World Scientific Research Journal (WSRJ) ISSN: 2472-3703
www.wsr-j.org

Reaserch on the Regional Production Efficiency in Guangdong Province--Empirical Analysis Based on Stochastic Frontier Function

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Abstract: Targeting the panel data of four regions in Guangdong Province from 2000 to 2014, this paper uses the parametric stochastic frontier method to measure the production efficiency of the four regions and explains the efficiency differences by analyzing the spatial distribution characteristics. The empirical results show that: (1) the production efficiency of the Pearl River Delta region in Guangdong is obviously higher than that of the other three regions, while the mountainous area of northern Guangdong is the lowest. (2) The economic geographical factors have an significant impact on the regional production frontier even determines the spatial distribution of regional technical efficiency. (3) The degree of opening to the outside world and infrastructure are the main factors influencing regional efficiency. This means that the mode of regional economic growth should be changed. The way to improve regional productivity lies in improving local technological efficiency and technological level, transfer the input-driven mode into capital-intensive and technology-driven to promote economic development.
Keywords: Stochastic frontier; technology efficiency; regional economy.

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1. INTRODUCTION

In the past three decades, China's has acquired great achievements in regional economic development, and Guangdong has also become a large and booming economic province.It ranks the first in total economy volume of the country with manufacturing and tertiary industries as the main economic brace , leading China's economic reform and opening up. Guangdong has been ahead of that of other provinces for many years in the GDP, the total retail sales of the social consumer goods, the savings deposits of the residents, the amount of patent application, taxes, import and export, the total tourism income, the number of mobile phones, the Internet users, the total turnover of the goods and so on. From 1985 to 2008, the total import and export volume ranks first in the country for 23 years in a row,about 25% of the country,and accounts for about 14% of the country's annual financial revenue, about 25% of the country's total foreign investment. In 2008, its GDP exceeded 3.56 trillion yuan, surpassing Singapore Hong Kong and Taiwan in succession, maintaining the top position in the country's economic

output for 20 consecutive year.However, due to the differences of Inter-regional natural conditions, original economic basis and preferential policies among regions, the economic differences between regions are ever-increasing, and the imbalance of economic development among regions has caused extensive concern in academic circles. China is in the transition period, there is obvious agglomeration in geographical space. Existing research on regional economic differences mainly focus on inter-country and inter-country provinces, studies about the differences among the regions within the provinces are relatively few. This paper focuses on Guangdong Province to explore whether there are great regional economic development differences within Guangdong Province and try to figure out the reasons behind the data.
This paper analyzes regional production efficiency and its influencing factors basing on the stochastic frontier c-d production function, the empirical results show that the production efficiency of the pearl river delta region is greater than the east and west and north guangdong mountains. The degree of opening to the outside world and the actual effective utilization of infrastructure have positive effect on the improvement of production efficiency. Industrial structure optimization has the most significant marginal effect on production efficiency in the east and west.

2. THEORY OF REGIONAL ECONOMIC DEVELOPMENT

Regional development gap and rapid economic growth have always been an important reality of economic and social development in China. In recent years, the debate on whether the development gap between provinces and regions in China is widening has become the focus of policy makers and scholars. Guangdong Province is leading in China's reform and opening up. According to its location distribution and economic development level, it is divided into four economic regions: the Pearl River Delta, the east and west wings and the northern mountainous area. The Pearl River Delta includes Guangzhou, Shenzhen, Zhuhai, Foshan, Jiangmen, Dongguan, Zhongshan, Huizhou and Zhaoqing. The east wing refers to Shantou, Shanwei, Chaozhou and Jieyang, and the west wing refers to Zhanjiang, Maoming and Yangjiang 3 cities, northern Guangdong mountain area includes Shaoguan, Heyuan, Meizhou, Qingyuan and Yunfu 5 cities. The Pearl River Delta is one of the most developed regions in China, so there is a certain gap between the economic development level of the other three regions and the pearl river delta, such unbalanced regional development is bound to influence economic development of Guangdong. From2000 to 2014, the regional economic unbalance of Guangdong Province are mainly reflected in the differences among the four regions, especially between the Pearl River Delta and the other three regions. It is the result of the interaction and joint promotion of market forces, policy and other factors since the reform and opening up. The pearl river delta region takes advantage of its proximity to Hong Kong and the opening policy of the country to undertake the industrial transfer of the economically developed regions of the world. Rapid economic growth has prompted plenty of production factors to flow into the Pearl River Delta region. However, the gradient transfer of industry from the pearl river delta to the east and west wings and the northern mountains areas has not been realized, and the gap in economic development has been increasing. According to Herschmann's theory of unbalanced growth, the emergence of growth poles will inevitably play a role in regional economic growth. The theory of "growth pole" indicates that the promotion of growth pole to the development of surrounding areas mainly depends on the comparison of "polarization effect" and "diffusion effect". In the early stage of economic development, polarization plays a dominant role, the power of growth poles is gradually strengthened, regional differences will gradually widen, and the region around the growth poles will be promoted.

