, to check which two regions should be grouped. The estimation results of these tests are presented in Table 3. For example, hypothesis 2 assumes the eastern and the central regions possess the same temporal variation in TE, that is $\eta_1 = \eta_2$, but the LR statistic is rejected at the 1 percent level. This means that these two regions display significantly different patterns of movement towards the frontier. In fact, of hypotheses 2, 3, and 4 from Table 4, the only one that cannot be rejected is hypothesis 3. Based on this result, the appropriate model for estimating regional productivity change is to form a two-group model, wherein the eastern and western regions are combined into one group and the central region is treated separately.

After determining which grouping was appropriate, the next step was to apply the translog production function with CRTS to the two groupings selected. The estimation result of this model is presented in Table 5. Based on this information, we can expect the hypothesis of no technical change $\beta_t = \beta_{tt} = \beta_{Kt} = 0$ to be rejected since all estimates of β_t, β_{tt}, β_{Kt} are significant. The hypothesis that TP is neutral ($\beta_{Kt} = 0$) is also rejected at the 5 percent level of significance.[4]

The mean elasticities of labor and capital have been calculated using Eq. (5) and their results are reported in Table 6. These results suggest that for both regional groups, labor elasticities have been rising continuously over the estimation period, whereas capital elasticities have been falling. This implies that the proportion of labor income contributing to the national output has been rising consistently as the reforms have taken place.

The next step is to determine the technical efficiency scores of the three regions and examine how they have changed over time in comparison to the frontier production unit. Table 7 reports the results, which show that the frontier economy of the country is Shanghai and the eastern region is the most efficient of the three we have classified. More interestingly, the technical efficiency of the western region, which has the lowest GDP per worker, is higher than that of the central area. Furthermore, although all three regions have shown improvements in their technical efficiencies, the change in the western area is particularly notable. As shown in Table 7, the average efficiency score of the western region rose from 46.6 percent in 1994 to 53.9 percent in 2003, representing an increase of 7.2 percentage points over a period of 10 years. In comparison, the eastern and central regions have only recorded increases of 1.3 and 1.8 percentage points respectively. It can therefore be seen that

[4] To investigate whether the 1997 Asian financial crisis has produced any impact on the model, we have added a dummy variable which equals to one in 1998 and 1999. However, the crisis effects were not found to be significant.

consistent catch-up effects with the frontier economy have been observed in all three regions, but they are most notable in the western region.

There are several economic factors that can explain the differential productivity performances of the Chinese provinces. Foremost among them is the market liberalization reform which promotes the growth of private enterprises that has changed fundamentally the economic landscape of the country. The nowadays household name enterprises like Lenovo Group Limited and Huawai Technologies Company were growing from their infancies during this period of time. .Because of this reason, it is not surprising to see that the productivity performance of the coastal region is the highest among the three as it is widely believed that the local government officials are more reform-minded and also they were allowed to carry out reform experiment ahead of the other regions. The second is the opening up of the economy to the international markets. Not only local economies were allowed to start trading with the international market, but they were also encouraged to attract FDI to help construct the local economies. Gradually, the FDI becomes a major source of advanced technologies that local firms can assimilate and modify. Again, the coastal region has some unique advantages that the other regions did not have as a result of reform. During the sample period, for instance, the costal region's share of gross industrial output has been increased consistently. The Hirschman-Herfindahl Index rises from 0.38 in 1993 to 0.57 in 2003, which means that the industrial production has been concentrated in the coastal region. The third is the investment on the human and physical capital. The new taxation system, introduced in 1993, was aimed to increase the tax revenue's share of the central government at the expense of the local governments. The increased revenue of the central government was then spent on key projects that were regarded important to the development of the country. On that matter, there were two types of investment that have important bearings on the productivity performance of the provincial China. The first is the increased expenditure on the higher education sector. Starting from 2000, the university enrollments have been increased by one hundred percent within a five year times. Although most of this enrollment increase was mainly due to the private sector, the central government has also increased its spending on key universities which locate mostly in the coastal region. At the same time, the country has also experienced a boom in its infrastructure constructions which concentrate also mainly on the coastal region

