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The Impact of Foreign Direct Investment on Income Convergence in China - A Spatial Panel Data Analysis

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Abstract

After taking into account the spatial dependence effects in the panel data consisting of all 31 provinces, direct-controlled municipalities, and autonomous regions in China between the years 1998 and 2017, it found significant spatial autocorrelation effects in both traditional absolute and conditional β income convergence models. At the national level, using the spatial econometric models (Spatial Error Model for absolute convergence and Spatial Durbin Model for conditional convergence), the analysis shows that in the past 19 years from 1999 to 2017, there is no absolute β income convergence. However, there is conditional β income convergence after controlling for all growth factors, while the positive effect of fixed asset investment on regional economic growth is significant, and the effect of population growth is significantly negative. The other growth factors such as FDI inflow, export, and higher education enrollment were surprisingly found no statistically significant effects on regional economic growth. From regional level (Spatial Durbin Model and Spatial Lag Model), there is no conditional β income convergence within each four economic regions. Nonetheless, the northeast region showed an income divergence trend, where only the fixed asset investment is positively significant. This study results imply that China should continue to improve fixed asset investment and control population growth to stimulate regional economic growth and income convergence.

Keywords: foreign direct investment, absolute and conditional β income convergence, Solow growth theory, Chinese economy, spatial autocorrelation, spatial econometrics

1. Introduction

1.1 Background

Over the past 40 years of reform and opening up, the People's Republic of China (PRC)'s economy has achieved rapid growth that has attracted worldwide attention. The average real GDP growth rate of post-1978 exceeded 9% (Hu & Khan, 1997). Its strong economic growth mainly derived from the surge of productivity growth as a result of the market-oriented reform in 1978 (Hu & Khan, 1997; Malesky & London, 2014). The total factor productivity (TFP) growth had an annual rate of 3% during 1978 to 1998 (Chow & Li, 2002). Nonetheless, behind the halo of rapid economic growth, contemporary China's economy is also facing many problems (Tao, 2012).

Since the mid-1990s, the capital mobility brought about by the restructuring of local state-owned and township enterprises, the fiscal centralization brought about by the tax-sharing system, and the spillover effect of the manufacturing industry on the service industry all have played a role in creating a strong driving force for local governments to develop the Chinese economy since the mid-1990s (Tao, 2012). Especially since 2002, China's economy has achieved rapid growth, but at the same time, China's development model has gradually deviated from the traditional East Asian model (Tao, 2012).

One of the most prominent problems is the imbalance in regional economic development (Zhao & Tong, 2000). The imbalance between urban and rural areas or across regions may cause serious social unrest, economic inefficiencies, and further hinder future economic growth (Lu et al., 2013). Therefore, how to coordinate the balanced development of regions and narrow the gap between regions has become one of the top priorities for China's deepening economic reforms.

The report of the 19th National Congress of the Communist Party of China (CPC) clearly pointed out that the implementation of the regional coordinated development strategy is one of the major strategic deployments for implementing the new development concept and building a modern economic system (National Development and Reform Commission, 2018). Regional coordinated development means that the economic ties between regions are getting closer, and the economic and social development gap is gradually narrowing and tending to converge.

Therefore, in order to achieve coordinated regional development, the key is to continuously narrow the gap between less developed and developed regions and achieve convergence of inter-regional economic growth. Because the change in the regional gap is mainly caused by the difference in economic growth rate, if the economic growth rate of less developed areas is faster, the regional gap will gradually narrow.

1.2 Current Research Gap

Many key debates on the recent economic growth issue in China are thus centered on income convergence (Islam, 2003). When looking into the economic growth problem, the common method is neoclassical framework (Hu & Khan, 1997). The convergence concept comes from the implication of neo-classical growth theory (Islam, 2003). There are two types of convergence called α and β convergence. In recent years, a large number of studies have analyzed the β convergence of China's regional economy, but many studies have reached different conclusions due to different methods and datasets.

Chen and Fleisher (1996) used cross section and panel data between 1952 and 1992 to show that in terms of GDP per capita, there is a divergent trend before the reform and opening up, but it showed a trend of convergence from 1978 to 1993. Jian et al. (1996) also concluded that there is strong divergence between 1965 and 1978 during which the cultural revolution happened, while there is strong evidence of convergence since 1978 until early 1990s in China. They argued that that since 1990s, there is divergence and it tends to continue this trend due to coastal provinces' geographic advantage over interior provinces.

Cai et al. (2002) found that using provincial panel data between 1978 and 1998, there has been a conditional convergence, while two club convergences have been formed in the eastern, central and western regions combined. Pedroni and Yao (2006) found that in terms of per capita provincial GDP, during the pre-reform period of 1952 to 1977, there was a convergence. Nonetheless, during the post reform of 1978 to 1997, the incomes of majority of provinces seem to be divergence. Wei et al. (2009) found that using the panel data between 1979 and 2003, there is a strong conditional convergence between different provinces.

The main difference between different studies is that the explanatory variables in the econometric model are not the same. Most studies didn't consider spatial effects either. However, when analyzing the convergence process at the regional level rather than the national level, spatial autocorrelation and spatial heterogeneity should be fully considered, because the possible existence of spatial correlation may cause the estimation result to be seriously biased (Ding et al., 2012).

In recent years, many researchers have begun to consider the impact of spatial autocorrelation and spatial heterogeneity on the study of the β convergence. Lin et al. (2005) used spatial econometric methods to study the β convergence of per capita GDP in 28 provinces and cities in China from 1978 to 2002. They found that there was convergence in China's regional economies, but the rate of convergence slowed down over time.

Feng (2008) used three spatial econometric models to analyze β convergence in China from provincial level between 1978 and 2003. The results show that only the spatial autoregressive error model can best explain variations across provinces and there is a trend of convergence where capital and labor as well as knowledge spillovers are instrumental to regional convergence progress. Chen and Sun (2013) found that for period from 1990 to 2000, there is evidence of spatial autocorrelation effect, where both spatial lag and error models show there is divergence.

1.3 Purpose of Study

At the provincial and regional level in China, the academic community has not yet reached a consensus on the traditional absolute and conditional convergence model. Therefore, it is necessary to adopt more convincing methods and data to conduct a more robust empirical investigation on this proposition. Most of the existing researches use traditional panel data model methods, ignoring the influence of geospatial effects on the research results.

China has a vast territory, and the spatial differences between regions are significant. A large number of studies above have confirmed that there are significant spatial spillover effects between economic growth in different regions of China. Therefore, this study uses spatial econometric methods and takes panel data of 31 provinces in China from 1998 to 2017 as the research sample. Under the condition of fully considering the spatial spillover effect between provincial regions, the empirical test of traditional β absolute and conditional convergence model is carried out to explore the recent β income convergence trend and provide additional evidence to the existing literature regarding regional economic growth in China.

1.4 Research Design

Based on the existing research, this paper uses the method of spatial econometrics to analyze the impact of foreign direct investment (FDI) on the provincial β absolute and conditional convergence, and answers three questions at the same time: 1) Considering the spatial autocorrelation of data, investigate if there is a β absolute convergence; 2) Considering the spatial autocorrelation of data, investigate if there is a β conditional convergence in China; 3) Considering the spatial autocorrelation effect, FDI and other growth factors such as exports, education, and population growth are tested to see if they have promoted regional economic growth and β income convergence. It is hoped that this study provides a reference for promoting China's provincial-level regional economic development and regional income convergence.

This rest of paper is organized as following: it first talks about FDI and its related growth factors in the following literature review part. The methodology part then briefly discusses about major spatial statistical methods and spatial econometric models used by this study to identify the existence of spatial autocorrelation and spatial heterogeneity. It also mentions the estimation procedure and research questions as well as hypotheses.

In the data analysis section, it presents the results of the absolute and conditional β income convergence measured by provincial per capita GDP growth, analyzing the possible influencing factors that affect China's regional economic growth both at national and regional level, under the influence of spatial effects. Lastly, it made discussions, conclusions, and policy recommendations.

1.4.1 FDI and Related Growth Factors

Recent studies have shown that FDI is one of the main driving forces for regional economic growth and income convergence (Choi, 2004; Ma & Jia, 2015). In terms of empirical research on China, Wei (2002) discussed the impact of FDI on regional economic growth of coastal and interior areas using time series and cross-section data from 1985 to 1999, and found that FDI inflow has made a great contribution to the vast majority of regional economic growth gap between these two areas. It has become an important industrial producer and exporter in coastal areas.

Yao and Wei (2007) analyzed the impact of FDI on China's regional economic growth using panel data consisting of 29 provinces between 1979 and 2003. They discovered that based on the augmented Cobb-Douglas production function, FDI is one of the growth factors that could contribute to significantly increase the regional productivity. The rest of the section discussed other related growth factors such as domestic investment in fixed assets, export, education, and population growth.

1.4.2 Domestic Investment in Fixed Assets

Investment has become the driving force behind economic growth. At the same time, it has also become an important means of implementing macroeconomic policy. In the existing research on the relationship between investment and economic growth, Li (2004) employed the VAR model to conduct a quantitative analysis of the relationship between fixed asset investment and regional economic growth, and the results show that there is only a one-way significant association between investment and economic growth in both the east and the west, indicating that accelerating investment in the west could be the main measure to fuel the economic growth of the west and thus narrow the regional gap.