According to the Petty-Clark theorem, the pearl river delta is in the late stage of industrialization with high processing and high added value, while the east and west wings are in the stage of transition from the early stage of industrialization to the middle stage, and the mountainous areas are still in the early stage of industrialization. Guangdong’s economic index is higher than the average level of the whole country, but it’s obvious unbalanced internally. The development difference between the more developed regions and the less developed regions far exceeds the difference between the east and the west of China, especially the economic difference between the pearl river delta and the vast mountainous areas, which is a typical phenomenon in China. The huge gap in regional development will seriously restrict the sustained and healthy economic development and social stability of Guangdong.

3. STOCHASTIC FRONTIER THEORY

The concept of technical efficiency is widely used in economics. Koopmans (1951) proposed the concept of technical efficiency and defines technical efficiency as: under certain technical conditions, it is impossible to increase any output without reducing other outputs. Or it is impossible to reduce any input without increasing other inputs, which is said to be technically effective. Farrell (1975) has for the first time proposed a frontier measurement method for technical efficiency, which has been widely accepted by the theoretical community and it becomes the basis of efficiency measurement. Currently, the main methods of calculating technical efficiency are non-parametric techniques and parameter techniques.The parameter method is based on the traditional idea of production function estimation and mainly uses OLS or ML estimation. It first constructs a specific function form, and then calculates with specific parameter value in the function. The non-parametric method firstly constructs a set of minimum production possibilities including all production modes according to the input and output, where the effectiveness of the non-parametric method refers to the maximum output produced with a certain input or the certain output produced with the minimum input.Data Envelopment Analysis (DEA) has been developed into a mature non-parametric efficiency measurement method and widely used in the management science. But the biggest limitation of the non-parametric method is that the method mainly uses linear programming method to calculate, but does not have the statistical test number as the reference of sample fitting and statistical properties. In addition, the nonparametric method has some limitations on the number of observations, the stability of the observation results is influenceed. Therefore, we choose the parameter method to calculate the frontier production function. There are two methods in the research of parametric frontier production function: the deterministic and random frontier production function.The first used linear programming method directly to calculate the frontier, does not take into account the influence of random factors. And it classifies all the errors influencing the optimal output and the average output into an error term ε on one side and calls it production inefficiency. On the basis of deterministic production function, stochastic frontier production function proposed a stochastic boundary model with complex perturbation term. It divides random disturbance term ε into two parts v and u. Part v is a random error term used to calculate the system inefficiency which is an random influence factor beyond the control of the enterprise.Part u is the technical loss error term used to calculate the technical inefficiency which the enterprise can control. Parametric stochastic frontier production function not only reflects the statistical characteristics of the sample, but reflects the authenticity of the sample calculation.

