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Analysis on the changes of convergence of regional economic growth in China: 1984-2010

Fei CHEN, Xiangwei SUN

Development of Economics, Nanchang University, 999 Xuefu Avenue, Nanchang, Jiangxi 330031, PRC
Email: chenfei@ncu.edu.cn, xiangwei_sun@163.com

Abstract:

This article mainly aims to examine the change of absolute σ-convergence, absolute and conditional β-convergence of regional economic growth at the Provincial level in China in the period of 1984-2010. Based on the regional division and the use of Per Capita GDP, to analysis the convergence process by Theil Coefficient in 1984-2010 and calculate T_B and T_W (intraregional and interregional inequality). Then to analysis the σ-convergence and Absolute β-convergence at provincial level in 1984-2010 and recognize the dynamics of convergence process of regional economic growth in China, to grasp the change of σ-convergence in prefecture level in 1992-2010, and check the change for each regions at the same time. Lastly, several control variables are chosen to establish a proper model for the test of conditional β-convergence of regional economic growth at the Provincial level in the period of 1990-2010 based on the Regression Equation and calculate the velocity of convergence. With the use of spatial econometric model, there is an additional test about spatial autocorrelation for absolute β-convergence and conditional β-convergence model in period of 1990-2010. Considering the robustness of the results, the spatial lag model and spatial error model will be set to analyze those spatial autocorrelation effects.

Key Words: Convergence, Regional economic growth, Spatial autocorrelation, China

1. INTRODUCTION

In the past two and half decades, China has achieved rapid economic development with the carry out of regional unbalanced development and opening-economy policies. However, the regional gap is widening gradually, which has become the biggest challenge that influences social stability in future. Recently, inclusive growth and harmony development between economic and social fields become two vital targets for China economic development. It is necessary for Chinese government to find a better routine to shift the national development policy.

Since the mid-1990s, the research on the convergence of regional economic growth in China is expanded gradually. One of the earlier of researcher is Wei Houkai (1997). Based on the application of Barro formulas, regional economic convergence of China is analyzed for the period of 1978-1995. The results show that there is not conditional convergence but absolute convergence in China and the speed of convergence of per capita GDP growth is fast in all areas in the same period, though not convergent from 1985 to 1995. Cai Fang and Du Yang (2000) also used Barro's analytical methods to prove that there is no absolute convergence among provinces in China, but a conditional convergence occurred in the period of 1978-1998. They believed that regulatory measures such as human capital, capital input, opening level to the outside world and the government's reform policies are the most important factors for the explanation of convergence occurred. Lin Yifu and Liu Mingxing (2003) obtained a similar conclusion and regarded that convergent periodical is related to the promotion of China's reform in time and space. In later 1980s, it is highlighted that China's economic reform transferred from the microscopic operation mechanism towards macroscopic policy environment.

Hu Angang and Zou Ping (2000), Luo Renfu, Li Xiaojian etc (2002) believed that a universal beta absolute convergence didn't exist in China since the reform and opening-up period, but conditional convergence existed with the consideration of the negative correlation between the growth rate of Per Capita GDP and the initial Per Capita GDP. And if the selected control variables are different, the speed of convergence differed too. Liu Kiang's research (2001) shows that the convergence of regional economic growth is weak on the whole in China, though such convergence is strengthening in some local regions and there is always convergence occurred in different periods within the scope of eastern regions, central China, western regions respectively. Sheng Kunrong and Ma Jun's research (2002) shows that there are three club convergences formed within each region since the reform and opening-up period, meanwhile the gap among three major regions have not been narrowed but even enlarged. According to Qin Chengling (2004) and Xu Xianxiang and Shu Yuan (2005), there is a periodical fluctuations for the change of convergence of regional economic growth and there is a σ-convergence of regional economic growth in the period of 1978-1990 in China, but no σ-convergence since the 1990's. Allowed for the complex relationship and mutual influence

existed among the various elements in real economic system, it is very difficult to analyze and grasp complicated inequality of economic growth and the change of convergence in details, so it is necessary to consider the feature of geographical space for the establishment of a more accurate convergence model. With the application of spatial econometrics model on the basis of new classical growth model, Wu Yuming (2006a, 2006b), Ling Guangping, Long Zhihe and Wu Mei (2006) believed that the convergence of regional economic growth is strengthen significantly in China with the consideration of spatial matrix W and spatial autocorrelation in initial model and it is not overlook the effect of spatial structure on the change of convergence of regional economic growth too, then concluded that there is a wave change of convergence of regional economic growth in China. Zhang Xueliang (2009) finds evidence of significant spatial autocorrelation or spatial dependence of economic growth of 132 counties, cities or regions in Yangtze River Delta by using spatial statistical and spatial econometrical techniques, as well as evidence of convergence tendency. But the speed of economic convergence is significantly falling, and the result is statistically significant. Hong Zhiguo, Hu Huaying and Li Xun (2010) combine the standard analysis method of economic convergence with spatial econometrics to explore regional convergence based on a total of 240 cities in China. The results based on the spatial models indicate the existence of absolute convergence between cities, although absolute convergence is not stable. Pan Wenqing (2010) using the spatial econometrical methods to explore the convergence tendencies of China, found that there exists a β-absolute convergence at national level ,but this convergence assumed different patterns. Prior to 1990, the national convergence was statistically significant and was quite significant in both the eastern and central/ western regions. After 1990, the national convergence disappeared and the convergence that had traditionally occurred in the eastern and central/ western parts of China was now taking place in the eastern, central and western parts of China.

Based on the regional division of five regions, the article aims to examine the change of absolute σ-convergence and absolute and conditional β-convergence of regional economic growth at the Provincial level and the prefecture level in China firstly, then the change of convergence in different regions is analyzed to illustrate the whole change of convergence of regional economic growth in the past two decades in China.

This article is divided into three sections. The first section is related to the basic theories and measures of convergence, Regional Divisions in China and Data Collection. The second is to analyze the change of convergence process of regional economic growth in China at the Provincial level in the period of 1984-2010and the prefecture level in the period of 1992-2010 and the third focuses on the establishment and the explanation of a proper model for the test of conditional β-convergence of regional economic growth at the Provincial level in the period of 1990-2010. With the use of spatial econometric model, there is an additional test about spatial autocorrelation for absolute β-convergence and conditional β-convergence model in period of 1990-2010 too.