It is also interesting to notice that the catching up effect is more noticeable in the western than in the central. The occurred probably because the central region faces several institutional and policy factors that work against its development. Chief among them is its responsibility to serve as a stable supplier of grain to the country. For a country with 13 billion of people, the supply of food is often regarded as an issue of top priority. However, because of the reform, a large part of agricultural tract in the coastal region has been converted to industrial land. In order to secure a stable supply, the government has an adopted a responsibility system which assigns grain production targets to each of the provinces. Since the 1990s, the central region has become a major grain supplier of the country. Under the current contract responsibility system in the rural areas, the agricultural land is parceled out more or less evenly to the farmers; the size of land that is under the control of each household is quite small. Understandably, there is limited room for the agricultural sector, which is dominated by small households, to raise its productivity. Second, for a long time, this region lacked a clear vision of development. As is well known, the government opened up the coastal region first in order to assimilate foreign know-how and technology. Massive investment and tax concessions have been given to this region for catching up with the developed countries. For the western region, where is considered poor and less developed, the development of this region is always being looked after by the government as it has a large number of ethnic minorities population. Relatively, the central region has not been treated as importantly as the other regions in the eyes of the policy makers at the central government.

We can investigate further the productivity changes of the regional economies of China. Table 8 presents the result of the TFP changes for the three regions, which were further decomposed into changes in technical efficiency and technical progress. The eastern region experienced the highest TFP growth rate, followed by the western, and finally the central. Throughout the sample period, the TFPs of all three regions declined, but the fall experienced by the central area appeared to be the most significant. In order to understand more about the changes in TFP, we have decomposed the TFP growth into changes in TE and TP. As shown in Table 8, TP was the most important contributor to the changes in TFP for all three regions, a finding which is consistent with the results of Zheng and Hu (2006). The comparatively low contribution of TE growth to TFP can be explained by the fact that our TE estimates are relative measures. In light of this, a slowly increasing rate of TE implies that (i) Chinese provinces have moved more or less homogenously during the study period and (ii) the TEs of all provinces have improved slightly faster on average than that of the frontier province (that is, Shanghai). The contribution of the TP in the eastern region was the largest, followed by the central, and finally the western. However, in respect of the TE improvement, the western region was the largest gainer, followed by the central and the eastern. This explains why the western region has been able to move closer to the frontier relative to the others.

The model can also be used to help identify the productivity performance of the Chinese economy at the provincial level. For this purpose, we have chosen Shanghai, Guangdong, Zhijiang, and Jiangsu for detailed comparisons, these being the most developed city and provinces in China. As is well known, Shanghai has long occupied a unique place in the economic development landscape of China. In the nineteenth century, Shanghai was the most prosperous city in China, which was often referred to as the Orient of the East. Since then, its importance to the country has never been elapsed. Some even described it as "the head of the dragon (Guthrie, 1999)." After the launch of reform in 1979, Shanghai has once again been elevated to unparalleled position in the mission of leading the country to achieve the modernization program. For example, in the early 1980s the government had used its scarce foreign exchange to import production plants from Japan to help modernize Shanghai's Baosteel Group Co., which until today remains one of the few steelmakers that could produce steel that is good enough to meets the demand of such high quality consumers as automobiles and high-rise buildings. Later, in order to assimilate foreign automobile manufacturing technology, the government decided to adopt a "using market share to exchange for foreign technology" strategy for upgrading its domestic automobile industry. Under this strategy, the government uses high tariff to deter the entry of foreign cars, thereby forcing the multinational automobile companies to form joint ventures with local makers. Massive funding was, at the same time, pumped to the three chosen Chinese automakers, including Shanghai Auto, which allowed them to assimilate foreign technology by forming joint venture with multinationals. More recently, the government's development plan expands to financial sector. As a stop towards achieving this objective, all the four national banks' headquarters are located in Shanghai and its inter-bank interest rate is used as a benchmark for determining the national monetary policy. All of these changes have made Shanghai into becoming an economic frontier of the country. Due to years of the heavy investment, Shanghai in 2003 ranked number one in many development indicators, such as the per capita urban resident's income, the per capital investment and the per capita FDI. Its human capitals are among the best of the country. The number of college level graduates as a percentage of the population ranked only second behind the capital Beijing. Studying its productivity change therefore allows us to understand whether its economic superiority is underpinned by equally impressive TFP improvements. The second province included in the comparison list is Guangdong, which was one of the first regions to be opened up to foreign investment and trade after the launch of the reform program in 1978. Over the years since then, the Pearl River Delta region, bordering the north of Hong Kong, has been the most economically dynamic region of China. In fact, it has now become the one of the world's most important manufacturing bases for such manufacturing products as electronic appliances, toys, garments, textiles, and so on. Equally impressive is the Yangtze River Delta which includes Shanghai and another 15 fast-growing cities in the neighboring Jiangsu and Zhejiang provinces, all of which are located at the mouth of the country's longest river, the Yangtze. Currently, the Yangtze River Delta accounts for roughly one-fifth of China's total gross domestic product (Naughton, 2007). Therefore, comparing the productivity performances of Guangdong, Jiangsu, Zhejiang, and Shanghai allows us to analyze the most advanced provinces in China, and in particular to detect any dissimilarity in the patterns of changes in their productivity.