Aigner and Chu (1968) put forward the frontier production function model, which decomposes the producer efficiency into two parts: technological frontier and technical efficiency. The former characterizes the boundary (frontier of the production function) of all producer input-output functions. The latter describes the gap between the actual technology and the technological frontier of individual producers. The deterministic frontier production function model is as follows:

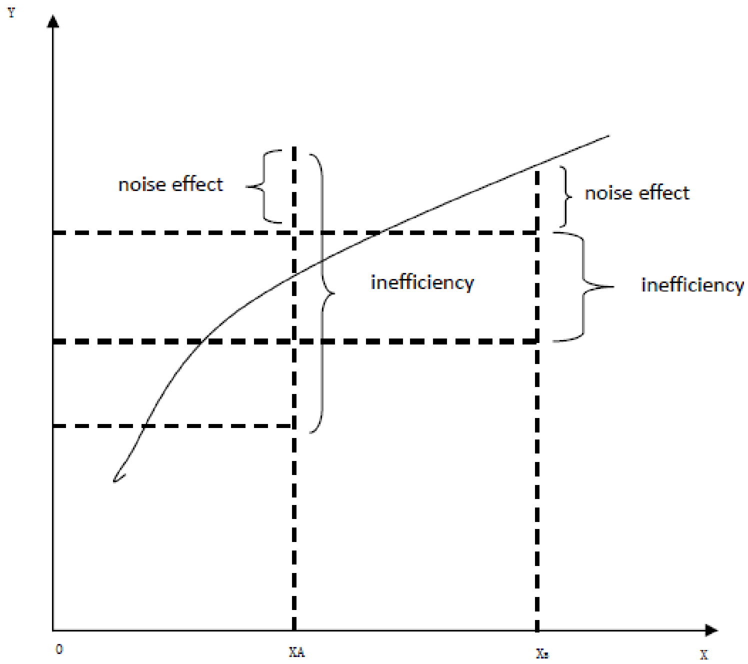
$$Y = f(x)\exp(-u)$$

Where u is greater than or equal to 0, the exp (-u) is between 0 and 1, reflecting the inefficiency of the production function, that is, the distance between the actual output and the maximum output. After determining the specific form of production function, the parameters can be calculated or estimated. However, compared with the stochastic frontier model, the deterministic frontier production function does not take into account the random phenomena in production activities. Aigner, Lovell and Schmidt (1977) and Meeusen and Broeck (1977) respectively propose the following form of stochastic frontier production functions:

$$Y = f(\chi;\beta)\cdot\exp(\nu - \mathrm{u})$$

V is the random factor that influences production activity. It is generally assumed that v is a normal random variable with independent distribution with zero mean and invariant variance. It is generally assumed that U is an independent semi-normal random variable or exponential random variable independent of v.

Stochastic frontier model



It is clear from figure 1 that the company's A frontier output is above the definite value of the production frontier, because the noise effect is positive, and the company B's frontier output is below the production frontier because the noise effect is negative. It can also be seen that the observed output of company A is below the deterministic value of the frontier because the sum of the noise effect and the technical inefficiency effect is negative. The characteristics of this frontier model can be extended to the case where the company has multiple inputs. In particular, the (unobserved) front outputs are uniformly distributed above and below the defined front.

The technical efficiency can be calculated by the ratio of the observed output to the corresponding random frontier output:

$$TE_i = \frac{q_i}{\exp(x_i^{'}\beta + v_i)} = \frac{\exp(x_i^{'}\beta + v_i - u_i)}{\exp(x_i^{'}\beta + v_i)} = e$$

According to function, the technical efficiency values are between 0 to 1. It is obvious that the first step of technical efficiency prediction is to estimate the parameters of the production function of random frontier. It is usually assumed that each v_i and u_i are independent of each other, and the two errors are not related to the explanatory variables in the model. In addition, the following assumptions are met:

$$E(v_i)=0 \quad E(v_i^2)=\delta^2 \quad E(v_i v_j)=0 \quad E(u_i^2)=c \quad E(u_i u_j)=0, \ i \neq j$$

Based on these assumptions, the maximum likelihood method (ML) or the modified ordinary least square method (COLS) can be used to estimate parameters and random variables, then obtain the technical efficiency. Maximum likelihood estimator has large sample characteristics such as asymptotic, it is generally superior to other estimators, such as COLS.

In the early stage, two-stage estimation was used to study the factors influencing efficiency. In the first stage, the efficiency estimate is measured, and then in the second stage, a series of explanatory variables are used for regression analysis. In recent works, including Kumbhakar (1991, Huang and Liu (1994), Battese and Coelli(1995)), single-stage approach is being used to estimate accurate efficiency value in line with the actual situation.

