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Testing the regional convergence in China

A spatial panel analysis

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AUTHOR: *Yaao Pang*
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Authors: Yaao Pang

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Abstract

This paper tests the regional convergence of GDP per capita across 27 Chinese provinces during the period 1961-2018 with considering the spatial interactions. First, this study only finds a slight divergence over the entire period. Furthermore, the flowing research of this paper divides the overall time span into three sub-period based on two major economic policies, namely the "Open Door Policy" and the "Western Development Strategy". During the period 1961-1977, which is regarded as a phase of planned economy, this paper finds the evidence of regional convergence. Moreover, the results indicate a slight divergence in GDP per capita during the period 1978-1999, proving that the "Open Door Policy" intensifies regional gaps of China. Finally, this study verifies the role of the "Western Development Strategy" in reducing regional differences since a convergence is found during the last period 2000-2018. The outcomes of this research reveal a strong relationship between economic policies and regional convergence, and thus the transition of policies should be considered when investigating the economic convergence. Furthermore, this research also verifies the importance of spatial effects in the process of convergence or divergence. The results are likely to be biased if the spatial dependence is neglected.

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1. Introduction

The aim of this section is to provide a preview of this article, including the research purpose, a short background and two research questions.

Regional convergence is a research topic that has been studied for many years. However, as Olejnik (2008) states, it is still quite popular in recent years. So, what is regional convergence? According to Rey and Montouri (1999), regional convergence means that economic conditions of several regions show a trend of convergence in the long run. In other words, poor areas would gradually reach the same level of economic development as rich regions. Thus, regional differences may be eliminated over time.

As Sala-i-Martin (1996) states in his article, the study of convergence could not only allow researchers to verify economic theories; it also has significant value for government decision-making. People have reasons to reduce concerns about the effectiveness of governmental policies in eliminating regional disparities if they observe an apparent trend of regional convergence (Sala-i-Martin, 1996). On the contrary, if regional gaps are enlarging, one might doubt whether moderate policies could really achieve the goal of decreasing regional differences (Sala-i-Martin, 1996). Thus, it is quite essential to investigate convergence.

However, research related to economic convergence shows inconsistent results. Some studies confirm the existence of regional convergence in developed countries. For example, a research conducted by Barro and Sala-i-Martin (1992) claims that there exists a absolute convergence in the United States and Japan, meaning that poorer regions tend to grow faster than richer ones without considering other factors. However, other studies in a different setting argue that the gap between rich and poor economies still exists, and there is not a trend of economic convergence (Terrasi, 1999; Siebern, 2000; Turganbayev, 2016; Borozan, 2017). Besides, some of these studies notice that governmental policies have a significant impact on economic convergence or divergence (Terrasi, 1999; Siebern, 2000). Therefore, it is hard to reach a consensus on convergence because different countries have different characteristics.

This article intends to conduct a convergence study in China for the following reasons. First, regional disparities still exist even if the economic status of China has increased rapidly over the past few years. As proposed by Lin et al. (2013), regional development in China is quite uneven, and there is a massive gap between eastern and western regions (See figure 1 and figure 2 in appendix).

In addition, some economic policies of China only focus on specific regions, meaning that not all areas could enjoy the benefits. Among them, the "Open Door Policy" and the "Western Development Strategy" are the two representative ones. The "Open Door Policy" was implemented in 1978 and the main purpose was to attract foreign investments and promote economic growth (Tung, Worm & Fang, 2008). Some research claims that the policy helps to narrow regional gaps because of a massive inflow of external investments (Jian, Sachs, & Warner, 1996; Raiser, 1998). However, the relationship between the "Open Door Policy" and regional convergence is still a controversial topic. As Wei et al. (2001) proposed, some evidence indicates that the primary beneficiaries of the economic reform might be coastal provinces in the eastern part of China. Thus, the "Open Door Policy" may expand the regional disparities and result in an economic divergence. The "Western Development Strategy" was implemented in 2000. This policy attempts to develop western regions and narrows the regional gaps (Tung, Worm & Fang, 2008). But it is still unclear whether regional differences decrease after the implementation of the "Western Development Strategy". Therefore, it is meaningful to investigate the relationship between economic policies and regional convergence. Moreover, as the first-level administrative region in China, province is the first one to be exposed to national policies. Thus, it will be more reasonable to conduct a convergence study at the provincial level.