Song (2011) uses time series data from 1980 to 2010 as the sample period to conduct an empirical study on the relationship between fixed asset investment and economic growth. The cointegration analysis shows that there is a long-term relationship between the two, and the simulation test shows that fixed asset investment and economic growth have a two-way Granger causality, that is, China's fixed asset investment and economic growth have a mutual promotion effect.

Ding et al. (2012) used the spatial panel model to measure the direct impact of factor allocation on local economic development, while it also measures the indirect spillover effects of factor allocation on the economy of other regions, in order to determine the actual effect of the impact of labor, fixed asset investment, and technological progress on China’s economic growth. The study found that fixed asset investment is still an effective driving force for China's economic growth. However, it should focus on the tertiary industry instead of the secondary industry. Technological progress is the core driving force that drives the healthy and sustained growth of China's economy, and it is also the direction and inevitable path choice for China to achieve industrial upgrading.

1.4.3 Export

The literature that studies the relationship between exports and GDP growth mainly focuses on two issues: whether exports can significantly promote GDP growth; how to measure the contribution of exports to GDP growth. Huang and Li (2006) found that the size of the regional market and the degree of export openness significantly affected the growth rate of per capita income in various provinces and regions from 1970 to 2000; in the formation and evolution of regional gaps, foreign and regional markets replaced each other. After controlling the for the market scale factor, each province has shown a clear trend of convergence.

Yao (2006) used panel data from 1978 to 2000 in 28 provinces to focus on the analysis of the impact of export trade and FDI on economic performance. Using Pedroni's panel unit root test, and dynamic panel data estimation method by Arellano and Bond, it found that export and FDI both have a significant positive effect on economic growth. Du and Cao (2010) analyzed panel data from 28 provinces, the characteristics and existing problems of China's economic growth pattern from 1990 to 2007 were specifically investigated through quantitative analysis. It discovered that foreign capital and exports have a clear role in stimulating economic growth. The economic growth of the eastern region is most notably driven by exports, but to a certain extent, it is weakened by the exports of foreign-invested enterprises (FIE).

Liu and Wu (2013) conducted a study based on the export data of more than 400 industrial sectors in 30 provinces of China, where the construction of three indicators of export specialization, export horizontal and vertical diversification, the role of export product structure in regional economic growth has been empirically tested. It found that the role of export diversification in promoting regional economic growth in China is very tremendous, and the impact of vertical diversification is significantly higher than that of horizontal diversification; at the same time, the impact of export commodity structure on economic growth also has significant regional differences: in the central region, the increase in the horizontal diversification of exports can significantly promote economic growth, but the impact of vertical diversification is not significant. The situation in the western region is just the opposite that vertical diversification of exports is an important source of economic growth, whereas the impact of horizontal diversification is not prominent.

1.4.4 Education

People’s initial estimates of the contribution of education to economic growth were when economists were looking for various influencing factors of economic growth. They discovered the effect of educational factors on economic growth and tried to isolate and quantify this effect to determine how much of the residual value of growth is attributable to the contribution of education. Scholars basically try various quantitative analysis methods on the basis of the Cobb-Douglas Production Function.

There are some scholars focusing on the analysis of the contribution of higher education to economic growth. Many studies maintained that the effect of higher education is not significant and often unequal in regional economic growth. Zheng and Zhu (2007) used a panel data of higher education in 31 provinces, direct-controlled municipalities, and autonomous regions in China from 1999 to 2005 and empirical research was made on the relationship between higher education in each province and regional economic growth. The results showed that since the expansion of college enrollment, colleges and universities in more than half of the regions have not played a good role in promoting the local economic development. Instead, they have blocked the local economic development to a certain extent.

Zhu and Wang (2010) extended on the basis of E. F. Denison and A. Maddison’s algorithm, using inter-provincial panel data to measure the contribution of higher education to regional economic growth, and compare the differences between regions. The research results show that the average contribution rate of China's higher education to economic growth from 1996 to 2006 is only 1.267%, and there are large differences between regions, showing a gradual declining distribution from the east to the central and western regions.

Other studies found that higher education can play a vital role in developing regional economies but its effect in economic growth still varies significantly in terms of different regions. Zhu et al. (2009) based on the idea of similar exports of education, draws on the ideas of Feder's two-sector model, and uses panel data from 1999 to 2005 to measure the contribution of higher education to regional economic growth. The results showed that the direct contribution of higher education to GDP growth and the spillover effect of higher education on other production sectors, both of which show a gradual distribution from east to central and western regions.

In a newer study by Qin and Wang (2017), in order to avoid the short-term impact of the university expansion policy implemented in 1999, it selects the panel data of 31 provinces, autonomous regions and municipalities in mainland China from 2004 to 2013 as the research sample. The ratio of the number of students in higher education to the total number of students at all levels of education and the ratio of the number of college students to the number of teachers are used as indicators to measure the scale of higher education, and the actual GDP of each region is used as an indicator to measure regional economic growth. The estimation method of adding variables analyzes the impact of the scale of higher education on regional economic growth.

The study has drawn the new conclusions: in the case of eliminating the short-term impact of the university expansion policy, the scale of higher education still has a positive effect on regional economic growth. With the expansion of the scale of higher education, the regional economic level will also be somewhat increase; the scale of higher education has a positive lagging effect on economic growth. The expansion of the scale of higher education in the previous period will promote the improvement of the current economic level; the scale of higher education has different effects on economic growth in different regions of China. The expansion of the scale of higher education in the central and western regions has a better effect on promoting economic growth than in the eastern regions.

1.4.5 Population Growth

Many demographers and sociologists believe that the excessive and rapid growth of the elderly population will enable more resources to be allocated to the elderly's medical and health consumption rather than in the production. Therefore, after entering the aging stage, the fertility rate will decline, the childbearing age will be delayed, the life expectancy will be extended, the number of working-age people will decline, and the demand for medical and health services will increase and stay at a relatively high level. It thereby may reduce domestic output, the savings rate, and investment rate, causing economic growth to be negatively affected (Gong & Yin, 2008).

There have been some theoretical and empirical studies that show that the increase in population may adversely affect economic development: population growth can hinder economic growth. Using a Cobb-Douglas production function that includes human capital, starting with Solow's growth theory, Hu et al. (2012) analyzed the impact of population aging and population growth rate on economic growth. The inference results of the theoretical model show that population aging and population growth both have an adverse effect. Based on the results of the theoretical model, an empirical model of the influence of population aging and population growth on economic growth was constructed, and China's provincial panel data from 1990 to 2008 was collected and used to empirically test the reasoning results of the theoretical model, which confirmed the reasoning of the theoretical model.

Nonetheless, the effect of population growth is in dispute. Some studies found no significant effect of population growth on regional economic growth but varies by region. Using panel data from 30 provinces in China from 1995 to 2012, Tong et al. (2014) established a panel model and an error correction model from the national, eastern, central, and western regions to analyze the impact of the three factors of birth rate, education level, and labor force participation rate on the effect of economic growth.

The results show that from a national perspective, the birth rate does not have a significant impact on economic growth. It, however, has a significant positive correlation between the birth rate and economic growth in the economically prosperous eastern region. The birth rate in the central region does not have a significant effect on economic growth. The increase in the birth rate in the relatively less developed western regions may even hinder economic growth.

2. Methodology

2.1 Data

The main data source is *China Statistical Yearbook* various editions between 1999 and 2018 (National Bureau of Statistics of China [NBS], 2019). This panel dataset has 620 observations with a sample interval of 20 years (1998-2017) including all 31 provinces, direct-controlled municipalities, and autonomous regions. This sample was compiled in the Excel file, then processed by Stata 15.1 edition.

This study also used NBS's method which breaks down these provinces, direct-controlled municipalities, and autonomous regions into four economic regions for regional level analysis. Eastern regions include: Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan; central region encloses provinces: Shanxi, Anhui, Jiangxi, Henan, Hubei, and Hunan; western region covers: Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang; northeast region comprises: Liaoning, Jilin, and Heilongjiang.

Most researches used spatial adjacency weight matrix. The construction of the spatial adjacency weight matrix follows the Rook or Queen adjacency judgment rule. The matrix element W is set as follows: the main diagonal element is 0; if the i area is geographically adjacent to the j area, W_{ij} is 1, otherwise it is 0. Given that Hainan

Province is an isolated island geographically and is relatively close to Guangdong Province in terms of spatial location, Hainan Province and Guangdong Province are assumed to be adjacent.

However, the spatial weight matrix based on Rook and Queen assumes that as long as the two regions are related, the degree of correlation is the same (equal weight). However, this assumption is often counterintuitive. For example, in the study of environmental pollution, it is generally believed that the areas that are close together have a higher degree of correlation; another example is that in the study of international trade, the areas with close contacts have a higher degree of correlation. In this study, another popular weight matrix based on spatial distance (inverse-distance spatial-weighting matrix where $\omega_{ij} = 1/d_{ij}$, and d_{ij} is the distance between province i and j from the specified coordinates and distance measure) is more appropriate and thus used (Drukker et al., 2013).