2. BASIC THEORIES AND MEASURES OF CONVERGENCE

2.1 σ-convergence and β-convergence

The idea of convergence is an implication of the Solow (1956) growth model. By assuming that labor and the level of technology grow with an exponential form, at rates *n* and *g* respectively, the below is a style of differential equation.

$$\dot{k} = sf(k) - (n + g + \delta)k \qquad (1)$$

where *s* is the constant rate of savings, δ is the constant rate of Capital depreciation.

Barro and Sala-I-Martin (1990, 1991) defined the σ-convergence and β-convergence from a strictly econometric point of view and β-convergence can be divided into absolute β-convergence and conditional β-convergence. Barro & Sala-I-Martin (1992) introduced σ-convergence, a stringent measure of convergence, which is obtained when the dispersion of per capita income across countries or regions declines near zero over time.

$$\sigma_t^2 = \frac{1}{n}(\sum_{i=1}^{n} \log y_{i,t} - \frac{1}{n}\sum_{i=1}^{n} \log y_{i,t})^2 \qquad (2)$$

where $y_{i,t}$ is the per capita GDP or Income of *i* region at *t* period. For two different times, one is *t* and another is *t+T*. If $\sigma_{t+T} < \sigma_t$, means that there is an σ-convergence occurred, otherwise there is no σ-convergence occurred from *t* to *t+T*.

β-convergence is an alternative form of convergence that accommodates for differences across countries and regions. It indicates that poorer countries are growing faster than the richer ones. The idea of β-convergence is also derived from Solow-Swan model. β-convergence does not imply that the countries will reach the same steady state, as implied by σ-convergence. Barro and Sala-I-Martin (1990, 1992) given the form of classical absolute β-convergence equation when they tested the convergence of 48 states in USA.

$$\frac{\ln y_{i,t+T} - \ln y_{i,t}}{T} = \alpha + \beta \ln y_{i,t} + \mu_{i,t} \qquad (3)$$

The cross-sectional framework of β-convergence involves the difference between the logarithms of per capita income at two distinct points in time over a constant and the logarithm of income at the earlier time. For convergence to exist, the average growth rate between time *t* and *t+T*, must decline with increasing levels of initial income. Hence, in the above regression β-convergence is associated with $\beta < 0$. And we can calculate the absolute β-convergence based on the equation (3). For example, Atkins and Boyd (1998) have studied convergence among CARICOM members and have found existence of different steady states. Furthermore, the rate of convergence, *b*, can be computed by the equation below for *b* as in Maurseth (2001):

$$\beta = -(\frac{1 - e^{-bT}}{T}) \qquad (4)$$

The Regression results of Equation (3) and (4) depend on the initial level of per capita income

only, and there is no the effects of other additional variables. However, the growth rate of region's per capita income depends not only on the initial level of per capita income, but also by the factors of resource endowments, industrial structure, factor mobility between regions and so on.

A less restrictive form of β-convergence is its conditional version, which is obtained by augmenting the estimation equation with control variables. If the regression results still shows a negative correlation between $(\ln y_{i,t+T} - \ln y_{i,t})/T$ and $\ln y_{i,t}$ when a few control variables have been considered in Equation (3), then there is a conditional β-convergence existed. The approach followed by Mankiw et al (1992) is to estimate conditional β-convergence by controlling for a set of control variables X_j. The model is estimated over a period of time T, leading to a cross-sectional equation of the type.

$$\frac{\ln y_{i,t+T} - \ln y_{i,t}}{T} = \alpha + \beta \ln y_{i,t} + \sum_j c_j X_i^j + \mu_{i,t} \qquad (5)$$

σ-convergence is the most restrictive form of convergence. It denotes that the standard deviation of GDP per capita of a group of countries decreases over time if they are converging. For σ-convergence to exist, countries with initial lower per capita GDP must grow faster than those with higher per capita GDP. In other words, for σ-convergence to exist, β-convergence must occur. Equation (6) shows the relation between σ-convergence and β-convergence.

$$\sigma_{y,t}^2 = (1+\beta)\sigma_{y,t-1}^2 + \sigma_u^2 \qquad (6)$$

where β is the coefficient estimated and σ_u^2 represents the variances of the error term u. Furthermore, for σ-convergence to occur, it is necessary that $\beta < 0$, indicating that β-convergence must hold.

2.2 Theil coefficient

Theil coefficient is also one of decomposable inequality indicators. Rey S J (2004) provided a formal explanatory framework to analyze the dispersion aspects of the convergence process. Jülide Y (2009) investigated regional income inequality and the convergence dynamics in Turkey in 1987–2001 with Theil coefficient. The form of Theil coefficient is:

$$T = \sum_{i=1}^{n} y_i \log \frac{y_i}{p_i} \qquad T = T_B + T_W \qquad (7)$$

$$T_B = \sum_r y_r \log \frac{y_r}{p_r} \qquad T_W = \sum_r \frac{Y_r}{Y} T_{Wr} \qquad (8)$$

$$T_{Wr} = \sum_r \frac{Y_r}{Y} \log \frac{y_{ir}/Y_r}{p_{ir}/P_r} \qquad (9)$$

where T denotes the total inequality, y_i and p_i are the shares of national income and population of unit i, respectively, and Y_r and P_r are the same shares for regions. T_W is within region

inequality, and T_B is between region inequality, measure intraregional and interregional inequality respectively, y_{ir} and p_{ir} are the income and population of unit *i* in region *r*.

In a spatial context, the intraregional inequality measures differences between the incomes of provinces belonging to the same region, whereas interregional inequality measures the difference between the mean incomes of aggregate regions.

2.3 Test of Spatial Autocorrelation for β-convergence

As the date structure of β-convergence is (special) cross-sectional, regional spillover effects and spatial dependence may exist. So it is necessary to test for spatial autocorrelation in the residuals and fit a spatial autoregressive model to deal with the effects of spatial autocorrelation. Before test for it, one important thing is to set a weight matrix W to measure the connectivity between regions. A weight matrix W is a squared symmetrical matrix .In this paper, the weight matrix W is defined as follows:

$$w_{ij} = \begin{cases} 0 \; if \;\; i = j \\ 1 \; if \;\; i \; and \;\; j \; share \; a \; common \; edge \\ 0 \; if \;\; i \; and \;\; j \; share \; no \; common \; edge \end{cases} \qquad (10)$$

where w_{ij} is an element of the weight matrix W. If region i and j share a common edge, the value of this element is 1; in other situation, the value is 0. And then, it needs to normalize the matrix, to make the elements of every row amount to one.

