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A NEW METHOD FOR MEASURING THE ECONOMIC CONVERGENCE AND ITS APPLICATION ON CENTRAL CHINA PROVINCES

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In order to solve the shortcomings of classical convergence analysis and spatial econometric analysis, this paper proposes a delta statistics method to assess economic growth convergence of central China cities. The result shows to be more close to the reality by analyzing the drawbacks of the classical relative beta convergence, combining the advantages of gams convergence, reference panel data, co-integration theory with the time factor into model. Then, Monte Carlo simulation method is used to analyze its distribution, which shows that it obeys to the normal distribution assumption in large samples. At last, our method is applied to the analysis of economic convergence of central China.

Keywords:
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I. INTRODUCTION

Economic growth is a base for the development of a country or a region. In a large economy, regions with different resource bases and endowments along with rigidity in factor mobility may result in regional disparities. For China, the economic growth rate of different systems has not kept the same since 1980. Usually, the poorer economic entities have higher economic growth rate than the rich economy entities. This is attributed to the economic convergence, which has drawn many attentions from domestic and foreign researchers. Although these researchers built a lot of economic models, most of them follow the same assumptions and have the same conclusions. However, the empirical conclusion doesn't completely follow up the pace of theoretical analysis and often is not accessible to suitable interpretation theory research in econometric analysis because of the inaccessibility of some of the data and the difference of the construction of evaluation index system (Quah, 1993). Development of economy takes it as one of focuses on debate. Does economic growth convergence spread widely or not? What are the factors that lead to the convergence? How to analyze the convergence quantitatively? Many classical measurement methods have effectively explained these problems to some extent, but often the conclusion is disputed because of the shortage of the measurement methods.

In many cases, simple theoretical analysis cannot catch the difference among the various forms of economic convergence phenomena. At the same time, the form and size of economic convergence in different regions of one country needs an empirical analysis into more in-depth understanding. This paper gives a new tool to measure the economic convergences considering geographic factors based on the review of previous related literature. Then we can adopt this method to evaluate 88 cities in six provinces located in the central China after the analysis on the distribution of state by using Mont Carlo simulation.

This paper focuses on the measurement of economic convergence. The rest is organized as follows. In Section 2, we briefly review the current research on this point. Then, including delta (δ) statistics and its distribution, the spatial discrimination rules and growth set and the judgment on economic growth relevance are discussed in Section 3. Section 4 supplies an illustration of the algorithm. An extension about this method is given in section 5. Finally, a conclusion is made.

II. LITERATURE REVIEW

The concept of economic convergence is derived from the neoclassical growth model of Solow (1956). That model shows that the further an economic entity's average per capita income from its steady state level, the higher the rate of return on capital and of per capita income grows. Classical studies mainly give four major kinds of convergence: σ convergence, β convergence, club convergence and γ convergence. σ convergence generally indicates that the standard deviation of the per capita output of each country or region will gradually decrease and eventually approaches 0 and per capita GDP is convergent as time goes by (Friedman, 1992). Club convergence generally denotes that the various economic entities have multiple steady state equilibrium growth paths. Even if the structures are the same, economic entities will not converge to the same steady balanced growth state. Only when the structure's characteristic and the initial state is similar, economy can converge to the same state and then forms the club of economic growth (Barro and Sala-i-Martin, 1991). β convergence contains two different models: absolute β convergence and conditional β convergence. Absolute β convergence denotes that the poorer countries will grow faster than the more affluent countries in the economic development and per capita GDP will eventually be convergent and the steady-state values in various economic entities are alike. Absolute β convergence is more suitable in the regional analysis because this assumption which is used to meet the regional economic growth is approximate but has certain deviations on international economic growth fitting. Relative β convergence widens the limitation of the assumption of absolute β convergence, and puts forward that various economic entities have a different steady state due to natural conditions and resource endowment effect. Thus, economic growth will gradually converge to a separate steady-state value, so as to ensure the authenticity of the neoclassical growth theory and the law of diminishing marginal returns. Therefore it has a very strong theoretical and practical significance. But for each economy data, relative beta convergence can't find its independent steady-state value. That is to say, when exerting relatively beta convergence regression equation, the factors are joined subjectively, which affect convergence, to judge whether the development is the convergent or divergent from the positive and negative value through the regression equation. Therefore, it is possible that different results will occur when the selection effects of convergence factors are different (Barro et al., 1991, 1992). Boyle and McCarthy (1997) also proposed another simple convergence method depending on the complexity of beta convergence, i.e., Kendall harmony index, which is also known as gamma convergence. Gamma convergence is characterized by the avenue to introducing economic entities per capita income rank to do sum calculation. It is an innovation to the previous research. It not only introduces the rank, but also sums up the total rank over years, because the stock index should be put into consideration in economic growth. When summing up the ranks over years in consideration of economic stock index, even if several former years hold reduced revenues, the income increase in the following years will also make up the stock loss a few years ago, thereby keeping the economy impact limited in some certain level.