To begin with, we have calculated the technical efficiency levels of the four locations, as shown in Table 9. In terms of technical efficiency, Shanghai was the best-performer, followed by Guangdong, Jiangsu, and Zhejiang. This is understandable as Shanghai is a leading centre of China. In terms of efficiency, Guangdong performed better than Jiangsu and Zhejiang. However, the gaps between these three provinces and the frontier did not narrow in a similar way. While Jiangsu and Zhijiang provinces were able to catch up with the frontier during the sample period, Guangdong failed to do so.

To understand more about these provinces' productivity performance, we have calculated and decomposed their TFP growth rates. The results of this are reported in Table 10. First, in terms of TFP changes, Shanghai performed better than the other three provinces throughout the observation period. Of the remaining three, the TFP growth rate of Jiangsu was the highest, while that of Guangdong was the smallest. Again, this result indicates that

Guangdong has not been able to perform as well as the other two provinces. We have also decomposed the productivity improvement of all four locations into efficiency change and technical progress. As Shanghai stayed consistently on the production frontier, it did not display any efficiency change over the observation period. For the other three provinces, both Jiangsu and Zhejiang recorded a positive TE improvement over the sample period, while the TE growth in case of Guangdong was small. This explains why the former two provinces have been able to catch up with the frontier economy, while Guangdong has failed to do so. However, as the TE improvements for Jiangsu, Zhejiang, and Guangdong were not large, the main contributors to the TFP growths for the three provinces stemmed mainly from TP improvements. Once again, this suggests that there remains considerable room for even these relatively advanced provinces to raise their TFP performance through efficiency improvements.

In this paper, we attempt to measure the regional productivity performance of the regional China. One noteworthy observation is the continued decline of the productivity performance of the three regions. This issue is undoubtedly important because whether China can maintain its current growth rate depends on its ability to arrest this trend. Therefore, the government must pay attention to the causes of the loss of momentum of its productivity improvement. To answer this question, one has to look at the reasons of why the Chinese economy could perform so well after reform. As we have explained before, there are at least three reasons that help explain the rise of the Chinese economy’s productivity performance: the emergence of private sector, the integration with the international economy and the investments on both human and physical capital. All of these factors have helped improve the economy. But there are evidences to show that the contributions of these factors to the growth of productivity of the economy have been weakened as the reform could not further progress. For example, as documented by Huang (2008), there was a reversal of the economy policy in the mid 1990s. Instead of allowing the private sector to expand, the state began to retreat from consumption good sectors to strategic industries. Gradually, the state-owned enterprises (SOEs) have dominated in such strategic sectors as banking, telecommunication, coal and oil industries. Because of high entry barrier, it is virtually impossible for the private enterprises to enter this kind of lucrative industries, which results in the formation of monopolistic markets in many utilities and strategic industries. Although these kinds of firms have produced huge sums of profit for their owners, it also means that the economic efficiency has been suffered as a result. Against this background, there is no room for the Chinese policy makers to be complacent about their economy.

5. Conclusion

This study has attempted to analyze the productivity performance of the Chinese economy at the regional level. Our analysis aims to understand how regional productivity performance changes over time. To do that, we have applied a group-specific stochastic frontier model to the provincial input-output data of China. Our analysis shows that the most productive economy in China is Shanghai, which has consistently stayed on the frontier. In terms of regional efficiency scores, the best performer is the eastern region, while the central region is the worst. Our analysis indicates that the gap between the frontier and the three regions is quite substantial. Fortunately, over the years, the regions studied have been able to narrow the gap with Shanghai. Another interesting observation is that the western region has made more notable improvements to its efficiency than the other two. This may have come about as a result of government investment in infrastructure and in social facilities such as education and health care, stimulating the performance of the less developed provinces.