After set a weight, spatial autocorrelation can be test with the Moran's *I* and Lagrange Multiplier. Moran's *I* can test whether there is positive or negative special autocorrelation in the residuals. Moran's *I* reflects the degree of similarity of the attribute value among the adjacent regional units in space. Similar to Correlation coefficient, the range of Moran's *I* is from -1 to 1. 1 means that there exits strong positive spatial correlation among random phenomena; 0 means the attribute values are distributed randomly and independently in space; -1 means there exits strong negative spatial correlation. However, the shortage of Moran's *I* is that it could not tell which way, spatial lag or spatial error, is better for dealing this spatial correlation. While Lagrange Multipliers Test (Robust Lagrange Multiplier Test) can supplement the shortage of Moran's *I*. Lagrange Multipliers Test (Robust Lagrange Multiplier Test) is based on the result of ordinary least-squares estimation. Anselin, et al. (2004) suggest criterions as follows: in the test, if LM LAG is more significant than LM ERROR, and Robust LM LAG is significant, while Robust LM ERROR is not, it can conclude that spatial lag model is more appropriate; on the country, if LM ERROR is more significant than LM LAG, and Robust LM ERROR is significant, while Robust LM LAG is not, it can conclude that spatial error model is more appropriate.

To deal with the effects of spatial autocorrelation, generally speaking, there are two approaches using Maximum Likelihood estimation, which are spatial lag model and spatial error model.

Spatial lag model includes a spatially weighted dependent variable, which is defined as follows:

$$y_i = \delta \sum_{j=1}^{n} w_{ij} y_j + a + x_i \beta + \varepsilon_i \qquad (11)$$

where yi denotes dependent variable of region i, $\sum_j w_{ij} y_j$ denotes the interactive effect of dependent from adjacent region to region i, α is constant, x is exogenous variable. ε is a normally distributed error term.

Spatial error model includes a spatially autocorrelated error term which is defined as follows:

$$y_i = a + x_i \beta + \varepsilon_i, \ \ \varepsilon_i = \rho \sum_{j=1}^{n} w_{ij} \varepsilon_i + u_i \qquad (12)$$

where $\sum_j w_{ij} \varepsilon_j$ denotes the interactive effect of error terms from adjacent regions to region i, u is a normally distributed error term.

Unlike Moran's I or Lagrange Multiplier Test, Likelihood Ratio (LR) Test is based on the result of Maximum Likelihood estimation. For spatial error model, the Null Hypo hypothesis of LR Test is H0: ρ=0, while for spatial lag model, the null hypothesis is H0: δ=0. Both two LR Statistics obey the chi-square distribution.

As the first researchers considering economic convergence issues with Spatial data analysis methods, Rey and Montouri (1999) reconsider the question of US regional economic income convergence over the 1929-1994 period from a spatial econometric perspective. Strong patterns of both global and local spatial autocorrelation are found throughout the study period. A spatial econometric analysis reveals strong evidence of misspecification due to ignored spatial error dependence. Ertur, Gallo and Baumont (2006) show that spatial dependence and spatial heterogeneity matter in the estimation of the β-convergence process among 138 European regions over the 1980 to 1995 period. Using spatial econometrics tools, they detect both spatial dependence and spatial heterogeneity in the form of structural instability across spatial convergence clubs. The estimation of the appropriate spatial regimes spatial error model shows that the convergence process is different across regimes. Based on a sample of 145 European regions over the 1980–1999 period, Gallo and Dall'erba (2006) estimate a Seemingly Unrelated Regression Model with spatial regimes and spatial autocorrelation and the estimation results point to the presence of spatial error autocorrelation, indicating the formation of a convergence club between the peripheral regions of the European Union.

3. REGIONAL DIVISIONS IN CHINA AND DATA COLLECTION

3.1 Regional divisions in China

There are different ways for regional divisions in China. Since 2003, one of the most popular is to divide whole China into four economic regions, which include Eastern Region, Central China, Northeast Region, and Western Region. And with the idea of regional harmony

development become more popular in the policies analysis of regional economic development, another typical ways is to divide the whole China into Five Regions, which include Eastern Region, Central China, Northeast Region, Southwestern Region, Northwest Region. The different between those two ways is that western region in the former is divided into two parts, Southwestern Region and Northwest Region. Eastern region is 11 provinces, includes Beijing, Tianjin, Hebei, Shandong, Jiangsu, shanghai, Zhejiang, Fujian, Guangdong, Hainan and Taiwan. Northeast Region is 3 provinces, includes Liaoning, Jilin and Heilongjiang. Central China is 6 provinces, includes Shanxi, Henan, Anhui, Hubei, Hunan and Jiangxi. Northwest Region is 6 provinces, includes Neimenggu, Shanxi, Gansu, Ningxia, Qinghai and Xinjiang. Southeast Region is 6 provinces, includes Sichuan, Chongqing, Yunan, Guizhou, Guangxi and Xizang.

3.2 Data collection

The data are obtained from the Chinese Statistical Yearbook at the Provincial level and the prefecture level. And the selected provinces included in this article are 31 provincial units, not include Hong Kong, Macao and Taiwan. And the major selected time period for this research is 1984-2010.

For the need of data analysis, the authors collect the data of Per Capita GDP at the Provincial level and the prefecture level from 1984 to 2010. To recognize the dynamics of convergence process of regional economic growth in China, it is necessary to eliminate the price effects by the use of Price Index too. Allowed for the need of model analysis, a few important indicators which affect the growth of Per Capita GDP should be considered, so eight control variables X_j are chosen to illustrate the change of conditional β-convergence at provincial level in the period of 1990-2010 in China.

Those selected variables include:

(1) Behavior of Government = Government Expenditure / GDP, marked as BG. As is known to all, government plays an important role in nation's economy control. Government expenditure is a significant component of gross domestic product, which reflects the Fiscal policy of government in some extent.

(2) Human Capital: Represented by the Average ratio between student and teacher, marked as HC. Human capital is a key factor which directly affects the production rate, especially in postindustrial age. Human capital has innovation and creativity, which is essential to allocate resource efficiently.

(3) Investment Rate = Total Investment / GDP, marked as IR. As an important part of GDP, the Investment Rate can reveal the quantity of investment, and the following factor, Efficiency of investment reveals the quality of investment.

(4) Efficiency of Investment = ΔGDP/ Total Investment, marked as EI.

(5) Growth Rate of Population, marked as GRP. Population plays a complicated role in

economy growth. On the one hand, the growth of population offer necessary motivation to economic growth, on the other hand, surplus of population consume too much resources, which can drag economic growth in a long term.