2.2 Basic Concepts

2.2.1 Income Convergence Concept

There are two types of income convergence. The first is σ convergence, which means that in regional economic growth, the dispersion of per capita output (income) distribution between regions gradually decreases with the passage of time, and finally the difference in economic development will disappear automatically (Barro & Sala-i-Martin, 1992; Wodon & Yitzhaki, 2006). The coefficient of variation (CV) is usually used to calculate σ convergence (Barro & Sala-i-Martin, 1992).

The second type is β-convergence, which means that in the process of regional economic growth, assuming diminishing returns in production, economies with low per capita income or output at the beginning will have a higher growth rate of per capita output, thereby achieving a faster growth rate than regions with high per capita output at the beginning of the period to catch up with rich regions, controlling for other growth factors (Wodon & Yitzhaki, 2006).

2.2.2 Spatial Dependence

It means that a certain economic phenomenon or a certain attribute value in a regional unit is always related to the corresponding economic phenomenon or attribute value in its neighboring regional units. Economic phenomena not only show correlation in time, but also have a certain degree of correlation in space. Classical econometric models always assume that conditions such as Gauss-Markov and fixed explanatory variables can be met.

However, in the analysis of spatial economy, the existence of spatial dependence or spatial autocorrelation violates the basic assumption that the samples are independent of each other. If the methods of classical econometrics are directly applied to data related to geospatial location, the spatial dependence of data will be ignored. Therefore, when processing data, spatial statistics and spatial econometric analysis methods should be introduced for analysis. In spatial statistics, the Moran' I statistics can be used to judge whether the spatial dependence of economic phenomena and the spatial autocorrelation of data exist or not.

2.3 Spatial Dependence Test

2.3.1 Global Spatial Autocorrelation Test

To test the existence of spatial dependence of regional variables, the more commonly used method is the spatial autocorrelation index proposed by Moran (Getis, 2007). The global Moran's I index reflects the similarity of the attribute values of adjacent areas in the study area, and its calculation formula is as follows:

$$I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{S^2 \sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}}$$

Where: w_{ij} is the matrix standardized by rows; n is the number of spatial units; x_i and x_j are the observed values of the attributes of spatial units i and j, and $\bar{x}$ is the mean value of the observed values of each spatial unit. The global Moran's I index ranges from -1 to 1. When I<0, it indicates that there is a negative spatial correlation in economic behavior, and similar observations are scattered in the region; I>0 indicates that there is a positive spatial correlation in economic behavior. That is, similar observations tend to agglomerate in space; I=0 indicates that there is no spatial correlation between regional economic behaviors.

2.4 Spatial Regression Models and Procedure Overview

2.4.1 Spatial Lag Model

The spatial lag model (SLM) reveals that regional economic growth is not only related to the growth within the region, but also closely related to the surrounding regions. In order to express the relationship between regional economic growth and space, a spatial lag variable is introduced (Lambert et al., 2010):

$$y = \rho Wy + X\beta + \varepsilon$$

Among them, ρ is the spatial autoregressive parameter; Wy is the spatial lagging dependent variable.

2.4.2 Spatial Error Model

The spatial error model (SEM) is an analysis method to separate the spatial autocorrelation component from the error term. It converts the error term of the equation into a spatial lag error in the form of a spatial adjacent matrix (Baltagi et al., 2003):

$$\varepsilon = \lambda W\varepsilon + \mu$$

Among them, ε is the spatial error term in vector form; λ represents the spatial error coefficient. W is n × n spatial adjacency matrix.

2.4.3 Spatial Durbin Model

The commonly used spatial regression models include the SLM and the SEM. However, these two models only consider the spatial correlation of the dependent variables, and do not consider the spatial correlation of the independent variables. Elhorst (2010) proposed a more comprehensive spatial econometric model, the Spatial Durbin model (SDM). The basic form of the model that takes into account both fixed effects and individual effects is as follows:

$$y_{it} = \delta \sum_{j=1}^{N} w_{ij} y_{it} + \alpha + x_{it}\beta + \sum_{j=1}^{N} w_{ij} x_{it}\theta + \mu_i + \lambda_t + \varepsilon_{it}$$

Where: i represents the space unit; t is the number of periods; N is the total number of space units; w_{ij} is the spatial weight matrix; y_{it} is the dependent variable; $x_{it}$is the independent variable; δ is the spatial autoregressive coefficient; θ and β are the parameters, α is a constant term, μ_i and λ_t are individual fixed effects and individual time effects; ε_{it} is a random error term.

2.5 Estimation Procedure

The setting of the spatial econometric model is to overcome the spatial correlation problems in the standard econometric model. However, if there is spatial dependence between entity, the estimated coefficients obtained by ordinary least squares (OLS) may be biased and inconsistent. Therefore, the estimation of the spatial econometric model needs to be carried out through the maximum likelihood method (MLE).

In accordance with the relevant theories and testing principles of spatial econometrics, first using the Global Moran index test method is to determine whether spatial interaction effects between regions exists (Elhorst, 2010). If it is statistically significant, it indicates there is spatial autocorrelation. Otherwise, the traditional panel data model should be adopted. Second, with the Wald test or likelihood ratio test (LR), it can determine whether the model can be reduced from SDM to SLM or SEM (Elhorst, 2010). In this study, it used the Wald test, and if the null hypotheses (coefficients of variables are simultaneously equal to zero) are rejected, then the SDM should be adopted. Otherwise, the Lagrange multiplier test (LM) would be conducted to determine whether SLM or SEM should be used (Elhorst, 2010).

More specifically, when selecting either SLM or SEM, LM-Lag test and LM-Error test should be used, and robust LM-Lag-test and Robust LM-Error test should also be used. The specific standard is: when the Moran index test is statistically significant, if the LM-Lag is statistically significant but the LM-Error is not statistically significant, the SLM model is used. Otherwise, the SEM model is used.

When both LM-Lag and LM-Error are statistically significant, it is necessary to further compare the significance of the Robust LM-Lag and Robust LM-Error statistics. If Robust LM-Lag is more statistically significant than Robust LM-Error, then SLM is selected. Otherwise select the SEM model. Lastly, as for panel model setting, Hausman test determines whether the study should select random or fixed effects model. The null hypothesis of the test is: the random effects model should be preferred. Otherwise, the fixed effects model should be used.

2.6 Model Specification

The Solow model has important implication that saving and population growth could impact the real income (Solow, 1956). Solow assumed that saving rate, population growth, and technology are exogenous (Mankiw et al., 1992; Solow, 1956). Based on Mankiw et al. (1992), the following Solow growth model's steady-state income per capita formular below is derived from the Cobb-Douglas production function ($production\ at\ time\ t: Y_t = K(t)^{\alpha}(A(t)L(t))^{1-\alpha}\ where\ 0 < \alpha < 1$):

$$Ln\left(\frac{Y(t)}{L(t)}\right) = LnA(0) + gt + \frac{\alpha}{1-\alpha}Ln(s) - \frac{\alpha}{1-\alpha}Ln(n+g+\delta)$$

Later, Mankiw et al. (1992) in their seminal work extended the Solow growth model by taking into consideration the human capital accumulation (measured as percentage of working-age population in secondary school), and the augmented Solow model used for β conditional convergence is shown below:

$$Ln\left(\frac{Y(t)}{L(t)}\right) = LnA(0) + gt - \frac{\alpha+\beta}{1-\alpha-\beta}Ln(n+g+\delta) + \frac{\alpha}{1-\alpha-\beta}Ln(S_k) + \frac{\beta}{1-\alpha-\beta}Ln(s_h)$$

$(Y(t))/(L(t))$ represents income per capita, n and g refer to population growth rate and technological growth rate respectively, δ is the rate of capital depreciation, S_k is the investment as part of income in physical capital, s_h is the investment as part of income in human capital. α is the physical capital's share of income, and β is the human capital's share of income, where $\alpha+\beta<1$.

If y^*represents the steady level of income per capita, then the convergence speed is defined as below:

$$\frac{dLn(y_t)}{dt} = \lambda[Ln(y^*) - Ln(y_t)]$$

Where $\lambda = (n+g+\delta)(1-\alpha-\beta)$, then:

$$Ln(y_t) = \left(1-e^{-\lambda t}\right)Ln(y^*) + \left(e^{-\lambda t}\right)Ln(y_{t-1})$$

The equation for estimating conditional convergence is thus formed below:

$$\begin{aligned} Ln(y_t) - Ln(y_{t-1}) \\ &= \left(1-e^{-\lambda t}\right)\frac{\alpha}{1-\alpha-\beta}Ln(s_k) + \left(1-e^{-\lambda t}\right)\frac{\beta}{1-\alpha-\beta}Ln(s_h) \\ &- \left(1-e^{-\lambda t}\right)\frac{\alpha+\beta}{1-\alpha-\beta}Ln(n+g+\delta) - \left(1-e^{-\lambda t}\right)Ln(y_{t-1}) \end{aligned}$$

Where y_{t-1} is GDP per capita in previous year.