4. THEORETICAL MODEL AND DATA SOURCE

The traditional Solow residual value (TFP) is based on the assumption that all producers can achieve optimal production efficiency, while in reality most producers fail to reach the input-output boundary. The stochastic frontier production function model decomposes the producer efficiency into two parts: technological frontier and production efficiency, includes the influence of random factors on the potential frontier technology output. The stochastic frontier production function model can evaluate the level of technical efficiency and explore the reason of efficiency difference. The two-step estimation is widely used in practice, first step is to estimate the production efficiency with the help of the frontier production model, and the second step is to estimate the production efficiency which is used to find out the exogenous factors that influence the production efficiency. There is a problem in the two-step method: the inefficiency term is assumed to be distributed independently and the production efficiency term varies with different external variables when the efficiency equation is established. The solution is one step regression, maximum likelihood estimation or nonlinear least square estimation. In this paper, the stochastic model is constructed as follows:

$$y_{\mathrm{it}} = \mathrm{x}_{it}\beta + (v_{it} - u_{it}), i = 1,2,3,4; t = 1,2,...15$$

The production function generally adopts C-D or logarithmic transcendence function. The latter one has the advantage of relaxing the assumption that the elasticity of substitution among factors is constant and allowing the existence of non-neutral technological progress. However, it is easy to generate multi-collinearity problems in estimation. According to previous research, C-D production function can better describe economic growth, so this paper also adopts this form and convert the above model into the logarithmic form:

$$\ln y_{it} = \beta_0 + \beta_k k \ln k_{it} + \beta_l \ln l_{it} + v_{it} - u_{it}$$

$\mathrm{y}_{it}$is GDP in region i at t year. Based on the constant price in 1978 and using the GDP deflator from 2000 to 2014, we can calculate the actual GDP sequence in 2005 constant price. First, thechain index was converted to the 2005 base index, and then the real GDP was calculated.

Actual GDP by year (constant price 2005) = nominal GDP* in 2005 GDP fixed 1978 index for each year / GDP fixed 1978 index for 2005

For L variable in the production function, the number of working hours is usually used abroad, but we can not get it in the statistics yearbook. We choose employment at the end of each year. It is necessary to point out that part of the data of employed population in northern Guangdong mountain area is missing.

For variable K, capital stock estimation is required. This paper adopt Holz (2006) method to estimate the capital stock sequence from 2000 to 2014.

$$K_t = \frac{I_t}{P_t} + (1-\delta)\ K_{t-1}$$

I_t is the amount of investment in the t year at the current price, P_t is the price index in the t period, δ is the depreciation rate. This formula represents the t-period capital stock is the sum of the stock of capital retained from the previous period $(1-\delta)\ K$ and actual investment in t period I_t/P_t .There is a consensus about the initial capital stock: . With gradual depreciation of K, the estimation of capital stock in the later period will become more and more accurate, and the difference will have little impact.

There are also great differences in the selection of indicators, as shown in table 1. Since 1993, China's statistical system no longer publishes indicators such as accumulated amount, so the method of zhang jun and zhang yuan (2003) is no longer used.

Table 1. Index selection in capital stock estimation

Document	Investment flow index	Price index index	Depreciation rate
Xie Qianli (1995)	Industrial new fixed assets	Weighted average of Construction installation cost Index and equipment purchase Price Index	statistical data
Wang Xiaolu, Fan Gang (2000)	Investment in fixed assets, utilization rate of investment delivery and formation of fixed capital in the whole society	Fixed assets investment price index	5%
Zhang Jun, Zhang Yuan (2003)	Productive accumulation, investment in fixed assets	Shanghai fixed asset investment price index	0
He Feng et al. (2003)	Total fixed capital formation	Investment implied deflator price index	0
Zhang Jun et al. (2004)	Total fixed capital formation	Investment implied deflator price index	9.6%
Holz(2006)	New fixed assets	Fixed assets investment price index	calculate