(6) Ratio of Dependence on Foreign Trade = Total imports and exports / GDP, marked as RDFT. Since reform and opening up, foreign trade makes a great contribution to economic growth. With the development of market economy, the higher openness, the growth more quick.

(7) Industrial Level = Value of Secondary Industry / GDP, marked as IL. In almost developed nations, industry is the main power for economy growth. So the value of secondary industry has a great affect on economy in countries like China,

(8) Location. The value is 1 (coastal) or zero (inland), marked as L. It is obvious that coastal region has advantages in foreign trade, not to speak of the preferential policy offered by government. So the location is a key factor to regional economic development.

4. CHANGES OF CONVERGENCE OF REGIONAL ECONOMIC GROWTH IN CHINA

4.1 Calculated result and explanation of Theil Coefficient

Based on the regional division and the use of Per Capita GDP at provincial level, the Theill coefficient is calculated to illustrate the convergence process in the period of 1984-2010 in China. And with calculated T_B and T_W (intraregional and interregional inequality), it is easy to explain the contribution rate of T_B and T_W to Theil Coefficient. Please see Figure 1 and 2.

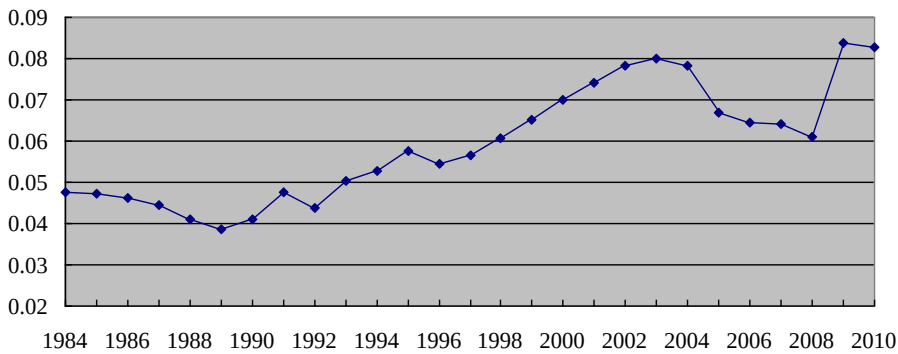


Figure 1. Change of Theil Coefficient at provincial level in China: 1984-2010

According to Figure 1, there is an upward trend on the whole for the change of Theil coefficient at provincial level in the period of 1984-2010 and there is a feature of wave change in different period. The whole change can be divided into three short periods. There is a down trend in the period of 1984-1989, an upward trend in the period of 1989-2003 and a down trend in the period of 2003-2008. However, a V shape change happened in 2009 for the reason of extremely loose financial and money policies started in the early of 2009 to reduce the compact of global

financial crisis on China economic growth. The Theill coefficient reaches its peak in 2009.

Figure 2 shows the change of T_B and T_W Coefficient and Figure 3 shows the contribution rate of T_B and T_W for Theil Coefficient respectively. Those two coefficients have been calculated based on the division of five regions in China. According to the result, Intraregional inequality is predominating to explain the inequality of regional economic development in China, meanwhile interregional inequality among provinces within each region is reduced gradually. That is to say, regional inequality in China is mostly decided by economic gap among five regions. The change of T_B Intraregional inequality is very similar with the change of Theill coefficient in the period of 1987-2010.

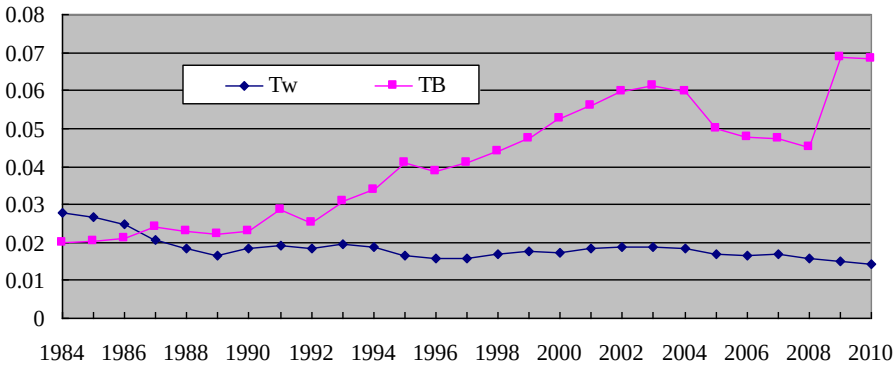


Figure 2. Change of T_B and TW Coefficient in China: 1984-2010

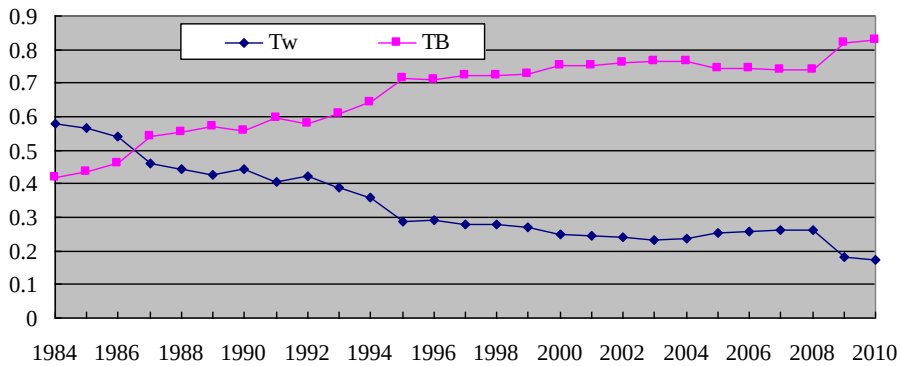


Figure 3. The contribution rate of T_B and TW for Theil Coefficient in China: 1984-2010

Based on the calculated value of Theil Coefficient, an experimental regression equation (13) is established to support the fact that the regional inequality of economic growth become more seriously since 1984. There is a positive coefficient of time trend in this equation. That means the economic gap among provinces is widening on the whole with the rapidly economic development in China. There is almost no sign related to that such gap is reduced in the last two decades.

$$T = 0.034867 + 0.001782*@TREND + 0.632041*AR(1) \quad (13)$$

（4.895**） （4.299**） （4.0786**）

where T is calculated Theil Coefficient, $@TREND$ is time trend term, $AR(1)$ means first-order autoregressive.

For equation (13), $R^2 = 0.856$, $Ad\text{-}R^2 = 0.835$, $DW = 1.838$, $F = 68.395$, $P(F) = 0$ and inverted AR roots is 0.63. According to Equation (13), the Time Trend Coefficient is positive which means an increasing trend about China's overall economic gap since 1984.