These four kinds of convergence methods have a common characteristic which analyzes the utilization of cross section data in the same period. Therefore, there are many researchers who put forward some new analysis methods in accordance with economic growth convergence dynamic problems, including the method of panel data, time sequence co-integration, clustering algorithms, panel unit root and so on (De la Fuente, 1997; Leonida et al., 2004; Azomahou et al., 2011). In these methods, the cross section and panel data method focus on the analysis of representative economy behavior and co-integration. Clustering law tends to focus on the economy of income gap, while the method of panel unit root puts more focus on the entire economy long-term income gap. Recently, Matsuki and Usami (2011) revealed that the convergence of the provincial per capita outputs exists in the Eastern, Central and Western regions of China. However, these methods rarely take space geographical factor into consideration.

Economy distance will be affected by the economic spillover and convergence to a certain extent, which requires the research exist on the space of the economic growth of an area and the surrounding area (Rey and Dev, 2006; Ma and Kang, 2011) when using spatial econometrics method to analyze and study the interdependent relationship. However, as for the classic convergence mode analysis method, the conclusion is often one whole economic system of convergence and diffusion (Costantini and Lupi, 2005). Although spatial econometric methods can analyze various economy of economic systems convergence or diffusion separately, they are only based on the cross section data without regarding the time dimension. This cannot make the data dynamic.

III. THE DELTA CONVERGENCE

The space influences among areas on economic growth can be divided into economic level effect and economic growth effect. This paper studies the economic effect based on the assumption of the economic level increase, that is to say, it assumes that the economy has self-growth trend even without outside influence. The paper puts forward two hypotheses which are restricted on economic entities' heterogeneity on that assumption, namely, the consumption patterns and the price of various economic entities are the same. The two assumptions ensure the stability and comparability of economic growth in different regions without substantially change. To describe economic entities which are affected by economic growth of spatially adjacent regions or other regions, we should compared it with self-growth period in separate cases in order to show the degree of impact by the economic growth. However, in reality it is impossible to carry on the observation because of the existence of observation obstacle. In order to analyze the economic growth convergence degree, we must overcome the observation obstacle. In their economic growth, the government only needs to meet the demand of growing population. Thus, using the population per capita GDP growth $y=\{Y_1,Y_2,\cdots,Y_t\}$ to quantitatively measure economic self-growth is a good choice. At the same time, it has comparability between the self-growth of GDP by calculating the average per capita income and the observation sequence because of the assumption that population consumption patterns and the price are equal.

According to this idea, we describe the external influence of economic entities from two respective aspects. One is to inspect the development sequence of economy over years and to determine whether the deviation between the observation sequence and self-growth sequence trend is influenced remarkably by the external economic impact. The other one is to join the adjacent economy together based on the Rooks adjacent judging rules, and then analyze the economic growth sets to obtain the relationship between spillover effect economy and convergence effect economy.