5. EMPIRICAL RESULTS AND ANALYSIS

This paper uses stata to analyze the panel data from 2000 to 2014 in four regions of Guangdong Province. The data are derived from the China Urban Statistics Yearbook (2000-2014). basic data description is given in Table 2. Model 1 (OLS), is obtained by the analysis. And model 2 (MLE), is shown in Table 3. And the available probability density map, see figure 1. From the results of Table 3, the OLS method in the stochastic frontier model is no longer applicable. The stochastic frontier model can be estimated by using the maximum likelihood method or moment estimation, which can be roughly divided into two steps: first, the maximum likelihood method is applied to estimate all the parameters of the model, and then the maximum likelihood method is applied to estimate all the parameters of the model. Under the condition that the parameters of maximum likelihood estimation are known, the residual error of maximum likelihood estimation is decomposed into noise term and technical inefficiency term by using JLMS technique, and the technical ineffectiveness of each production unit of the sample is measured. The likelihood ratio test can be used to determine whether the SFA model can be used, and the LR value can be obtained. If the original hypothesis is rejected, the SFA model is more suitable. In addition, compared with the cross-section data, the panel data can reflect the continuous performance of each production unit in a certain time interval, thus providing more accurate information.

Table 2. Basic statistical analysis

Variable	Obs	Mean	Std. Dev.	Min	Max
lny	60	8.056174	1.323301	6.192506	10.77528
lnk	60	7.191243	1.225466	5.276992	9.772369
lnl	56	6.947921	.6379431	5.767883	8.254594

Figure 1.

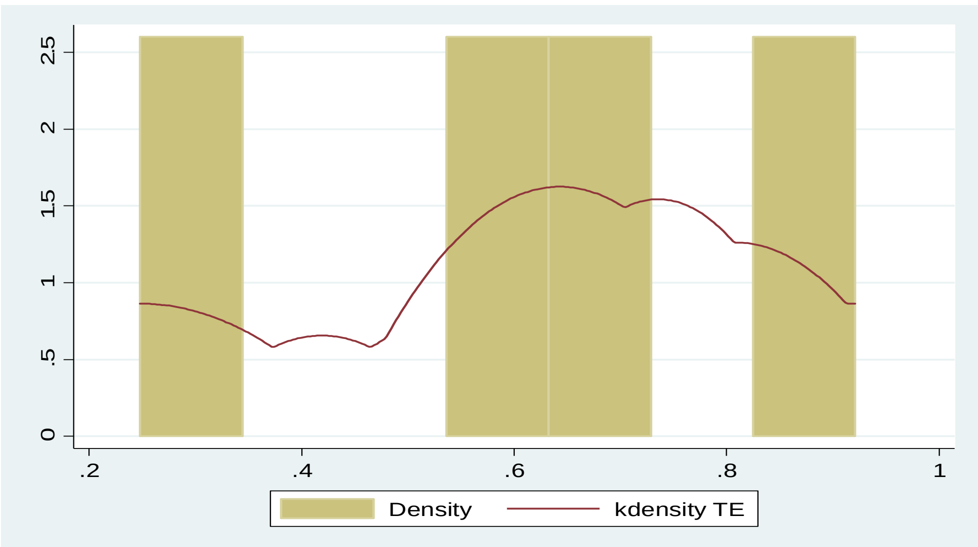


Table 3. Stochastic frontier Cobb-model Douglas production equation

	(1)	(2)
	OLS	MLE
lnl	1.730***	1.820***
	(6.69)	(4.52)
lnk	0.073	0.011
	(0.55)	(0.04)
lnt		22.316
		(0.29)
_cons	-4.416***	-174.292
	(-4.04)	(-0.30)
N	56.000	56.000
r2_a	0.776	0.772
ll	-52.284	-52.238
t statistics in parentheses		
="* p<0.1	** p<0.05	*** p<0.01"

According to the previous model, we use the Cobb Douglas production function of four regional panel data from 2000 to 2014 to obtain table 4.