4.2 The change of σ-convergence of regional economic growth in China

According to the existing research results, the researchers believe that the wave change of economic convergence is consistent with the overall economy development in China, mainly related to the Chinese economic system reform and relevant policies. Contract responsibility system implemented in rural areas successfully narrowed the gap between the backward agricultural provinces with developed provinces, thereby reducing the overall gap in 1980's. In 1992, the pace of development is accelerated in eastern coastal areas and the overall gap is enlarged again. But with the implementation of western development strategy and the policy of regional cooperation in the beginning of new century, the overall gap has been reduced significantly in 2003-2008, which showed by the change of Theill in figure2.

To recognize the dynamics of convergence process of regional economic growth, it is necessary to eliminate the price effects by the use of Price Index too. With the use of adjusted Per Capita GDP at provincial level, the value of σ-convergence is calculated to analyze the change of σ-convergence of regional economic growth in the period of 1984-2010 in China.

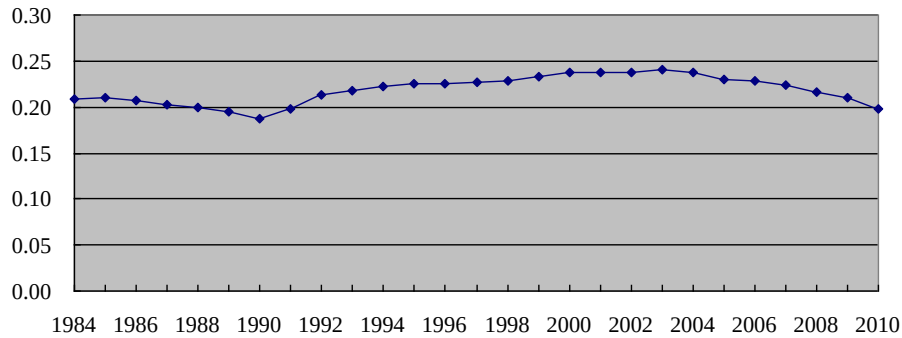


Figure 4. The change of σ-convergence of regional economic growth at provincial level in China: 1984-2010

Figure 4 shows the change of σ-convergence of regional economic growth at provincial in China. There is an evidence of wave change of σ-value, but it is almost without the trend of reverse 'U' relation in the period of 1984-2010 in China. To some extent, the wave change trend of σ value is similar to the change trend of Theil coefficient analyzed above, except for

evident different between those two results in 2008-2010. The whole change of σ-value can be divided into three short periods, which are 1984-1990, 1990-2003 and 2003-2010. The calculated σ-value shows that there is a convergence trend of regional economic growth at provincial level in the periods of 1984-1990, 2003- 2010 and a divergence trend in the period of 1990-2003.

Based on the calculated σ-value, an experimental regression analysis on σ-value is made to further describe the overall change of σ-convergence in China in the period of 1984-2010. See Equation (14) for details. Though both of *t*-test and *F*-test passed in the regression model, but the goodness of fit is poor with serial correlation existed by *DW* value. For the Time Trend Coefficient is positive which indicates an overall increasing trend for σ-value, so there is no σ-convergence existed on the whole in the period of 1984-2010.

$$\sigma = 0.204899 + 0.000969*@\mathrm{TREND}(1983) + \mu \qquad (14)$$

（38.474**） （2.914**）

where σ is calculated σ-value, *@TREND*(1983) is time trend term. And for Equation (14), R^2=0.254，*Ad*-R^2=0.225，*DW*=0.209，*F*=8.494，*P*(F-stat)=0.

The σ-convergence test results at provincial regional illustrated the changes of China's regional economic disparities generally. But those results are not ideal in fact. This is due to the serious problem of insufficient sample for the analysis of σ-convergence for five regions respectively. To compensate for this deficiency, it is necessary to analyze the σ-convergence of China's regional economic growth at prefecture-level on the whole and to illustrate the change of σ-convergence of regional economic growth at prefecture-level for five regions respectively. For the difficult of data collection, the selected time period is 1992-2010.

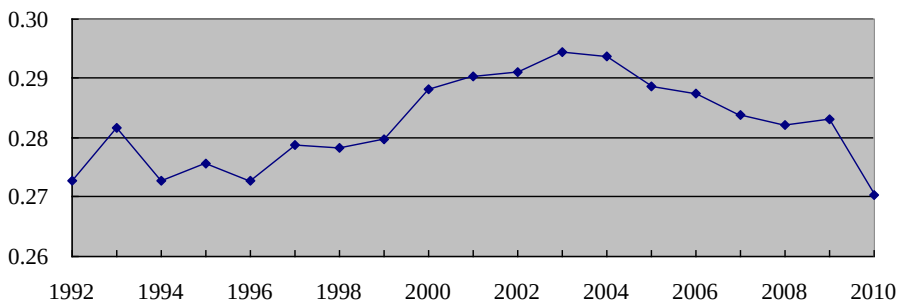


Figure 5. The change of σ-convergence of regional economic growth at prefecture level in China: 1992-2010

Figure 5 shows the change of σ-convergence of regional economic growth at prefecture level in China with the use of adjusted Per Capita GDP. The change trend of σ value at prefecture level is more evident and it is similar to the change trend at provincial level. Based on the Figure 5, the change can be divided into two short periods, which are 1992-2003 and 2003-2010. There is a divergence trend of regional economic growth at prefecture level in the period of 1992-2003

and a clearly convergence trend in the period of 2003-2010.

Furthermore, the change of σ-convergence of regional economic growth for five regions at prefecture level can be calculated respectively and the result will helpful to recognize the changes of σ-convergence for each region and to show the different change trend among five regions. See figure 6 for details. There are obvious differences among the analysis of σ-convergence for five regions. There are convergence trend occurred in three regions of Eastern, Northeast and Southwestern regions, but divergence trend occurred in Central China and Northwestern region.