To deal with the income convergence test, this study first employs the traditional β absolute convergence based up the previous work (Baumol, 1986; Wei et al., 2009):

$$Ln(y_{it}) - Ln(y_{it-1}) = \alpha + \beta Ln(y_{it-1}) + \varepsilon_{it}\ where\ \beta = \left(1-e^{-\lambda t}\right)\ Eq.(1)$$

λ= rate of convergence

y_{it} and y_{it-1} represents GDP per capita of the current and previous year. If β is statistically significant and negative, there is an absolute income convergence. This means that the original poor countries can achieve higher growth to catch up with the original rich countries. On the other hand, if β is statistically significant and positive, there is an absolute income divergence. This implies that countries with higher initial incomes are growing faster than the initial poor countries, which will cause the income gap to expand further over time.

If β absolute income convergence exists, then it implies that β conditional convergence exists as well (Wei et al., 2009). Thus, it extended previous research (Mankiw et al., 1992; Wei et al., 2009) and forms a new β conditional convergence model below:

$$\begin{aligned} Lny_{it} - Lny_{it-1} &= \alpha + \beta_1 Ln(y_{it-1}) + \beta_2 Ln(s)_i + \beta_3 Ln(n+g+\delta)_i + \beta_4 Ln(FDI)_i + \beta_5 Ln(Export)_i \\ &+ \beta_6 Ln(Education)_i + \varepsilon_i, where\ \beta_1 = \left(1-e^{-\lambda t}\right)\ Eq.(2) \end{aligned}$$

y_{it} and y_{it-1} are the same as the previous absolute convergence formula (Baumol, 1986). All growth factors mentioned in the augmented Solow model are included: s is specified as the ratio of the investment in fixed assets to GDP. n is the annual population growth rate; g is the technological growth rate; δ refers to the capital depreciation rate; (g + δ) is set to be 0.05 for all provinces over the entire period; Education is specified as the ratio of the number of students enrolled in higher education over population. FDI and export are introduced as important growth factors that promote economic growth, based on the previous work (Wei et al., 2009). FDI is defined as the ratio of actually used FDI to GDP. Export is defined as the ratio of total value of export to GDP. λ is estimated within the Stata software.

If β_1 is statistically significant and negative, there is a conditional β income convergence. Otherwise, there is a conditional β income divergence. The dummy variable for each region will be introduced at regional level to help identifying if there is convergence or divergence within each four economic regions (Wei et al., 2009). A total 3 dummy for the 4 economic regions will be added using the Stata to avoid the dummy variable trap: central region, west region, and northeast region.

2.7 Research Question

The first question is that after taking into account the spatial dependence effect, if there is an absolute β income convergence among regions in China between the years 1999 and 2017? The hypothesis below addresses this question:

Hypothesis One

H_0: There is no absolute β income convergence among regions between the years 1999 and 2017 ($\beta = 0$: previous level of income per capita does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017).

H_1: There is an absolute β income convergence among regions between the years 1999 and 2017 ($\beta < 0$: previous level of income per capita has a statistically significant and negative impact on the provincial economic growth between the years 1999 and 2017).

The second research question is that after taking into account the spatial dependence effect, if there is a conditional β income convergence among regions in China between the years 1999 and 2017? The hypotheses below address this question:

Hypothesis Two

H_0: There is no conditional β income convergence among regions between the years 1999 and 2017 ($\beta_1 = 0$: previous level of income per capita does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017).

H_1: There is a conditional β income convergence among regions between the years 1999 and 2017 ($\beta_1 < 0$: previous level of income per capita has a statistically significant and negative impact on the provincial economic growth between the years 1999 and 2017).

Hypothesis Three

H_0: Domestic investment in fixed assets does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017.

H_1: Domestic investment in fixed assets has a statistically significant impact on the provincial economic growth between the years 1999 and 2017.

Hypothesis Four

H_0: Population growth rate does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017.

H_1: Population growth rate has a statistically significant impact on the provincial economic growth between the years 1999 and 2017.

Hypothesis Five

H_0: FDI inflow does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017.

H_1: FDI inflow has a statistically significant impact on the provincial economic growth between the years 1999 and 2017.

Hypothesis Six

H_0: Total value of export does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017.

H_1: Total value of export has a statistically significant impact on the provincial economic growth between the years 1999 and 2017.

Hypothesis Seven

H_0: The number of students enrolled in higher education does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017.

H_1: The number of students enrolled in higher education has a statistically significant impact on the provincial economic growth between the years 1999 and 2017.

3. Data Analysis

3.1 Variable and Definition

Table 1. All Variables and Their Definition

Variables	Definition
$rgdp_{it}$	real GDP in RMB, calculated using 1978 price, for province i at year t
$rgdppa_{it}$	real GDP per capita, calculated using *rgdp* divided by provincial population
g_rgdppa_{it}	annual growth rate of $rgdppa$, calculated by taking the natural log difference of $rgdppa$ between two consecutive years for each province i
$lag\_lnrgdppa_{it}$	natural logarithm of $rgdppa$ of the previous year for province i $lag\_lnrgdppa_{it} = lnrgdppa_{it-1}$
$rinvest_{it}$	real domestic investment in fixed assets in RMB, calculated using 1978 price, for province i at year t
$rfdi_{it}$	real FDI in RMB for province i at year t, calculated by first multiplying the annual exchange rates, then divided using 1978 price
$lnrfdiratio_{it}$	natural logarithm of the ratio of *rfdi* to *rgdp* for province i at year t
east	all provinces, direct-controlled municipalities, and autonomous regions located in the east region
central	all provinces, direct-controlled municipalities, and autonomous regions located in the central region
west	all provinces, direct-controlled municipalities, and autonomous regions located in the west region
northeast	all provinces, direct-controlled municipalities, and autonomous regions located in the northeast region
s_{it}	the ratio of *rinvest* to *rgdp*, for province i at year t
$lnsratio_{it}$	natural logarithm of the ratio of *rinvest* to *rgdp*, for province i at year t
ng_{it}	annual population growth rate for province i at year t, $ng_{it} = \frac{ng_{it}}{ng_{it-1}} - 1$
$lnng_{it}$	natural logarithm of the sum of *ng*, g (technological growth rate), and δ (capital depreciation rate), for province i at year t. (g + δ) is set to be 0.05
$rexport_{it}$	the total value of export in RMB for province i at year t, calculated by first multiplying the annual exchange rates, then divided using 1978 price
$lnrexportratio_{it}$	natural logarithm of the ratio of *rexport* to *rgdp*, for province i at year t
edu_{it}	the ratio of the number of students enrolled in higher education to population, for province i at year t
$lneduratio_{it}$	natural logarithm of *edu*, for province i at year t
Implied λ	the speed rate of convergence or divergence

Note. Data ranges from 1998 to 2017 and data on all variables (except annual exchange rates) are taken from various editions *China Statistical Yearbook* (1999-2018 edition) available in NBS's official website (NBS, 2019). Base year of CPI is 1978 with (1978's CPI = 100). The annual exchange rates from 1998 and 2017 are retrieved from the OECD website (OECD, 2021).

3.2 Income Convergence Model Estimation Results

3.2.1 Absolute β Income Convergence

Table 2. Spatial Dependence Test for Absolute Income Convergence (1999-2017)

Spatial Dependence	Statistics	Results	P-Value
GLOBAL Moran I	0.5009	P-Value > Z (34.162)	0.0000
LM Lag (Anselin)	553.6720	P-Value > Chi2(1)	0.0000
LM Error (Burridge)	995.1549	P-Value > Chi2(1)	0.0000
LM Lag (Robust)	0.1147	P-Value > Chi2(1)	0.7348
LM Error (Robust)	123.6432	P-Value > Chi2(1)	0.0000

Note. These calculations were made in Stata for Eq. (1) and then manually added in the table.

Table 2 suggests that the Moran' I index is significant even at the 1% level, showing that China's regional economic growth does have significant spatial dependence. The Moran I index is about 0.5, indicating that there are strong spatial agglomeration characteristics among the economic growth of various provinces, implying that the spatially adjacent provinces have similar growth patterns and spatial connection structures. It thus suggests that the residuals estimated by OLS have obvious spatial autocorrelation, and the classic linear regression model (OLS model) may have inappropriate model settings.

In the Wald test, it failed to reject the null hypothesis (Prob>chi2 = 0.35, more than 0.05 significance level) and thus it can be reduced to either SLM or SEM without significantly harming the fit of model. Because both LM-Lag and LM-Error are significant at the 1% level, and the significance level of Robust LM-Error is higher than that of Robust LM-Lag. Therefore, SEM is chosen for further analysis.

Table 3. Absolute Income Convergence at National Level (SEM)

VARIABLES	(1) Spatial Absolute Income Convergence 1999-2017 SEM with Fixed Effects
lag_lnrgdppa	0.0320
	(0.0257)
Observations	589
R-squared	0.000
Number of _ID	31

Note. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Estimation results for Eq. (1)

The fixed effects model is selected based on the Hausman test result (reject the null hypothesis. Prob>chi2 = 0.0118<0.05 significance level). According to table 3, the estimated coefficient of lag_lnrgdppa is 0.032 and is statistically insignificant even at the 10% level. It also carried out the absolute β income test (H_0: =0; H_1:<0) with a left-tail t-test. The t-statistic for lag_lnrgdppa is 1.25 much more than the critical left-tail t-test value of -1.647, thus it fails to reject the H_0 at 5%, indicating that there is no absolute β income convergence between years 1999 and 2017.