A. The δ statistics and its distribution

As a result of the observation that sequence $x=\{X_1,X_2,\cdots,X_t\}$ is subjected to outside influence, the internal industry is vulnerable to outward economy deflection or absorption of external economy industry. Thus the observation sequence trend is not necessarily similar with the trend of self-growth sequence. So there may be faster or slower rates than the rate of self-growth sequence growth. We define that the observation sequence trend which is faster than the self-growth sequence trend as being affected positively by the outside world, and define the slower on as being affected by the negative effect. The agglomeration of economic entities by positive effects can be defined as generating economic growth convergence, and the agglomeration economic entities set can be called the growth set. (See FIGURE 1.) However, different degrees of using resources of different areas lead to different output efficiencies, which make the overall level of series of self -growth higher or lower than the observed growth series. So we should subtract the mean of observation sequence from the mean of self-growth sequence, and then modify it as follows:

$$z_i = x_i + \left(\overline{x} - \overline{y}\right) \qquad (1)$$

z is defined as the modified self-growth sequence, x is defined as observation sequence, y is defined as self-growth sequence. To modify the self-growth sequence by formula 1 can get rid of the effect of different input output efficiencies which caused by resources, the manpower, the environment and some other factors.

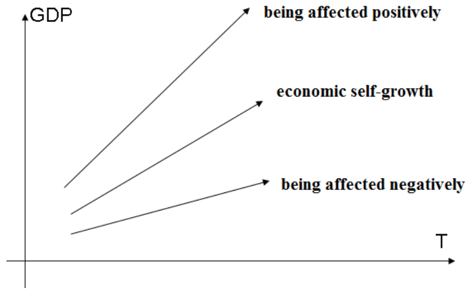


FIGURE 1. ECONOMIC GROWTH TREND AND ITS INFLUENCE

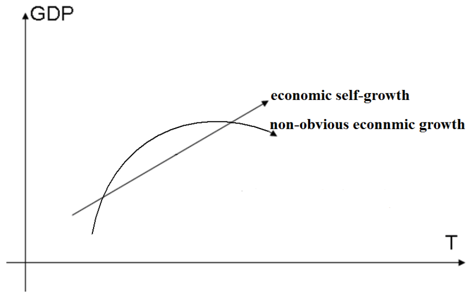


FIGURE 2. ECONOMIC SUBJECTED TO UNCERTAIN EFFECT

Here, we use the variance between the observation sequence and the self-growth sequence to describe the relationship between observation sequence and modified self-growth sequence, as follows:

$$\Delta x = x - z \tag{2}$$

$$S = Var(\Delta x) = \frac{1}{n}\sum\left(\Delta x - \overline{\Delta x}\right)^2 \tag{3}$$

The variance is 0 if the observation sequence and self-growth sequence show the synchronous growth. The variance is not 0 if observation sequence is subjected to external economy effect. The greater the effect is, the bigger the variance is. Then, we introduce the sign function to describe the direction which is positive or negative influence imposed on the economic entities.

$$\mathrm{Sgn(x)} = \begin{cases} 1 & \mathrm{x} > 0 \\ 0 & \mathrm{x} = 0 \\ -1 & \mathrm{x} < 0 \end{cases} \tag{4}$$

The sign function is to sum the difference between the observation sequence and modified self-growth sequence, so it can generalize the development of economic entities subjected by outside influence over these years. When the sign function is 0, then there's no outside influence. If the economy is always subjected to external positive or negative influences, the sign function is positive or negative. If there is the situation as shown in Figure 2, it indicates that the economy is subjected to external positive influence in the initial period, and to the negative influence in the terminal period. So we define the effect as a non-obvious one. But this situation is not common in reality. Then the statistic δ is defined as:

$$\delta = \frac{Var\left(\Delta x_i\right) \times \mathrm{sgn}(\Delta x_i) - \overline{\Delta x}}{\sqrt{Var(\Delta x_i)}} \tag{5}$$

Then we use the statistics to carry on the Monte Carlo simulation. The result shown in Figure 3 is gained through 100000 times simulation estimation. Therefore, statistics δ obeys double peak distribution. If delta > 0, it is said that the economy is subjected to external positive influence and plays an increasing important role on internal stock index. If δ < 0, it is said that the economy is subjected to external negative influences and plays a decreasing role on internal stock index.