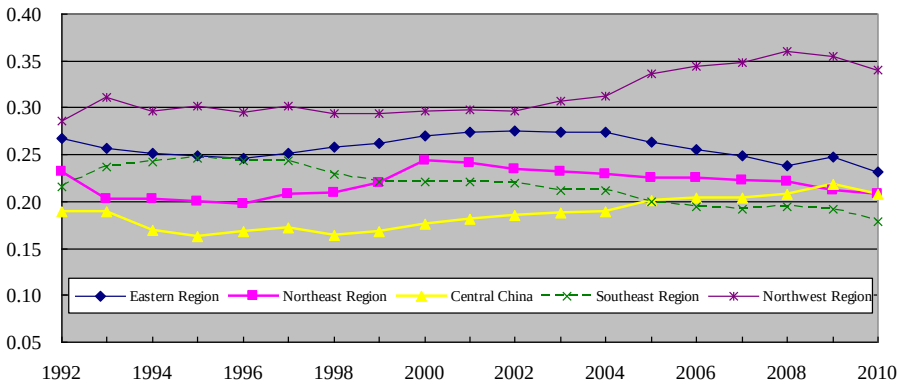


Figure 6. The change of σ-convergence of regional economic growth at prefecture level for five regions respectively: 1992-2010

For Eastern region, the σ-value shows a wave change on the whole with a reduced trend since 2002, which means an σ-convergence trend since 2002. For Northeast region, the σ-value decreased from 1992 to 1996, increased from 1996-2000 and insistently decreased since 2000, which means an σ-convergence trend since 2000. For Central China, except for the short period of 1992-1998, the σ-value shows an upward trend in the period of 1998-2009, which means a divergence trend of regional economic growth since 1998. For Southwest region, there is a down trend of σ-value in the period of 1995-2010, which means an σ-convergence trend of regional economic growth since 1995. For Northwest region, the change of σ-value can be divided into two extinct short periods. The σ-value shows no significant change in the period of 1992-2002 except 2003, and shows an upward trend in the period of 2002-2008, which means a divergence trend of regional economic growth may be occurred and inequality of economic growth is widening within northwest regions.

4.3 The change of absolute β-convergence of regional economic growth in China

According to the Equation (3) and (4), the method of cross-sectional data analysis has been applied to grasp the change of absolute β-convergence. With the use of Eviews6 software tools, Table 1 illustrates the OLS and adjusted regression results for the test of absolute

β-convergence at provincial level in China in the period of 1984-2010. The initial variable is $\ln Y_{i,t}$.

Allowed for the division of China economic growth period and the requirements to the test of the change of absolute *β*-convergence, the whole period can be divided into three short period, which are 1984-1990, 1990-2000, 2000-2010. According to Table 1, the change of absolute *β*-convergence at provincial level in China can be recognized or explained on the whole or in different periods.

Table 1. The result of the test of absolute β-convergence model in China: 1984-2010

Period	1984-1990	1990-2000	2000-2010	1984-2010
Intercept Term	0.090816***	-0.03657**	0.093066***	0.047299***
t-value	4.758099	-1.96709	5.063682	4.712334
$\ln Y_{i\,t}$	-0.022308***	0.021798***	-0.023211***	-0.008323**
t-value	-3.109641	3.340248	-3.921465	-2.206114
R^2	0.250062	0.277839	0.346521	0.143708
Ad-R^2	0.224202	0.252937	0.323988	0.11418
F	9.669869***	11.15726***	15.37789***	4.866939**
Velocity of convergence	0.023949144	-0.019719375	0.026410879	0.009375173
Judgment	Convergence	Divergence	Convergence	Weak Convergence

* Significant at 10 percent. ** Significant at 5 percent.
In Eviews, the existence of heteroscedasticity can be discovered by the White test. If the significant level is less than 5 percent, the null hypothesis (homoscedasticity) will be rejected. The description is similar for the following table.

Based on the regression equation included in Table 1, it is easy to recognize the convergence or divergence occurred in different periods. There is a negative coefficient of $\ln Y_{i,t}$ in the period of 1984-2010, which means that there is an absolute *β*-convergence of regional economic growth on the whole in China. Though the velocity of convergence is 0.94% per year and is very weak, but it shows that the gap among provinces is reduced on the whole. Furthermore, it is necessary to realize that those result are obtained based on an inaccurate model. The *t*-test for the coefficient of $\ln Y_{i,t}$ is not passing and the values of *F*-test and *Ad-AR*^{2} are not good at all, so it is not proper to use a simple liner regress model to explain the change of absolute *β*-convergence.

According to the results of three short periods, the change of absolute *β*-convergence of regional economic growth in China can be recognized too. Please see Table 1 for more details. In the period of 1984-1990, there is an absolute *β*-convergence occurred for the coefficient of $\ln Y_{i,t}$ is negative, and the velocity of convergence is about 2.39% which shows strong convergence. Both of *t*-test and *F*-test passed in the regression model, but the goodness of fit for regression model is poor. In the period of 1990-2000, there is divergence occurred for the coefficient of $\ln Y_{i,t}$ is positive, and the velocity of divergence is about 1.97%. Both of *t*-test and *F*-test passed in the regressive model, but the goodness of fit is poor. In the period of 2000-2010, there is an absolute *β*-convergence occurred for the coefficient of $\ln Y_{i,t}$ is negative, and the velocity of convergence is about 2.64%. Both of *t*-test and *F*-test passed in the regressive model, but the goodness of fit is poor too.

Apart from standard regression, it is necessary to test for spatial autocorrelation effect, considering the date structure is cross-sectional. With the use of the software GeoDA, Table 2 illustrates the result of the test for spatial autocorrelation. In the four periods considered, it shows that only the period of 1990-2000 has evidence to prove the existence of spatial autocorrelation, which Moran's I is significantly positive at the level of 5%. It means that China has significantly spatial correlation in the period of 1990-2000. The other periods of 1984-1990, 2000-2010 and 1984-2010 do not show the significant sign of spatial autocorrelation. Moreover, for the period of 1990-2000, the Robust Lagrange Multiplier specifies both spatial lag model and spatial error model are fit for dealing with the autocorrelation. So then, the two models will be set.

Table2. The test for spatial autocorrelation of absolute β-convergence model

Period	1984-1990	1990-2000	2000-2010	1984-2010
Moran's I	0.116	0.174**	0.047	0.008
P-value	0.184	0.044	0.386	0.709
Lagrange Multiplier (lag)	0.430	0.407	0.590	0.839
Robust LM (lag)	0.862	0.048	0.692	0.846
Lagrange Multiplier (error)	0.346	0.156	0.705	0.950
Robust LM (error)	0.586	0.022	0.920	0.983

Note: ** Significant at 5 percent.