Table 4

Iteration 0: log likelihood = -1473.8703
Iteration 1: log likelihood = -1473.0565
Iteration 2: log likelihood = -1472.6155
Iteration 3: log likelihood = -1472.607
Iteration 4: log likelihood = -1472.6069

Time-invariant inefficiency model Number of obs = 948
Group variable: id Number of groups =91
Obs per group: min = 6
avg = 10.4
max =14
Wald chi2(2)= 661.76
Log likelihood = -1472.6069 Prob > chi2=0.0000

lnY	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lnK	.2904551	.0164219	17.69	0.000	.2582688	.3226415
lnL	.2943333	.0154352	19.07	0.000	.2640808	.3245858
_cons	3.030983	.1441022	21.03	0.000	2.748548	3.313418
/mu	1.125667	.6479217	1.74	0.082	-.144236	2.39557
/lnsigma2	1.421979	.2672745	5.32	0.000	.898131	1.945828
/ilgtgamma	1.138685	.3562642	3.20	0.001	.4404204	1.83695
sigma2	4.145318	1.107938			2.455011	6.999424
gamma	.7574382	.0654548			.6083592	.8625876
sigma_u2	3.139822	1.107235			.9696821	5.309962
sigma_v2	1.005496	.0484143			.9106055	1.100386

From the table above, $\gamma = 0.757$, we can see that part of the error comes from technical inefficiency. The results show that the stochastic frontier method is better than the least square method in estimating the parameters, and the correctness of the stochastic frontier model for the regional economic efficiency difference in Guangdong. The logarithmic likelihood function (-1472.6069) of the model has passed the significance test, but the significance of L in the model is not high, so the model needs to be modified. The following table reflects the results of the model under different distribution of U:

Table 5

	m1	m2	m3
Frontier			
lnk	0.405***	0.475***	0.480***
	(11553.07)	(2762453.39)	(84156.08)
lnl	0.813***	0.745	0.742***
	(15370.91)	(.)	(101569.09)
_cons	0.115***	0.066	0.057***
	(811.07)	(.)	(4007.32)
Usigma			
_cons	-0.230	-1.163***	6.092**
	(-1.22)	(-4.35)	(2.41)
Vsigma			
_cons	-36.605	-51.769	-37.714
	(-0.02)	(-0.00)	(-0.13)
Mu			
_cons			-789.077
			(-0.40)
N	56	56	56
pseudo R2			

t statistics in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Among them, part U of m1 m2 m3 model subordinate semi-normal distribution, exponential distribution and truncated semi-normal distribution respectively. σ_u and σ_v are unknown parameters that need to be estimated. $\sigma^2 = \sigma_u^2 + \sigma_v^2$, $\lambda = \frac{\sigma_u^2}{\sigma^2}$ represents the proportion of inefficiency variance in the total variance.In this paper, the inefficiency and efficiency values are obtained by semi-normal distribution, and the density function graph of normal distribution and semi-normal distribution is shown.

Figure 2.

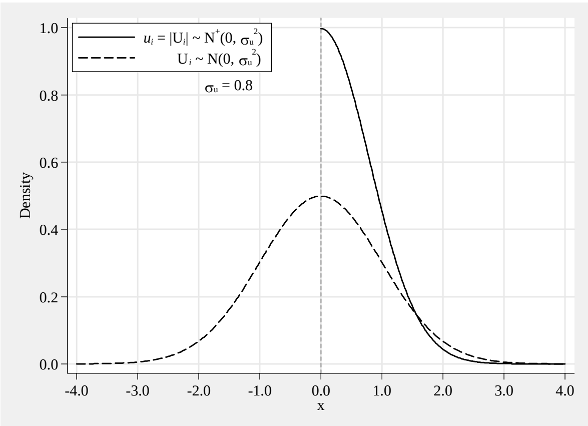


Table 6. Comparison of efficiency values in different regions
Summary for variables: TE
by categories of: id

Four regions of Guangdong Province	technical efficiency
Pearl River Delta	0.9209648
East wing	0.5899457
West wing	0.6956576
Northern Guangdong mountain area	0.2479481
Total	0.6136291

We can see that the productivity of the Pearl River Delta region in Guangdong is significantly higher than that of the other three regions, and the gap between the east wing and the west wing is relatively small, the northern mountainous area has the lowest productivity. The economic geographical factors not only influence the frontier of regional production, but also determine the spatial distribution characteristics of regional technical efficiency.