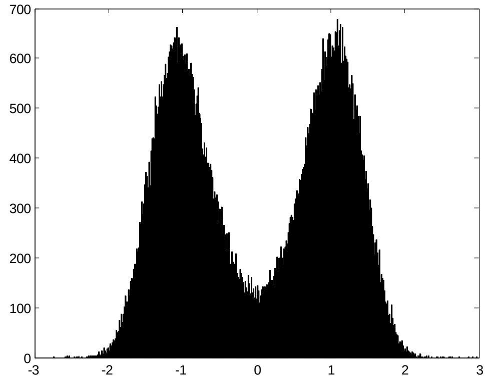
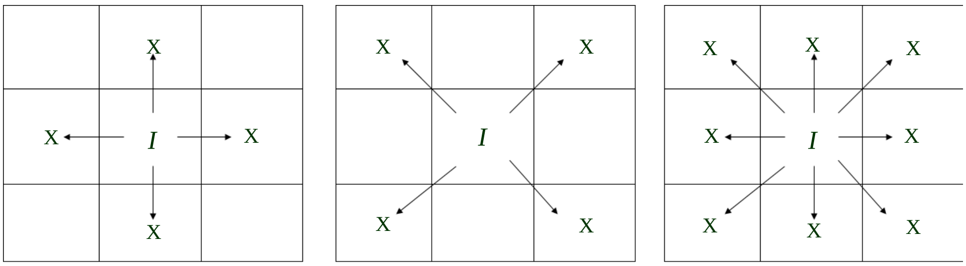


FIGURE 3. RESULTS OF MONTE CARLO SIMULATION

B. The spatial discrimination rules and growth set

The spatial correlation analysis requires certain rules on the measurement of relationship of the location of proximity. Most spatial correlation analysis use common adjacent relationship definitions. As for the adjacent position measurement criteria, there are three kinds of measurement methods: Rooks (total edge adjacency, namely direct four neighborhood adjacency), Bishops (concurrent adjacency to the diagonal direction, namely four neighborhoods adjacency) and Queen's (total edge or concurrent are contiguous, namely eight neighborhoods adjacency).



(a) Rooks (b) Bishops (c) Queen's

FIGURE 4. SIMPLE DEMONSTRATION OF THE NEIGHBORHOOD RELATIONSHIP

In this paper, the Rook method is used, which assumes the effects among economic entities only exist in the adjacent economic entities. Based on this method, we define the trend effect of regional economic growth aggregation and diffusion, as shown in FIGURE 5:

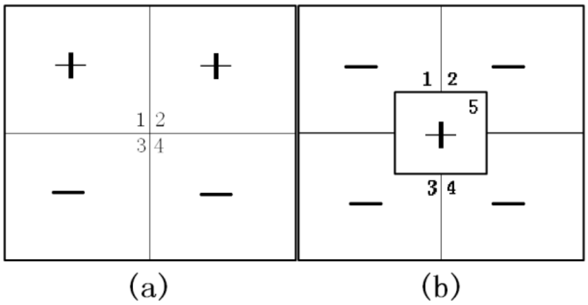


FIGURE 5. THE RELATIONSHIP OF AREA AFFECTED

If the economic entities behave as Figure 5(a) shown, the area 1 and the area 2 is affected by the external world where the economic growth is faster than its self-growth. Then we nominate area 1 and area 2 as the forward diffusion effect, which forms a set of economic growth; area 3 and area 4 generate economic spillover effect, and overflow to the area 1 and area 2 respectively. According to Rooks discriminant rules, there is no transformation between area 1 and area 2, and between area 4 and area 3. If the relationship of economic entities is the situation as FIGURE 5 (b) shown, all of these areas 1,2,3 and 4 generate economic overflow, and area 5 is positively effected by them, so area 5 is defined as generation of polarization effect and area 1,2,3 and 4 each is defined as generation of negative diffusion effect. The economic entities which are significantly positively or negatively related to each other can be judged by the method as shown in Figure 5 in order to determine the degree of convergence of economic growth and obtain the economic growth set.

IV. ILLUSTRATIONS

According to the method proposed above, we use δ test for convergence on the 88 cities of six provinces in Central China. The sources of the data are the statistical yearbooks of Shanxi, Henan, Hubei, Anhui, Hunan and Jiangxi of China. By formulate (5), δ values for 88 cities are calculated. If we define the city of which δ statistical value is more than 1 as being affected by significantly positive correlation, and define the city whose δ statistical value is less than - 1 as being affected by significantly negative correlation. Through GIS software, we sign the results in the map of Figure 6. Then, Hengyang, Shaoyang, Shangqiu, Wuhan, Xinyang, Zhumadian, Zhoukou and Nanyan city were affected obviously positive influence from the external world, and their economic growth sequence and self-growth observation sequence would show obvious fluctuation trend. Among these cities, Wuhan, Shangqiu, Xinyang, Zhumadian, Zhoukou and Nanyang are in the adjacent position in the geographical space, while Hengyang and Shaoyang are also in the adjacent position, constitute the economic growth set. On one hand, the development of these economic growth sets may be derived from each other and then promoted by each other. On the other hand, it may be affected by external shocks at the same time. But this certain kind of impact is beneficial to the development of the city, and promote economy grows faster than its self-growth.

The results are shown in Table 1 and FIGURE 6.

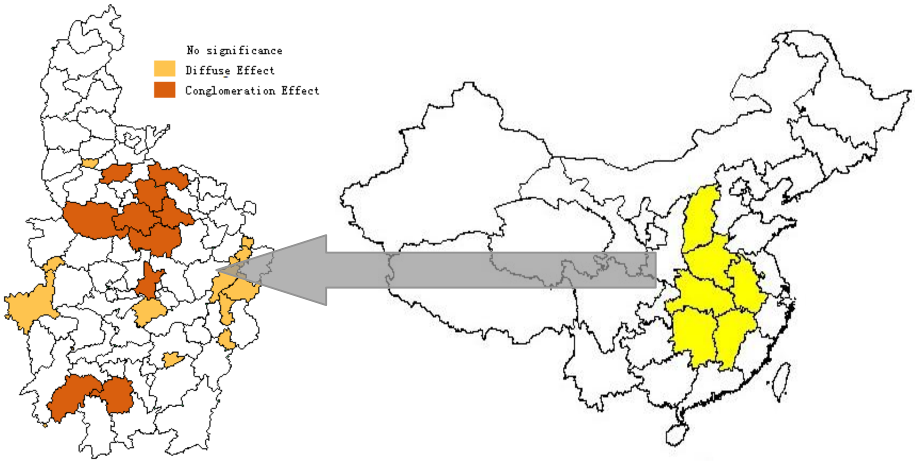


FIGURE 6. RESULTS OF CONVERGENCE TEST

TABLE 1 - THE δ STATISTIC VALUES OF 88 CITIES FROM SIX PROVINCES IN CENTRAL CHINA.