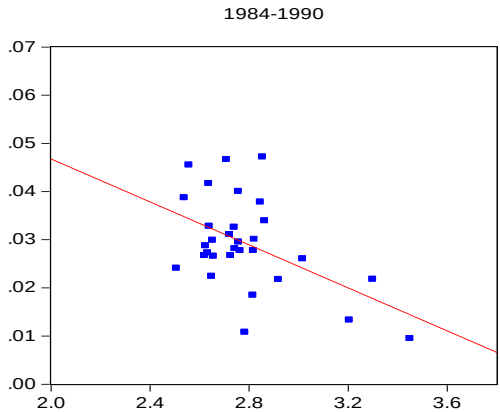
Table 3 shows the result of absolute *β*-convergence in the period of 1990-2000, considering the effect of spatial autocorrelation. It can be seen that, the coefficient of $\ln Y_{i,t}$ are significantly positive both in lag and error model, which are similar to the result of standard regression. So as to there is divergence occurred in the period of 1990-2000. Unfortunately, both the coefficient of spatial lag dependent and the spatial error term are not significant, nor are the value of Likelihood Ratio Test, which means the spatial econometrics regression for absolute *β*-convergence model maybe not proper.

Table3. The result of spatial econometrics regression for absolute β-convergence model

period	1990-2000	
Model	Spatial lag model	Spatial error model
Constant	-0.030	-0.021
z-value	-1.609	-1.039
$\ln Y_{i,t}$	0.023***	0.019***
z-value	3.628	2.776
W_Y	-0.111	/
z-value	-0.745	/
LAMBDA	/	0.329
z-value	/	1.492
R^2	0.294	0.337
Log likelihood	112.020	112.636
Likelihood Ratio Test	0.430	0.173
Velocity of convergence	-0.021	-0.017
Judgment	Divergence	Divergence

Note: *** Significant at 1 percent

Figure 7 is the scatterplot of $r_{i,t+T}$ (vertical axis) and $\ln Y_{i,t}$ (horizontal axis) in different periods, where $r_{i,t+T}$ is the growth rate of per capita GDP of i province from t to t+T period, $\ln Y_{i,t}$ is the natural logarithm of $Y_{i,t}$. Figure 8 is helpful to understand the change of absolute β-convergence more directly in China. The trend of scatterplot can be seen with the shape of regression model. The straight line is the fitting line of linear regression in each scatterplot. Convergence or divergence intensity determined by the slope of the size, the greater the slope the greater the convergence rate.



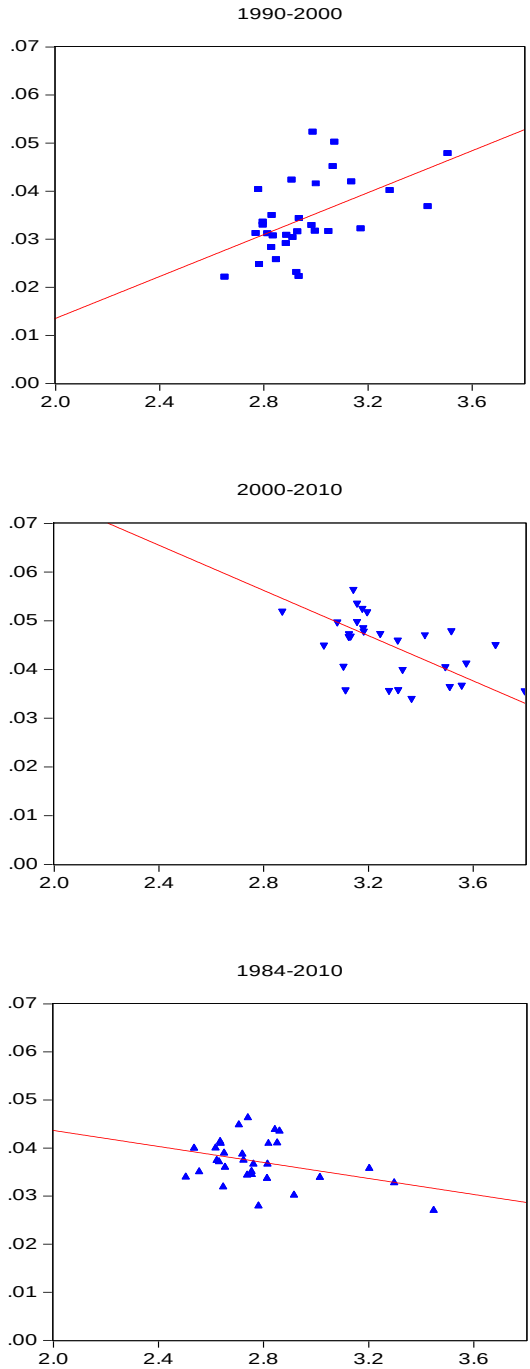


Figure 7. The scatterplot of $r_{i,t+T}$ and $\ln Y_{i,t}$ for all provinces in different periods

4.4 The change of conditional *β*-convergence of regional economic growth in China

Per capita income growth rate of a region depends not only on the initial level of per capita income, but also by the compact of resource endowments, industrial structure, inter-regional flow of production factors and so on. The test results of absolute *β*-convergence of regional economic growth show that the explanation of model results, which simply relied on the test of absolute *β*-convergence, is not satisfied on the whole. It can be considered to add several control variables into the original model for the analysis of *β*-convergence. If the regression result shows that the coefficient of $\ln Y_{i,t}$ is still negative when several control variables have been considered into the test model, it means a conditional *β*-convergence occurred in that period. As mentioned above, selected eight control variables have been considered in the original model to test whether a conditional *β*-convergence trend of regional economic growth occurred or not at provincial level in China.

Allowed for the difficulties of data collection for more indicators, the chosen period is 1990-2010. It is also need to eliminate the price effects by the use of Price Index. Based on eight selected variables and the choice of simple liner regression equation, the change of conditional *β*-convergence of regional economic growth can be illustrated at provincial level in the period of 1990-2010. Based on the importance of various factors which affect regional economic growth and Equation (5), the form of econometric model for conditional *β*-convergence is:

$$\frac{\ln y_{i,t+T} - \ln y_{i,t}}{T} = \alpha + \beta \ln Y_{i,t} + \beta_1 BG_i + \beta_2 HC_i + \beta_3 IR_i + \beta_4 EI_i + \beta_5 RDFT +_i \beta_6 IL_i$$

$$+\beta_7 GRP_i + \beta_8 L_i + \mu_i \qquad (15)$$

where the right of (15) consists of the term of $\ln Y_{i,t}$ and eight terms of control variables.

The process of multiple regression analysis is also completed by the use of Eviews6. The principles is to remove the variable that cannot pass the *t*-test firstly, then deal with the variable which its coefficient is not consistent with expected results, and the regression results should be modified if there is heteroscedasticity or serial correlation existed. Table 4 shows the different of calculated result between absolute *β*-convergence model and conditional *β*- convergence model.