According to the analysis above, it fails to reject the H_0 of hypothesis one (H_0: There is no absolute β income convergence among regions between the years 1999 and 2017 (β=0: previous level of income per capita does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017)). There is no absolute β income convergence among regions between the years 1999 and 2017.

3.2.2 Conditional β Income Convergence

Table 4. Spatial Dependence Test for Conditional Income Convergence (1999-2017)

Spatial Dependence	Statistic	Result	P-Value
GLOBAL Moran I	0.5497	P-Value > Z (37.447)	0.0000
LM Lag (Anselin)	476.6764	P-Value > Chi2(1)	0.0000
LM Error (Burridge)	1176.8216	P-Value > Chi2(1)	0.0000
LM Lag (Robust)	4.1589	P-Value > Chi2(1)	0.0414
LM Error (Robust)	704.3041	P-Value > Chi2(1)	0.0000

Note. These calculations were made in Stata for Eq. (2) and then manually added in the table.

Table 4 indicates that there is great positive spatial autocorrelation (Global Moran I statistic is 0.5497 and its p value of 0.00 smaller than 0.05 significance level), meaning that China's regional economic growth does have significant spatial dependence. The Moran's I index is about 0.55, indicating that there are strong spatial agglomeration characteristics among the economic growth of various provinces and OLS is thus no longer appropriate. In the Wald test, it rejects the null hypothesis (Prob>chi2 = 0.00, less than 0.05 significance level) and thus SDM is a better fit for the model.

Table 5. Conditional Income Convergence at National Level (SDM)

VARIABLES	(1) Spatial Conditional Income Convergence 1999-2017 SDM with Fixed Effects
lag_lnrgdppa	-0.124***
	(0.0393)
lnsratio	0.0425***
	(0.0100)
lnng	-0.0113***
	(0.00320)
lnrfdiratio	0.00703
	(0.00635)
lnrexportratio	0.00191
	(0.00524)
lneduratio	0.0244
	(0.0151)
Observations	589
R-squared	0.251
Number of _ID	31

Note. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Estimation results for Eq. (2)

The fixed effects model is selected based on the Hausman test result (reject the null hypothesis. Prob>chi2 = 0.00<0.05 significance level). Based on table 5, the estimated coefficient of lag_lnrgdppa is -0.124 and is statistically significant even at the 1% level, indicating that 1% increase in lag_lnrgdppa is estimated to decrease the g_rgdppa by 12.4%.

It also carried out a left-tail t-test (H_0: =0; H_1:<0). The t-statistic for lag_lnrgdppa is -3.17 greater than the critical left-tail t-test value of -1.647, thus it rejects the H_0 at 5%, indicating that there is conditional β income convergence between years 1999 and 2017.

According to the analysis above, it rejects the H_0 of hypothesis two (There is no conditional β income convergence among regions between the years 1999 and 2017 ($\beta_1 = 0$: previous level of income per capita does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017). There is conditional β income convergence among regions between the years 1999 and 2017.

The estimated coefficient of lnsratio is 0.0425 and is statistically significant even at the 1% level, meaning that 1% increase in lnsratio is estimated to increase the g_rgdppa by 4.25%. Thus, for hypothesis three, it rejects the H_0 (H_0: Domestic investment in fixed assets does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017). Domestic investment in fixed assets has a statistically significant impact on the provincial economic growth between the years 1999 and 2017.

The estimated coefficient of lnng is -0.0113 and is statistically significant even at the 1% level, indicating that 1% increase in lnng is estimated to decrease the g_rgdppa by 1.13%. Thus, for hypothesis four, it rejects the H_0 (H_0: Population growth rate does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017). The Population growth rate has a statistically significant impact on the provincial economic growth between the years 1999 and 2017.

Lnrfdiratio, lnrexportratio, and lneduratio are all statistically insignificant even at 10%. Thus, for hypothesis five, it fails to reject the H_0 (H_0: FDI inflow does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017). FDI inflow does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017.

For hypothesis six, it fails to reject the H_0 (H_0: Total value of export does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017). Total value of export does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017.

For hypothesis seven, it fails to reject the H_0 (H_0: The number of students enrolled in higher education does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017). The number of students enrolled in higher education does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017.

3.2.3 Conditional β Income Convergence by Region

Table 6. Spatial Dependence Test for each Region (1999-2017)

Region	East		Central		West		Northeast	
Spatial Dependence	Stats	P Value	Stats	P Value	Stats	P Value	Stats	P Value
GLOBAL Moran I	0.2819	0.0000	0.6193	0.0000	0.6207	0.0000	0.5040	0.0000
LM Lag (Anselin)	13.6468	0.0002	56.0362	0.0000	183.1048	0.0000	10.7965	0.0010
LM Error (Burridge)	20.9949	0.0000	65.9434	0.0000	298.4160	0.0000	9.8051	0.0017
LM Lag (Robust)	0.0283	0.8663	0.0284	0.8663	0.6059	0.4363	3.0632	0.0801
LM Error (Robust)	7.3764	0.0066	9.9356	0.0016	115.9170	0.0000	2.0718	0.1500

Note. These calculations were made in Stata for Eq. (2), then manually added in the table.

For all regions, table 6 suggests that there is great positive spatial autocorrelation (Global Moran I statistic for each region has a p value of 0.00 smaller than 0.05 significance level) meaning that China's regional economic growth does have significant spatial dependence. The Moran’s I index ranges from 0.28 to 0.62, indicating that there are mild to moderate spatial agglomeration characteristics among the economic growth of various provinces within four regions respectively and thus OLS is no longer appropriate.

In the Wald test, it rejects the null hypothesis (for east, Prob>chi2 = 0.0015; for central, Prob > chi2 = 0.0126; for west, Prob > chi2 = 0.0003; all less than 0.05 significance level) for all regions but northeast, and thus SDM is a better fit for these regions. Nonetheless, for northeast, it failed to reject the null hypothesis and thus it can be reduced to either SLM or SEM without significantly harming the fit of model. Because both LM-Lag and LM-Error are significant at the 1% level, and the significance level of Robust LM-Lag is higher than that of Robust LM-Error. Therefore, SLM is chosen for northeast.

Table 7. Conditional Income Convergence by Region (SDM and SLM)

VARIABLES	(1) Spatial Conditional Income Convergence 1999-2017 SDM with Fixed Effects for East Region	(2) Spatial Conditional Income Convergence 1999-2017 SDM with Fixed Effects for Central Region	(3) Spatial Conditional Income Convergence 1999-2017 SDM with Fixed Effects for West Region	(4) Spatial Conditional Income Convergence 1999-2017 SLM with Fixed Effects for Northeast Region
lag_lnrgdppa	-0.0979	0.212*	-0.0278	0.565***
	(0.0780)	(0.125)	(0.0702)	(0.0882)
lnsratio	-0.00771	-0.0219	0.0444**	0.122***
	(0.0201)	(0.0233)	(0.0209)	(0.0230)
lnng	-0.00956	-0.0141**	-0.00645*	-0.0677*
	(0.00926)	(0.00620)	(0.00381)	(0.0353)
lnrfdiratio	0.00874	-0.0336*	0.0172**	-0.00187
	(0.0102)	(0.0199)	(0.00864)	(0.0240)
lnrexportratio	-0.00563	0.0219*	0.00382	0.00993
	(0.0185)	(0.0114)	(0.00642)	(0.0172)
lneduratio	0.0873***	-0.0299	0.00983	0.0327
	(0.0264)	(0.0422)	(0.0218)	(0.0336)
Observations	190	114	228	57
R-squared	0.269	0.382	0.280	0.050
Number of _ID	10	6	12	3

Note. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Estimation results for Eq. (2)

The fixed effects model is selected based on the Hausman test result (reject the null hypothesis. Prob>chi2 = 0.00<0.05 significance level for all regions). According to table 7, for east region, the estimated coefficient of lag_lnrgdppa is -0.0979 and is statistically insignificant even at the 10% level. It also carried out a left-tail t-test (H_0: =0; H_1:<0). The t-statistic for lag_lnrgdppa is -1.25 greater than the critical left-tail t-test value of -1.653, thus it fails to reject the H_0 at 5%, indicating that there is no conditional β income convergence between years 1999 and 2017.

According to the analysis above, it fails to reject the H_0 of hypothesis two (H_0: There is no conditional β income convergence among regions between the years 1999 and 2017 (β=0: previous level of income per capita does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017)). There is no conditional β income convergence among regions between the years 1999 and 2017.

Among all other variables, only lneduratio is statistically significant (0.0873) even at the 1% level, meaning that 1% increase in lneduratio is estimated to increase the g_rgdppa by 8.73%. Thus, for hypothesis seven, it rejects the H_0 (H_0: The number of students enrolled in higher education does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017). The number of students enrolled in higher education does have a statistically significant impact on the provincial economic growth between the years 1999 and 2017.