City	δ	City	δ	City	δ	City	δ
Anqing	0.3574	Huainan	-1.5626	Nanyang	6.2269	Xiangxi	-1.0964
Anyang	1.4627	Huanggang	1.4872	Pingdingshan	1.1197	Xiangfan	0.6710
Bengbu	-0.9939	Huangshan	-2.1718	Pingxiang	-1.9069	Xiaogan	0.1605
Changsha	1.5593	Huangshi	-1.3313	Puyang	-0.0043	Xinzhou	0.0711
Changzhi	0.0537	Ji'an	-0.1979	Qianjiang	0.2512	Xinxiang	1.5948
Changde	1.1908	Jiyuan	-2.4098	Sanmenxia	-1.1653	Xinyu	-2.3222
Chaohu	-0.5047	Jiaozuo	-0.1313	Shangqiu	3.8476	Xinyang	3.9793
Binzhou	0.2361	Jincheng	-0.9590	Shangrao	0.7831	Xychang	0.8327
Chizhou	-2.1059	Jinzhong	-0.0596	Shaoyang	2.1833	Xuancheng	-1.4847
Chuzhou	-0.5119	Jingmen	-1.1777	Shennongjia	-2.9249	Yangquan	-1.7874
Datong	-0.0592	Jingzhou	0.9112	Shiyan	-0.8127	Yichang	-0.1501
Ezhou	-2.2525	Jingdezhen	-2.0699	Shuozhou	-1.5605	Yichun	0.1759
Enshi	-5.0958	Jiujiang	-0.2226	Suzhou	0.5135	Yiyang	0.2155
Fuhzou	-0.7312	Kaifeng	0.9994	Suizhou	-1.3481	YIngtan	-2.3324
Fuyang	2.6455	Linfen	0.9682	Taiyuan	0.1628	Yongzhou	0.9982
Ganzhou	1.8775	Lu'an	0.9093	Tianmen	0.1969	Yueyang	0.7704
Bozhou	0.3605	Loudi	-0.0993	Tongling	-2.5736	Yuncheng	1.8618
Hefei	-0.2292	Lvliang	0.5829	Wuhu	-1.6965	Zhangjiajie	-1.8471
Hebi	-1.7846	Luoyang	2.3771	Wuhan	3.8839	Zhengzhou	2.3414
Heyang	2.0187	Luohe	-0.8076	Xiantao	-1.3266	Zhoukou	6.1205
Huaihua	0.4769	Maanshang	-2.2619	Xianning	-4.1668	Zhuzhou	-0.3801
Huaibei	-1.7617	Nanchang	-0.2998	Xiangtan	-0.9453	Zhumadian	4.1878

Sources: calculating consolidation according to the formula (5).

From FIGURE 6 and TABLE 1, we can also see that the provinces near six central provinces influence those cities of the six provinces. Some cities are affected not only by those cities in central six provinces, but also by those provinces around them. For example, from these macro-structures of six central provinces, we can see the spillover effect of the northeast and the south of six central provinces and the west of Hubei-Hunan are more obvious. There are two main reasons. One is that the northeast and south cities are adjacent to the eastern coastal areas with a relatively quick economic development which affect the development of mid economy of certain degree very naturally and makes capital and technology spillover. Especially Jiangxi and Anhui, that are adjacent to Zhejiang and Jiangsu with high levels of economic development, must cause this kind of situation. The other reason is related with western Hubei, such as Shennongjia and Enshi. Their adjacent areas face Guizhou and Yunnan whose economic are extremely low, so they develop in coordination with western provinces and result in slow economic development. Due to the relatively rapid economic development in the eastern provinces, the current resource of six central provinces can not keep up with the economic development of eastern provinces, thereby resulting in their own economic capital spillovers. Generally speaking, because the economy of the western provinces is relatively backward and have no core industry that can support their economic development, so these areas compose the economic negative overflow set, which is bad for the development of these areas with western province together. It should be noted about the development of Wuhan. The fluctuations of the economic development of the surrounding cities of Wuhan are not obvious, while the economy of Wuhan develops faster, which might be caused by the absorption of the Xianning city economic development factors as well as the rapid growth resulting from economy central and local policy support.