We have further decomposed the productivity change of the three regions into the separate components of technical change and efficiency improvement. Our results indicate that most of the productivity changes in the three Chinese regions have come about as a result of the former component. This would imply that Chinese policymakers should focus on how to improve the efficiency of their current operations, as there are still large unexploited opportunities for improving efficiency without the need to add new resources.

Finally, we have also compared the productivity performance of the three major provinces with Shanghai. These three provinces are the most developed economies in China, containing two of the world's most important manufacturing centers, namely the Pearl River Delta and Yangtze River Delta. We find that although the efficiency of Guangdong was higher than those of Jiangsu and Zhejiang, the gaps between them have narrowed. The latter two provinces have been able to improve their TE in terms of closing in on the frontier economy and narrowing their gaps with Guangdong. Recently, this problem may have drawn the attention of the provincial government of Guangdong, which has been trying hard to upgrade its economic structure. For instance, it has just outlined a plan to shift from manufacturing businesses to a service-oriented economy (Zhan, 2008). Whether such a plan can produce a desirable outcome remains to be seen. However, our analysis indicates that the lag in the productivity performance of Guangdong has been present for quite some time, so it may take some more fundamental changes, such as giving a greater role to the private sector in its development strategy, to address this problem.

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Table 1. China's TFP growth rate estimates

Source	Period	Coastal region (%)	Inner region (%)
Ezaki and Sun (1999)	1991-1995	8.20	6.70* 5.10#
Dong et al.(2006)	1993-2003	3.70	4.50
Zheng and Hu (2006)	1980s	5.34	
	1990s	2.60	
Chen et al. (2009)	1996-2004	4.86	4.64

* denotes the central region; # denotes west.

Table 2. Descriptive statistics of input and output variables for 31 provinces/municipalities in China (1993-2003)

		Mean	S.D.	Min	Max	Average growth rate
Total	GDP	91.45	79.69	4.20	455.15	10.49
	Capital stock	28.86	24.59	2.52	136.18	10.81
	Labor	21.22	14.32	2.17	63.35	0.73
East	GDP	144.28	98.14	10.12	455.15	11.46
	Capital stock	46.83	29.19	3.38	136.18	11.66
	Labor	21.76	14.79	3.20	48.51	0.75
Central	GDP	83.14	37.76	30.24	201.34	10.48
	Capital stock	22.82	10.40	9.41	59.35	10.09
	Labor	25.81	12.53	10.45	55.72	0.46
West	GDP	39.99	30.96	4.20	169.72	9.43
	Capital stock	13.93	11.22	2.52	69.60	10.46
	Labor	16.96	14.02	2.17	63.35	0.92

The measuring units of GDP and capital stock are billion Renminbi, while the labor is millions of workers.

Table 3. Comparison between the Cobb-Douglas and Translog production functions

	Cobb-Douglas with CRTS	Translog with CRTS
ln(K/L)	0.657* (15.70)	0.514* (20.99)
t	-0.026* (-3.79)	0.056* (12.01)
$ln(K/L)^2$		-0.022 (-1.60)
t^2		-0.002* (-8.15)
$ln(K/L)\cdot t$		-0.020* (-7.20)
η_1	0.015* (3.07)	-0.004 (-1.00)
η_2	0.017* (3.14)	0.010* (2.34)
η_3	0.023* (2.97)	-0.002 (-0.40)
SSE	1.896	0.357

* 5% significance level

Table 4. Hypothesis test results for groupings

Hypothesis	LR statistic	Degrees of freedom	p-value
1. $\eta_1 = \eta_2 = \eta_3$ (BC Model)	57.517	2	0.000
2. $\eta_1 = \eta_2$ (East = Central)	46.455	1	0.000
3. $\eta_1 = \eta_3$ (East = West)	0.350	1	0.554
4. $\eta_2 = \eta_3$ (Central = West)	25.088	1	0.000

Table 5. Coefficient estimates of the stochastic frontier production function

	Translog with CRTS
ln(K/L)	0.513* (21.13)
t	0.058* (14.17)
$ln(K/L)^2$	-0.020 (-1.53)
t^2	-0.002* (-8.26)
$ln(K/L) \cdot t$	-0.020* (-7.48)
η_1	-0.005 (-1.43)
η_2	0.008* (2.70)
η_3	
SSE	0.358