Based on the results in Table 4, it can be known that there is a weak absolute *β*-convergence in the period of 1990-2010 at provincial level in China, the velocity of convergence is 0.38% and there is a conditional *β*-convergence of regional economic growth occurred in the period of 1990-2010 at provincial level. With those selected control variables (behavior of government, invest rate, industrial level, etc) are added into the basic model, the velocity of conditional *β*-convergence increased obviously, the rate of is 1.21% and the *β*-value is also negative. The other coefficients of some variables are within the expectation, and the *t*-test, *F*-test passed in

the regression model. Furthermore, the two results of conditional β-convergence in the period of 1990-2000 and 2000-2010 is completely different, as shown on the Table 4. There is a divergence of conditional β-convergence occurred in former period, whereas a convergence of conditional β-convergence occurred in later period.

Table 4. The compare of the test of absolute β-convergence model and conditional β-convergence model at provincial level in China: 1990-2010

	Absolute β-convergence	Conditional β-convergence		
	1990-2010	1990-2010	1990-2000	2000-2010
Intercept Term	0.033844***	0.044925***	/	0.104887
$\ln Y_{i,t}$	-0.003696***	-0.010715***	0.01256***	-0.024595
BG	/	-0.021853***	-0.012987***	-0.018847**
HC	/	/	/	/
IR	/	0.021469***	0.012172***	0.046277
EI	/	/	-0.019774**	/
RDFT	/	/	-0.005995***	0.00149
IL	/	0.014372***	/	0.014341*
GRP	/	-0.090452*	-0.218314*	-0.274775
L	/	0.002669***	0.009399***	/
R^2	0.641822	0.944164	0.982082	0.999119
$Ad\text{-}R^2$	0.629471	0.930205	0.974404	0.998741
F	51.96526	67.63788***	127.8931***	2646.012***
Velocity of convergence	0.003839733	0.012059012	-0.011831623	0.02822966
Judgment	Weak Convergence	Convergence	Divergence	Convergence

And compared with the results of Table1 and Table 4, it will be detected that both coefficients of absolute and conditional β-convergence are positive or negative in the same period.

As the expected results, there is a range of impact factors in the growth rate of per capita income. To narrow the regional economic gap, it is necessary to pay more attention to the behaviors of government, industrial development and investment intensity in future.

4.5 Test of Spatial autocorrelation for Absolute β-convergence and conditional β-convergence in China

From Table 5, there is no spatial autocorrelation for the Absolute β-convergence in the period of

1990-2010, as the Moran's I is not significant, nor Lagrange Multiplier. The Conditional β-Convergence Model in period of 1990-2010 is neither sign of spatial autocorrelation. While considering the shorter period, which divide the period of 1990-2010 into two periods 1990-2000 and 2000-2010, it can be known with the Lagrange Multiplier that there is spatial autocorrelation in the period of 1990-2000, although the Moran's I does not show the existence of spatial autocorrelation. Considering the robustness of the results, the spatial lag model and spatial error model will be set to deal with this spatial autocorrelation effect.

Table 5. The compare of the test for spatial autocorrelation between absolute *β*-convergence model and conditional *β*- convergence model

OLS	Absolute β-convergence	Conditional β-convergence		
Period	1990-2010	1990-2010	1990-2000	2000-2010
Moran's I	0.052	-0.069650	-0.199	-0.132
Prob	0.379	0.795	0.31	0.66
Lagrange Multiplier (lag)	0.304	0.277	0.008	0.352
Robust LM (lag)	0.348	0.16	0.03	0.729
Lagrange Multiplier (error)	0.675	0.57	0.106	0.281
Robust LM (error)	0.998	0.29	0.58	0.52

From Table 6, it can be seen that both two models of the period 1990-2000 show goodness of fit, which supported by the R-squared and the Likelihood Ratio. The judgment of economic growth is divergence for this period, considering spatial autocorrelation effect. The most interesting part is the spatial autocorrelation effect obtained is negative (the coefficient of W_Y is -0.282, and the coefficient of LAMBDA is -0.791, significantly), which is consistent with the result of Moran's I in Table 5. It could be the reason for divergence in China at the period of 1990-2000.

Table 6. The result of spatial econometrics regression for absolute *β*-convergence model

Period	1990-2000	
Model	Spatial Lag Model	Spatial Error Model
Constant	0.012	0.02
lnYi, t	0.014*	0.029***
BG	-0.023*	-0.021

HC	0.008	0.008
IR	0.015	0.002
EI	-0.017	-0.024
RDFT	-0.006*	-0.005
IL	-0.007	-0.013
GRP	-0.26	-0.099
L	0.01***	0.011***
W_Y	-0.282***	/
LAMBDA	/	-0.791***
R^2	0.72	0.73
Log likelihood	126.113	124.940
Likelihood Ratio Test	0.006	0.002
Velocity of convergence	-0.013	-0.026
Judgment	Divergence	Divergence

Note: *** Significant at 1 percent, ** Significant at 5 percent, * Significant at 10 percent

5. CONCLUSIONS

According to the analysis above on the change of convergence of regional economic growth in the period of 1984-2010 in China, some meaningful conclusions can be summarized.

One of the conclusions is that decision-maker should pay more attention to intraregional inequality to control the regional inequality on the whole in future. The change of σ-value shows there is no σ-convergence of regional economic growth occurred on the whole in the period of 1984-2010 at provincial level in China. There is an evidence of wave change of σ-convergence with economic development in China and the change trends of σ-convergence of regional economic growth are different in the period of 1992-2010 at prefecture level for five regions respectively.

There is a weak absolute β- convergence trend of regional economic growth on the whole in the period of 1984-2010 at provincial level in China. There is a conditional β-convergence of regional economic growth occurred in the period of 1990-2010. It can be seen the promotion of conditional β-convergence when selected control variables have been added into the basic model for the analysis of absolute β-convergence and the velocity of convergence is speed with the consideration of control variables X_j in model.

After testing spatial autocorrelation both in Absolute and conditional β-convergence, there is evidence supporting that the spatial autocorrelation exits in the period of 1990-2000, and no evidence in the rest of periods. For conditional β-convergence model, the spatial autocorrelation is significantly negative, which can partly explain the divergence in the period of 1990-2000.

These results provide guidance for further research in this area. However, in this article, there is no discussion on the change of absolute and conditional β-convergence of regional economic growth at smaller level (such as prefecture-level), and no analysis on Club convergence of regional economic growth at provincial level and prefecture level too. Those are meaningful to test and understand the change of different convergences of regional economic growth in China.

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