V. EXTENSION OF THE METHOD

Based on the δ convergence judgment method, we can introduce the improved theoretical model of spatial econometric analysis. Thus, classical first-order pure spatial autoregressive model (SAR) can be expressed as:

$$y = \alpha + \rho W y + \beta X + \varepsilon \tag{6}$$

In the formula above, α is defined as the constant; ε is defined as the random error vector; ρ is defined as the spatial auto-regressive coefficient; X is defined as the explanatory variables. W matrix is defined as a two-element matrix, which is defined as:

$$w_{ij} = \begin{cases} 1 & i \ and \ j \ are \ neighbors \\ 0 & otherwise \end{cases} \tag{7}$$

But according to the judgment results of δ convergence, we can analyze the areas directly whose test results are significant and adjacent to each other in space without using w matrix. Then the formula is conveyed as:

$$y = \alpha + y_{\delta} + \beta X + \varepsilon \tag{8}$$

Wherein, y_{δ} stands for the areas whose tests are significant and near to each other in space, X is defined as explanatory variables. It can greatly simplify the problem caused by too many variables that its result cannot be estimated accurately. This way, the estimation accuracy can be enhanced.

VI. CONCLUSIONS

This paper summarizes the advantages and disadvantages of the previous evaluation of economic growth convergence methods. Then a new evaluation method of convergence is proposed by adopting above methods' advantages and abandoning their shortcomings. Through the examination of Monte Carlo simulation method, we find that δ statistics obeys the normal distribution assumption in a large sample. And δ convergence is applied to the evaluation of six central provinces in order to obtain the development suggestion for theses six provinces. The new δ convergence evaluation method has the following advantages compared to the previous evaluation method.

First, the traditional β convergence, γ convergence and σ convergence judge whether there is convergence in the whole economic system through comparing the beginning with ending values of one economic system without separate analysis and judgment on each entity of the whole economic system. Because δ convergence method evaluates each entity through the convergent and divergent judgment, the analysis is more accurate.

Second, the local Moran index can judge the convergence of a single economic entity's convergence through one period of cross-sectional data, but it is unable to grasp the convergent or divergent trend of the economic entity in a period compared to spatial econometric Moran index. Thus it cannot give a dynamic analysis on convergence.

δ convergence method judges on not one time of cross section data but the time series. Because some economic entities are in convergent state in a period and in divergence state in another period, we can get the final judgment through accumulating the various states of economic entity over the years. By doing so, it can make the convergence trend more dynamic.

Third, compared to the panel model and co-integration model which make convergence analysis by introducing a time factor, but ignore the heterogeneity and space contact among economic entities of each economy, and finally influence the accuracy of analysis results, δ convergence applies the judgment rules of spatial econometrics (Rooks) to consider the impact of spatial distance on convergent or divergent state. It has the advantages that panel and co-integration do not have.

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NOVA METODA MJERENJA EKONOMSKE KONVERGENCIJE I NJENA PRIMJENA NA CENTRALNE KINESKE PROVINCIJE

Sažetak: Kako bi se otklonili nedostaci klasične analize konvergencije i prostorne ekonometrijske analize, ovaj rad predlaže delta statističku metodu za potrebe procjene konvergencije ekonomskog rasta u gradovima centralne Kine. Rezultati pokazuju da se dolazi bliže stvarnosti analizirajući loše strane klasične relativne beta konvergencije kombinirajući prednosti gama konvergencije, referentnih panelnih podataka, kointegracijske teorije s vremenskim faktorom u modelu. Zatim, Monte Carlo model simulacije se koristi za analizu distribucije što pokazuje da odgovara pretpostavci normalne distribucije u velikim uzorcima. Naposljetku, naša se metoda primjenjuje na analizu ekonomske konvergencije u centralnoj Kini.

Ključne riječi: ekonomski razvoj, δ konvergencija, Monte Carlo simulacija, Centralna Kina