Guangdong saw its first round of rapid development in the 1990s, which is closely associated with 1992 the South Talks. After the southern talks, Guangdong's economy as a whole showed amazing vitality, and the pearl river delta region quickly widened the gap with other regions by virtue of its popularity, geographical and policy advantages.From 2000 to 2003, the spatial gap narrowed, and economic development showed a certain degree of decline. In particular, the outbreak of SARS had a significant negative impact on Guangdong's economy. However, ,Guangdong started a new round of take-off before long, and has been developing at a high speed till now with steady growth.

Table 7. Comparison of the level of Foreign Investment Utilization in different regions in 2008

region \ index	Newly signed foreign direct investment projects	Contractual foreign investment (billion)	FDI
Total	6999	286.4	191.67
Pearl River Delta	6159	244.78	169.21
East wing	188	10.39	6.33
West wing	178	6.32	3.75
Northern Guangdong mountain area	452	15.27	12.16

Based on the analysis above, the development among the four regions is unbalanced. The the pearl river delta region accounts for more than half of GDP of the whole province, and its development speed is the fastest while other three regions is slow in development. There is both spatial correlation and heterogeneity in the regional economic development of

Guangdong, economically developed pearl river delta region and underdeveloped region tend to be concentrated in space. The capital flow of Guangdong is largely limited within the pearl river delta, investment between different regions is unbalanced. The development policy of prioritizing the development of specific regions weakens the influence on regional disparities of globalization and economic liberalization. Limited capital and human resource and other production factors constantly flow to the pearl river delta uniaxially, it is difficult to exert its economic radiation and driving role in the short term.

Spatial location is an important factor influencing the economic distribution of Guangdong Province, so infrastructure and the degree of opening to the outside world would also influence economic distribution. In the next integration process, Guangdong needs to take relevant measures to promote regional coordinated development and narrow the gap.

6. CONCLUSIONS AND POLICY RECOMMENDATIONS

Give full play to the leading role of the Pearl River Delta and Special Economic zones: Guangzhou, Shenzhen and other citys should maintain their advantages. As the capital of the province, Guangzhou should promote the economy of cities around it. The Pearl River Delta has the advantages of technology, management, marketing, brand and capital, while the less developed region enjoy lower price of resource, we can achieve complementary multi-win; Implementing a differentiated regional policy to accelerate economic development in bacward areas, improve the development environment in mountainous and underdeveloped areas, and to focus on the construction of infrastructure such as transportation, communications, energy etc. Government should lead underdeveloped areas to the road of attracting investment and developing local characteristic industries. And should also promote the industrial process in backward areas and accelerating the optimization and upgrading of industrial structure: the less developed areas should make use of the opportunity and make active use of their own advantages to create conditions to undertake industrial transfer and radiation in the Pearl River Delta. In the western part of Guangdong, the favorable port advantages and location conditions should be used to develop the port industry. The eastern part should actively create a good investment environment and emphasize the development of labor-intensive industries, mountainous areas should use urbanization and agricultural industrialization as breakthrough and Implement flexibility policy of talent flow to promote "reverse" flow of talents. The flow of talents depends the market mechanism and the macro-control of the government. In order to promote the rational allocation of talents and make the best use of human resource. Government must use various means, from financial, legal, economic, administrative, to promote the "reverse" flow of talents. That is, from the Pearl River Delta region to the more backward east-west wings and northern mountain areas.

This paper adopts stochastic frontier analysis method to analyzes the production efficiency and its influencing factors of Guangdong Province by establishing a model of four regions, and preliminarily obtains the reasons for the difference of production efficiency and puts forward some reasonable policy suggestions. The stochastic frontier method is praised by many scholars in measuring efficiency for its convenience and effectiveness to deal with data. However, there are still some shortcomings in multi-output problems. This paper has some shortcomings in the data processing, the methods need to be improved and developed, and the analysis is not deep enough. As a matter of fact, in the process of processing cross-section data, the iterative process of variant efficiency does not converge when calculating, so it is impossible to compare the variation of different time efficiency in the same area. It will result in the fact that the efficiency changes with time in the actual economic development, which still needs to be further improved.

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