Furthermore, for central region, the estimated coefficient of lag_lnrgdppa is 0.212 and is statistically insignificant at the 5% level. It also carried out a left-tail t-test (H_0: =0; H_1:<0). The t-statistic for lag_lnrgdppa is 1.69 greater than the critical left-tail t-test value of -1.658, thus it fails to reject the H_0 at 5%, indicating that there is no conditional β income convergence between years 1999 and 2017.

According to the analysis above, it fails to reject the H_0 of hypothesis two (H_0: There is no conditional β income convergence among regions between the years 1999 and 2017 (β=0: previous level of income per capita does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017)). There is no conditional β income convergence among regions between the years 1999 and 2017.

Among all other variables, only lnng is statistically significant (-0.0141) at the 5% level, meaning that 1% increase in lnng is estimated to decrease the g_rgdppa by 1.41%. Thus, for hypothesis four, it rejects the H_0 (H_0: Population growth rate does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017). The population growth rate has a statistically significant impact on the provincial economic growth between the years 1999 and 2017.

Moreover, for west region, the estimated coefficient of lag_lnrgdppa is -0.0278 and is statistically insignificant even at the 10% level. It also carried out a left-tail t-test (H_0: =0; H_1:<0). The t-statistic for lag_lnrgdppa is -0.40 greater than the critical left-tail t-test value of -1.658, thus it fails to reject the H_0 at 5%, indicating that there is no conditional β income convergence between years 1999 and 2017. According to the analysis above, it fails to reject the H_0 of hypothesis two (H_0: There is no conditional β income convergence among regions between the years 1999 and 2017 (β=0: previous level of income per capita does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017)). There is no conditional β income convergence among regions between the years 1999 and 2017.

Lnsratio and lnrfdiratio both are statistically significant at 5%. The estimated coefficient of lnsratio is 0.0444 and is statistically significant at 5%, meaning that 1% increase in lnsratio is estimated to increase the g_rgdppa by 4.44%. Thus, for hypothesis three, it rejects the H_0 (H_0: Domestic investment in fixed assets does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017). Domestic investment in fixed assets does have a statistically significant impact on the provincial economic growth between the years 1999 and 2017.

For lnrfdiratio, its estimated coefficient is 0.0172 and is statistically significant at 5%, meaning that 1% increase in lnrfdiratio is estimated to increase the g_rgdppa by 1.72%. for hypothesis five, it fails to reject the H_0 (H_0: FDI inflow does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017). FDI inflow does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017.

In addition, for the northeast region, the estimated coefficient of lag_lnrgdppa is 0.565 and is statistically significant even at the 1% level, indicating that 1% increase in lag_lnrgdppa is estimated to increase the g_rgdppa by 56.5%. It also carried out a left-tail t-test (H_0: =0; H_1:<0). The t-statistic for lag_lnrgdppa is 6.41 more than the critical left-tail t-test value of -1.6725, thus it fails to reject the H_0 at 5%, indicating that there is no conditional β income convergence between years 1999 and 2017.

Thus, it rejects the H_0 of hypothesis two (H_0: There is no conditional β income convergence among regions between the years 1999 and 2017 (β=0: previous level of income per capita does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017)). There is no conditional β income convergence among regions between the years 1999 and 2017.

Among all other variables, only lnsratio is statistically significant (0.122) even at the 1% level, meaning that 1% increase in lnsratio is estimated to increase the g_rgdppa by 12.2%. Thus, for hypothesis four, it rejects the H_0 (H_0: Population growth rate does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017). The population growth rate has a statistically significant impact on the provincial economic growth between the years 1999 and 2017.

Thus, for hypothesis three, it rejects the H_0 (H_0: Domestic investment in fixed assets does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017). Domestic investment in fixed assets does have a statistically significant impact on the provincial economic growth between the years 1999 and 2017.

Table 8. Hypothesis Summary

Research Question 1: Whether there is an absolute β income convergence among regions in China between the years 1999 and 2017, with regional spatial effects?		
No.	Hypothesis (H_0)	Results
1	There is no absolute β income convergence among regions between the years 1999 and 2017	Fail to reject H_0
Research Question 2: Whether there is a conditional β income convergence among regions in China between the years 1999 and 2017, with regional spatial effects?		
No.	Hypothesis (H_0)	Results
2	There is no conditional β income convergence among regions between the years 1999 and 2017	Reject H_0
3	Domestic investment in fixed assets does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017.	Reject H_0
4	Population growth rate does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017.	Reject H_0
5	FDI inflow does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017.	Fail to reject H_0
6	Total value of export does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017.	Fail to reject H_0
7	The number of students enrolled in higher education does not have a statistically significant impact on the provincial economic growth between the years 1999 and 2017.	Fail to reject H_0

4. Discussions

From the above analysis, there is no absolute β income convergence even using spatial econometric model, while there is conditional β income convergence. It is also clear from the results that economic growth is not only closely related to growth factors such as domestic investment in fixed assets and population growth, but also that regional economic growth has significant spatial dependence effect.

The accumulation of capital and effective population control will increase the productivity of any province. In other words, the role of geographic spillover effects between regions on economic development should not be ignored by academia and local governments. In a strict academic sense: any econometric analysis that ignores spatial dependence may have econometric analysis error. The rest of this section discusses empirical results in greater detail.

4.1 Absolute β Income Convergence

In the context of the neo-classical economic growth theory, Robert Barro and Xavier Sala-i-Martin greatly extended the concept of β-convergence based on Baumol's vital work, that is, there is a negative correlation between the economic growth rate and the initial level of economic development, and over time, all countries or the region will converge to the same per capita income level. However, absolute β convergence contains a strict assumption that for a group composed of some economies (countries or regions), although they are isolated and closed from each other, they have exactly the same basic economic characteristics, economic growth path, and equilibrium steady state.

In such a group with exactly the same characteristics, the economic growth rate of an economy is inversely proportional to its distance from the steady state. Therefore, the β coefficient calculated by the equation 1 actually reflects an absolute convergence. However, the reality is that most empirical studies believe that it is difficult to find absolute β convergence under a wide range of sample conditions, and conditional β convergence has replaced it as the main content of the convergence test. This study result also is consistent with most studies, finding no evidence supporting absolute β income convergence even after considering spatial dependence effect.

4.2 Conditional β Income Convergence

The growth of regional per capita income not only depends on the level of per capita income at the beginning of the period, but is also affected by many other factors, such as resource endowments, industrial structure, and inter-regional factor flows not mentioned in this study. If appropriate variables are selected for control, it can also be verified that there is a negative correlation between initial income and economic growth rate, that is, condition β convergence.

This study, after controlling all other growth factors in equation 2 and taking into account the spatial autocorrelation, it found strong evidence of conditional β convergence at the national level, while increase in domestic investment in fixed assets and reducing population growth rate both can significantly contribute to the regional economic growth and promote income convergence over time.

On the other hand, it found no evidence of conditional β convergence within all four regions when introducing dummy at regional level, and each has very different growth factors (education in the east vs. fixed investments in northeast), which implies that the four economic regions have dramatic different economic conditions and development paths.

4.3 Domestic Investment in Fixed Assets

In the study, it found strong evidence that increase in domestic investment in fixed assets can significantly promote regional economic growth and income convergence. Fixed asset investment continues to grow rapidly and has played an important role in the sustained and healthy development of the economy and society in China, according to NBS history data below (NBS, 2019).

In the 70 years since the founding of New China, fixed asset investment across the country has maintained sustained and rapid growth, with an average annual growth rate of 15.6%. In the early days of the founding of the PRC, all industries were waiting to be developed, the country's economic foundation was very weak, and fixed asset investment maintained rapid growth.

From 1953 to 1980, the national investment in fixed assets of units owned by the whole nation increased by 10.7% annually, and a number of basic industrial projects such as metallurgy, automobiles, machinery, coal, petroleum, electric power, chemistry, and national defense that were necessary for the country's industrialization were completed to ensure the production activities of the national economy on track.

The Third Plenary Session of the Eleventh Central Committee of the CPC proposed the notion of focusing on economic construction and vigorously developing productivity. Fixed asset investment showed a trend of rapid growth, and the investment growth rate was significantly accelerated.

From 1981 to 2012, the average annual growth of fixed asset investment in the whole society was 21.1%. Since the 18th National Congress of the CPC, investment has maintained steady growth, the investment structure has continued to improve, and the quality of investment has continued to improve. From 2013 to 2018, the average annual growth of investment in fixed assets in the whole society was 10.7%.

The rapid growth of investment has stimulated sustained and rapid economic growth, while it also expanded production capacity and expanded the living space of residents. Over the past 70 years, investment has been one of the important driving forces of economic development. The national capital formation rate was 38.9% in 1978 and rose to 48% in 2011, reaching the peak since the reform and opening up.

4.4 Population Growth

The Seventh Census (The Seventh National Population Census of the PRC, also referred to as the 2020 Chinese Census) has confirmed the main situation of China’s demographic changes. Based on the published data (NBS, 2021), it confirmed the following trends in China's future population development. First, China has entered an era of ultra-low fertility. Second, the population is aging at a high degree and may accelerate development. Once again, the total working-age population continues to decline, and the peak of the total population will come soon.