* Significant at the 5% level

Table 6. Mean elasticity estimates of inputs over time

	Labor elasticity		Capital elasticity	
Year	East+West	Central	East+West	Central
1994	0.528	0.542	0.472	0.458
1995	0.544	0.558	0.456	0.442
1996	0.559	0.575	0.441	0.425
1997	0.575	0.590	0.425	0.410
1998	0.589	0.606	0.411	0.394
1999	0.605	0.622	0.395	0.378
2000	0.622	0.638	0.379	0.362
2001	0.638	0.655	0.362	0.345
2002	0.655	0.672	0.345	0.328
2003	0.671	0.688	0.329	0.312
Yearly average	0.599	0.616	0.401	0.384

Table 7. Changes in regionally averaged technical efficiency over time

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Yearly average
East	0.643	0.645	0.646	0.647	0.648	0.650	0.651	0.652	0.654	0.655	0.656	0.650
Central	0.387	0.389	0.390	0.392	0.394	0.396	0.398	0.399	0.401	0.403	0.405	0.393
West	0.466	0.473	0.480	0.487	0.494	0.501	0.508	0.516	0.523	0.531	0.539	0.502
Shanghai	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Total	0.512	0.515	0.518	0.522	0.525	0.528	0.532	0.535	0.539	0.543	0.546	0.529

Table 8. Decomposition of total factor productivity estimates by group

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Yearly average
Average TFP growth rate by region											
East	0.049	0.048	0.046	0.044	0.043	0.042	0.041	0.040	0.040	0.039	0.043
Central	0.042	0.041	0.040	0.039	0.038	0.037	0.037	0.036	0.035	0.034	0.038
West	0.047	0.046	0.045	0.044	0.042	0.043	0.042	0.041	0.040	0.040	0.043
Total	0.046	0.045	0.043	0.042	0.042	0.041	0.040	0.039	0.039	0.039	0.042
Average technical efficiency growth rate by region											
East	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Central	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
West	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
Total	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
Average technical progress growth rate by region											
East	0.044	0.043	0.041	0.039	0.038	0.037	0.036	0.035	0.035	0.034	0.038
Central	0.039	0.038	0.037	0.036	0.035	0.034	0.034	0.033	0.032	0.031	0.035
West	0.036	0.035	0.034	0.032	0.031	0.031	0.028	0.027	0.026	0.026	0.031
Total	0.040	0.039	0.037	0.036	0.036	0.035	0.034	0.033	0.033	0.033	0.036

Table 9. Changes in the four province's/city's averaged technical efficiency over time

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Yearly average
Shanghai	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Guangdong	0.793	0.794	0.795	0.796	0.797	0.798	0.798	0.780	0.780	0.781	0.781	0.790
Zhejiang	0.663	0.665	0.666	0.667	0.669	0.670	0.671	0.672	0.674	0.675	0.676	0.671
Jiangsu	0.674	0.676	0.677	0.678	0.680	0.681	0.682	0.683	0.685	0.686	0.687	0.681

Table 10. Productivity performances of four selected provinces/city

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Yearly average
					Total factor productivity growth rate						
Shanghai	0.053	0.053	0.051	0.049	0.047	0.045	0.044	0.043	0.042	0.041	0.047
Guangdong	0.052	0.049	0.048	0.047	0.045	0.044	0.042	0.040	0.039	0.038	0.044
Zhejiang	0.054	0.053	0.052	0.051	0.050	0.049	0.048	0.046	0.045	0.044	0.049
Jiangsu	0.055	0.054	0.053	0.052	0.052	0.051	0.050	0.050	0.049	0.048	0.051
					Technical efficiency growth rate						
Shanghai	0.000[1]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Guangdong	0.113	0.113	0.112	0.111	0.111	0.110	0.110	0.109	0.109	0.108	0.111
Zhejiang	0.244	0.242	0.241	0.240	0.239	0.238	0.237	0.235	0.234	0.233	0.238
Jiangsu	0.193	0.192	0.191	0.191	0.190	0.189	0.188	0.187	0.186	0.185	0.189
					Technical progress growth rate						
Shanghai	0.053	0.053	0.051	0.049	0.047	0.045	0.044	0.043	0.042	0.041	0.047
Guangdong	0.051	0.048	0.047	0.046	0.044	0.043	0.041	0.039	0.038	0.037	0.043
Zhejiang	0.047	0.046	0.045	0.044	0.043	0.042	0.041	0.039	0.038	0.037	0.042
Jiangsu	0.047	0.046	0.045	0.044	0.044	0.043	0.042	0.042	0.041	0.040	0.043

[1] The numbers are multiplied by 100.