Changes in the demographic situation will have a more obvious impact on economic development. Changes in the demographic situation characterized by ultra-low fertility rates, rapid aging and the peak of the total population are currently or about to have an important impact on China’s economic development: it is not only an important determinant of potential economic growth for a long time in the future, but also possibly become an incentive for short-term economic fluctuations.

Lower fertility rates can greatly improve the quality of the population. The improvement of the quality of the population can greatly enhance the overall cultural quality and knowledge level of the whole society, which laid the foundation for the long-term economic development. China's population is aging, and the number of working-age people is declining. Population opportunities need to match economic conditions. Only when a series of economic and social development decisions match population opportunities can the population opportunities be stimulated and transformed into economic dividends.

In the early stage of China's reform and opening up, labor was almost unlimited supply, and the price was very low, which created a good population opportunity; at the same time, reform and opening up promoted the free flow of labor, introduced a large amount of foreign capital, and formed a labor-intensive industrial structure. The match between the two enabled China to reap the first demographic dividend by relying on the high labor participation rate, creating a miracle of economic growth.

China's demographic dividend will not disappear, but will transform. To turn such demographic opportunities into dividends requires economic transformation. China’s economy can no longer rely on labor-intensive industries in the past, but must transform to rely on capital-intensive, financial-intensive, and technology-intensive industries to increase labor productivity.

In such an industrial environment, it is more dependent on the quality of labor, which is human capital. Therefore, demographic opportunities will be transformed with the demographic transition, and the means and conditions for reaping the demographic dividend will also be transformed. In the future, the demographic dividend will be transformed from a high labor participation rate to a high labor productivity.

4.5 FDI inflow

FDI plays a very important role in China's economic growth. In the early stage of reform and opening up, the main purpose of introducing FDI was to make up for the domestic funding gap and to use foreign funds. In economic construction, the emphasis is on the capital effect of foreign direct investment. In the mid-to-late 1980s, China put forward the strategy of “open market for technology” in the policy of utilizing FDI. It aimed to open part of the domestic market, introduce FDI, and then introduce technology to improve China’s technological level, focusing on taking advantage of the technology spillover effect of FDI.

These understandings of the role of FDI have historical limitations and are not comprehensive. We believe that we must fully understand the role of foreign direct investment in China since the reform and opening up. It is necessary to analyze how FDI promotes China's economic growth, that is, to find out its mechanism in the process of economic growth.

As a package of resources, FDI not only has capital attributes, it promotes economic growth through direct capital effects, and indirectly leads to an increase in China's domestic capital and affects economic development through industrial chain effects and demonstration and impact effects. At the same time, the inflow of FDI has external effects, which is one of the main reasons for changes in TFP.

It caused changes in the industrial structure, changes in human capital, and institutional changes, which increased China's TFP, which in turn led to China's GDP growth from another channel. However, research and analysis show that the impact of FDI was minimal on regional economic growth. The possible reason could be its impact on technological progress is incomplete. It mainly affects the soft technology part of China through changes in human capital, while the hard technology progress caused by changes in R&D capital does not play a role in technical spillover effects.

4.6 Export

The starting point of export-promoting growth is determined by external demand. Under the condition of insufficient domestic demand, external demand is used to stimulate domestic supply and create an export-domestic investment linkage mechanism. At the same time, under the incentive of export-biased policies, with the gradual development of the international market, and cost reductions resulting from imported technology and economies of scale, so that supply in turn promotes the growth of exports and realizes the benign interactive loop relationship between export and domestic supply.

The key to the success of China’s export-oriented development strategy lies in the fact that according to the above-mentioned logic, it has gradually completed the spontaneous development of comparative advantages through export-oriented policies to relying on imported technology, the economies of scale cultivated by the international and domestic markets, and the nearly unlimited supply of labor conditions. This change in comparative advantage has gradually formed a pattern of specialized division of labor in which China participates in international trade.

So far, the export-driven growth model of China's economy has been hailed as a successful model of export-oriented development strategy, but it is now being challenged. Affected by the 2008 U.S. financial crisis, the net export stimulus rate for GDP from January to June 2009 was -2.9% (Wang, 2009). In this special period, how to reconsider the export-oriented development model of China's economy? in the short run, China's economy will not be able to reproduce the "golden period" of the export-growth development model that emerged in 2005-2007, the high rate of external demand pulling GDP and small fluctuations (Wang, 2009).

However, due to the inertia of the significant driving effect of exports on China’s economic growth in the past years, domestic demand cannot simply replace external demand. It is necessary to balance the relationship between the two economic growth fulcrums of domestic demand and external demand-while promoting domestic demand through reform, further exploration can be expanded new growth point of external demand. No single point can support the sustainable growth of the Chinese economy.

4.7 Higher Education

Since Schultz (1961) and others put forward the theory of human capital in the 1960s, the role of education in promoting economic growth has attracted the attention of Western economics circles. The expansion of higher education enrollment in China has a positive impact on economic growth. However, with the continuous advancement of college enrollment expansion, the positive effect of higher education on economic growth is not significant, found in this study.

Since the beginning of the 21st century in China, the expansion of higher education enrollment has become more and more important. In January 1999, the State Council of China approved and promulgated Ministry of Education’s "Educational Promotion Action Plan for the 21st Century." As a manifestation of the plan in the field of higher education, the expansion policy of China's higher education at the turn of the century puts forward the development goals of higher education, involving the cultivation of high-level innovative talents, the construction of first-class universities and institutional reforms and many other requirements (Ministry of Education, 1999).

The "Action Plan" clearly stated for the first time the development goal of enrollment rate close to 15% by 2010, and the expansion and reform of China's higher education was officially launched (Ministry of Education, 1999). Since then, in July 2010, the "Outline of National Medium and Long-term Education Reform and Development Plan" promulgated by the State Council revised and improved the 1999 "Action Plan", which paid more attention to the impact of higher education on student development (State Council, 2010).

The impact of higher education on economic growth has great regional differences. Among them, most of the regions whose economic development is negatively affected by the expansion of college enrollment are underdeveloped regions. This is mainly because the quality of colleges and universities in underdeveloped areas is generally not high, and the ability to absorb students is weaker than in developed areas. In order to maintain their own development, colleges and universities in these underdeveloped areas have basically invested a lot of human and financial resources to build "garden-like" campuses, ignoring the quality management of school teaching and research.

The huge amount of funds absorbed by colleges and universities and the inefficient use of college funds have already brought negative effects on the economic development of some regions. Influenced by the views that education promotes economic development and soft budget constraints of universities, universities have basically used bank loans to accelerate the expansion of universities in the case of insufficient investment in public education and weak self-ability to attract research funds. Facts show that the amount of bank loans in colleges and universities continues to increase, but the per-student indicators of colleges and universities, such as per-student books, are far from reaching the national requirements. This shows that the allocation of funds in colleges and universities lacks efficiency.

There is a general tendency of China's universities to emphasize scale expansion and neglect connotation construction, and their management concepts are inadequate. For example, many colleges and universities regard teachers' access to scientific research topics and supporting scientific research funds as the criteria for job promotion.

Under this incentive, a considerable number of teachers, in order to apply for scientific research projects and scientific research funds, ignore their professional ethics and obtain scientific research projects and funds through fraudulent means. Once applications for scientific research funds were applied, universities also lacked effective scientific research funds management regulations, which in the end led to the corresponding teachers often misappropriating scientific research funds, and the academic level of scientific research was not improved.

5. Conclusions and Policy Implications

5.1 Conclusions

China has created an economic miracle since the 1978 reform and opening up. Its economic growth since 1978 has been faster than other states except East Asian “four small dragons” (Malesky & London, 2014; Yang & Zhao, 2015). China’s GDP ranks second only after America at present (Yang & Zhao, 2015). However, it has been struggling with the inequality of regional economic development. Hence, the Chinese central government is dedicated to the reduction of regional income gap to achieve income convergence through more coordinated regional policies over time.

The current state of income convergence in China is in dispute due to different methodology and dataset used by studies. This study thus uses the latest provincial data from the NBS to provide more evidence on traditional income convergence derived from neoclassical growth theory while also taking into account the spatial effects, recognized by previous studies.

Using a panel data consisting of 620 observations of all 31 Chinese provinces, direct-controlled municipalities, and autonomous regions collected from the NBS between years 1998 and 2017, with the consideration of spatial autocorrelation, this study found that: first, there is no absolute β income convergence in the SEM. China's regional economic growth does show a significant spatial dependence, and spatial agglomeration characteristics is strong.

Second, there is strong evidence of conditional β income convergence in the SDM after controlling for growth factors (fixed asset investment, population growth, FDI inflow, export, and higher education enrollment). China's regional economic growth also shows an obvious spatial dependence. Last, there is no conditional β income convergence across all four economic regions in the SDM and SLM, even after controlling for growth factors. There is still weak to moderate level of spatial dependences within each region.

Moreover, from the national level in the conditional β income convergence, it suggests that increase in investment in fixed assets and reduction of population growth could significantly promote the regional economic growth and lead to income convergence over time. However, FDI inflow, export, and higher education enrollment are statistically insignificant.

On the other hand, from the regional level in the conditional β income convergence, it suggests that increasing higher education enrollment can potentially spur the economic growth in the east region. In the central region, the higher priority of growing economy is controlling population growth. In the west region, fixed asset investment and FDI inflow both show a positive effect on stimulating regional economy. In the northeast region, the fixed asset investment is still the most vital growth factor that propels the economic growth.

5.2 Policy Implications

5.2.1 Continue to Better Domestic Investment in Fixed Assets

Over the past 40 years of reform and opening up, investment in fixed assets has maintained rapid growth, the proportion of investment in the service industry has increased significantly, the structure of regional investment has become more reasonable, investment in infrastructure has grown rapidly, investment in innovation has increased significantly, and the proportion of investment in people’s livelihood has increased, established a solid foundation and strong guarantee providing for sustained and healthy economic development.

Especially since the 18th National Congress of the CPC, fixed asset investment has focused on the overall requirements of stabilizing growth, adjusting the structure, making up for shortcomings, and benefiting the people's livelihood, focusing on improving the effectiveness of investment, continuously optimizing the investment structure, and investing in the process of building a well-off society in a holistic way (State Council, 2019). The

Chinese central government continues to play an active and important role in helping the steady development of China's economy. China should continue to promote the following policies to continue to stabilize economic development and promote the balanced development of the regional economy.

First, it is vital to improve the effectiveness of fixed asset investment. Since the 18th National Congress of the CPC, the Party Central Committee has adhered to the general keynote of seeking progress while maintaining stability, unswervingly promoted supply-side structural reforms, moderately expanded aggregate demand, and deeply explored the potential of domestic demand, especially consumer demand, to enable China's economic growth.

The situation has changed from over-reliance on investment and exports in the past to a coordinated pull of consumption, investment and exports (NBS, 2019). In 2017, the national capital formation rate was 44.4%, which was 9.2% lower than final consumption expenditure; the contribution rate to economic growth was 32.1%, which was 26.7% lower than final consumption expenditure; and it spurred economic growth by 2.2%. A good interaction between effective investment and consumption upgrade is gradually taking shape.

Second, it is necessary to significantly increase the proportion of fixed asset investment in the service industry to continue to promote the optimization and upgrading of the industrial structure. Investment in the primary industry has always maintained steady growth. The primary industry is the production basis of China's economic operation, and the Party Central Committee has always attached great importance to it. In the early stage of reform and opening up, with the comprehensive implementation of the rural households' contract responsibility system with joint output, investment in the primary industry was revitalized.

Since 2004, the central government issued the No. 1 document with the theme of "agriculture, rural areas and farmers" for 15 consecutive years. The issue plays an important role in China's economic construction, and investment in the primary industry has reached a new level. From 1982 to 2017, China's investment in the primary industry has completed a total of nearly 15 trillion yuan; an average annual growth rate of 18.3% (NBS, 2019). The rapid growth of investment in the primary industry has effectively improved the labor efficiency of farmers, increased their income, and improved their quality of life.

The investment structure of the secondary industry has improved significantly. Since the reform and opening up, the secondary industry has always been an important force driving investment growth. From 1982 to 2017, the total investment in the secondary industry was 198 trillion yuan, with an average annual growth rate of 20.2% (NBS, 2019). Since the 18th National Congress of the CPC, the Party Central Committee and the State Council have adhered to supply-side structural reforms as the main line, focused on promoting the "three eliminations, one reduction and one supplement", and vigorously developed new energy. Industrial investment in the secondary industry has shown accelerated structural optimization and new energy.

The proportion of investment in the tertiary industry has steadily increased. With the acceleration of the urbanization process, driven by infrastructure and real estate development investment, the proportion of investment in the tertiary industry in China has steadily increased. In 1993, the proportion of investment in the tertiary industry surpassed that of the secondary industry, and its leading position in investment subsequently is increasingly consolidated.

From 1982 to 2017, investment in the tertiary industry totaled 277 trillion yuan, with an average annual growth rate of 21.3%; in 2017, investment in the tertiary industry accounted for 59.6% of total investment, 22.8% higher than investment in the secondary industry (NBS, 2019). The tertiary industry's role in leading and supporting investment is increasing day by day, and it is an important engine driving investment growth.

Third, it is necessary to continue to improve the regional fixed asset investment structure to better promote the coordinated development of the regional economy and society. The coordinated development of investment in the four economic regions forms a benign interaction. In the early stages of reform and opening up, Comrade Deng Xiaoping pointed out: Some areas where conditions are able to develop first, and some areas develop more slowly.

The areas that developed first lead to the development of other areas later, and ultimately achieve common prosperity. This theory adheres to the principle of giving priority to efficiency and giving consideration to fairness, fully respecting the reality of uneven regional economic development in China at that time, effectively promoting the rapid development of investment in the eastern region, and laying a good economic foundation for the development of the central and western regions.

Subsequently, in order to promote the coordinated development of the regional economy, the Chinese central government issued a series of regional policies. In November 1999, the strategy for the development of the western region was determined. Driven by the development, the growth rate of investment in the three economic regions has accelerated significantly, and the development pattern of the four economic regions in the east, central, west and northeast is gradually taking shape.

From 1983 to 2017, investment in the eastern region has completed a total of 211 trillion yuan, with an average annual growth rate of 20.3%; investment in the central region has completed a total of 115 trillion yuan, with an average annual growth rate of 21%, and investment in the western region has completed a total of 115 trillion yuan, with an average annual growth rate of 22.4%; the accumulated investment in northeast China was 41 trillion yuan, with an average annual growth rate of 18.8% (NBS, 2019).

Investment in new regional growth poles is booming. In December 2014, the Central Economic Work Conference decided to focus on the implementation of the "Belt and Road Initiative", "Coordinated Development of the Beijing-Tianjin-Hebei Region" and "Yangtze River Economic Belt" three major strategies, which gave birth to new growth poles (State Council, 2014). The “Belt and Road Initiative” has greatly promoted the cooperation between China and countries along the route, and has effectively driven the growth of investment in relevant domestic regions.

5.2.2 Dealing with the Aging of Population

China has now entered an era of low fertility rate (which may be conducive to long-term economic development), but China is still a developing country with the most populous population in the world. It has entered an aging society at a relatively low per capita income level, encountering the challenge of aging populations similar to those in developed countries. With the aging of the population becoming more and more serious, the momentum of China's rapid economic growth since the reform is likely to be greatly impacted by the aging of the population.

This is because the aging of the population will change the foundation of China's rapid economic growth since the reform, that is, the advantage of low labor costs. The savings rate will drop significantly, and investment and exports will also be negatively affected. In this context, there should be following several policies which can actively respond to the adverse effects of future population aging to minimize the negative impact of population aging on economic growth.

First, speed up the strategic adjustment of the industrial structure. This is the main direction of accelerating the transformation of the economic development mode. It should continue to reduce agricultural labor force and transfer to various non-agricultural industries, which to a certain extent. This can relatively reduce the demand for labor, especially unskilled labor.

Second, accelerate the shift from factor-driven to innovation-driven economic growth. According to the reasoning of the neoclassical growth theory, the most direct driving force of economic growth is technological progress. The Chinese government has taken scientific and technological progress and innovation as an important support for accelerating the transformation of economic development. China's investment in science and technology has increased substantially.

By 2030, the number of scientists and engineers in China's full-time research and development will be the sum of the United States and the European Union (EU), and the number of patent applications by Chinese residents will be close to the sum of the United States, the EU and Japan. The improvement of scientific and technological strength and innovation capabilities will provide a steady stream of impetus for the sustainable development of China's economy.

In addition, strengthen human capital investment and give full play to the role of human resources. This is China's basic countermeasure in response to an aging population. The Chinese central government has formulated the "Outline of National Medium and Long-term Education Reform and Development Plan (2010-2020)", by 2020, the gross enrollment rate of high school education will reach 90%; the popularization of higher education will be further improved, and the gross enrollment rate will reach 40%; and illiteracy among young and middle-aged people will be eliminated (State Council, 2010).

The average years of education for the newly added labor force increased from 12.4 years to 13.5 years; the average years of education for the main working-age population increased from 9.5 years to 11.2 years, of which the proportion of higher education reached 20%, and the number of people with higher education in the year was doubled higher than that in 2009 (State Council, 2010).

When the population is gradually aging and the demographic dividend effect is gradually reduced, the rapid development of education, talents, and technology will bring a new form of dividends with higher added value to China, that is, human resources dividends. The human resource dividend is essentially a high-quality demographic dividend, and the marginal efficiency of the human resource dividend is significantly higher than the demographic dividend.

Finally, steadily adjust the family planning policy. It should adjust the population birth policy timely, flexibly and steadily, and then spend the previous generation's time to softly land and transform from a couple giving birth to one child to a couple giving birth to two children, thus making China's the rate of actual birth rose slightly to approach the level of population replacement, that is, the total fertility rate of women remained stable at 2.1 children per woman (OECD, n.d.). In the long run, it is possible to gradually realize the stability of China's children, youth, working-age population, and total population.

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