Research on regional convergence in China also displays inconsistent results because of differences in research methods and sample selection. Some early studies tend to use cross-sectional techniques to analyze the economic convergence of China (Gundlach, 1997; Zhang, Liu, & Yao, 2001; Fujita & Hu, 2001). However, cross-sectional analysis is proved to be limited in estimating convergence model. As Arbia and Piras (2013) states, cross-sectional analysis could not capture the regional heterogeneity. Later studies adopt fixed-effect models or random-effect models to reduce omitted variable bias and expand the sample size (Ding, Haynes, & Liu, 2008; Lau, 2010; Matsuki & Usami, 2011). But these techniques fail to explain the interaction between regions, and each area is often regarded as an independent unit. Thus, it is essential to introduce spatial effects in the study of economic convergence. As Badinger et al. (2004) state, spatial effects could capture the circulation of labor, technology, and capital between regions. Magalhães et al. (2005) point out that space is playing an increasing role in economic analysis. The estimated results are likely to be biased if the spatial dependence is omitted. Besides, the speed of convergence is found to be different between studies that incorporate spatial effects and those who do not take spatial dependence into account (Magalhães, Hewings & Azzoni, 2005). Thus, more recent Chinese studies tend to use a weight matrix to measure spatial interactions and analyze the speed of regional convergence after controlling for spatial spillovers (Cheong and Wu, 2013; Mei & Chen, 2016; Qin, Ye & Liu, 2017). But in general, no one has combined the spatial convergence model with economic policies. This point is one of the contributions of this paper.

The research purpose of this article is to test the regional convergence in GDP per capita of China at the provincial level. There are two research questions: The first research question is to examine the regional convergence during the period 1961-2018. In order to investigate this research question, this paper adopts two spatial models based on the research conducted by Rey and Montouri (1999). The first one is the spatial lag model (SAR), and the other is called the spatial error model (SEM). The second research question is to analyze the relationship between economic policies and regional convergence or divergence. For this purpose, this research divides the overall time span into different sub-periods based on two economic policies: the "Open Door Policy" in 1978 and the "Western Development Policy" in 2000. Thus, this study could detect the variation of convergence or divergence before and after the implementation of each policy.

By running two spatial models, namely spatial lag model (SAR) and spatial error model (SEM), this study finds a slight divergence over the entire period. Furthermore, the following research observes a strong relationship between regional convergence and economic policies. A regional divergence is found after the implementation of the "Open Door Policy", and regional differences tend to decrease after the "Western Development Strategy" is implemented. Thus, economic policies play a role in the process of regional convergence.

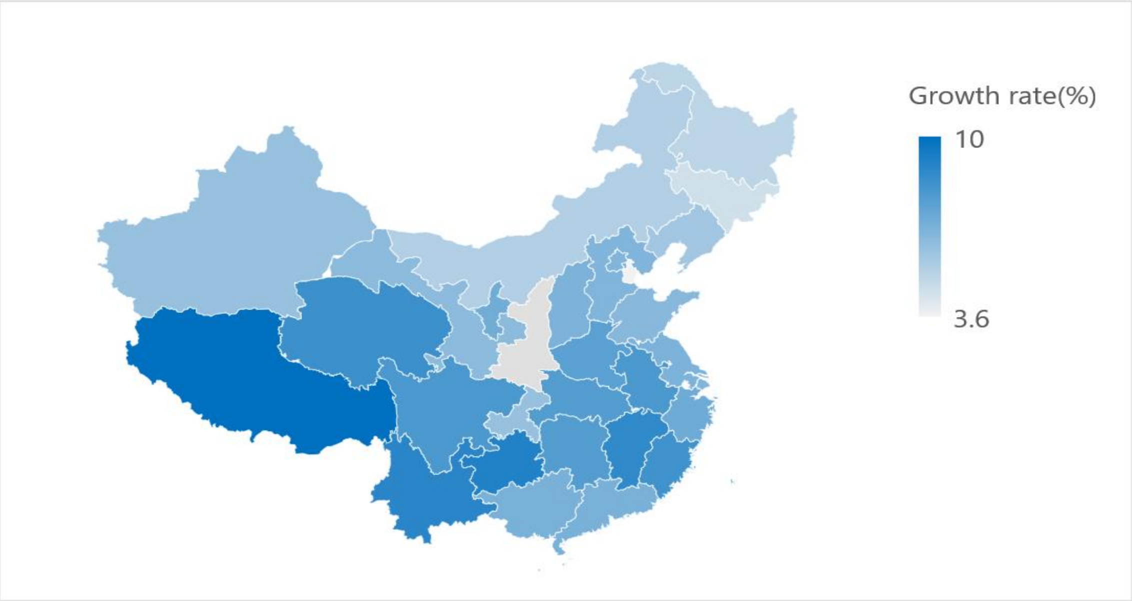
The structure of this paper is as follows: Section 2 gives a short background about major economic policies in difference sub-periods. Section 3 explores the theoretical basis of regional convergence, emphasizing the importance of the neoclassical theory in this research field. Moreover, a literature review will also be provided in this part. In section 4, this paper will describe techniques to collect the data and explain the primary methods used to estimate the convergence model. Section 5 presents the empirical analysis and discusses the estimated results. In the last part, this paper provides conclusions, deficiencies, policy implications and recommendations for future research.

2 Background

2.1 Regional growth in China

As mentioned earlier, regional development is uneven in China. In general, western provinces contribute more to the total GDP than eastern and central provinces. Therefore, the gap between eastern regions and other areas is still considerable. However, results are quite different if we look at the growth rate of GDP. Table 3 displays the GDP growth rate at the provincial level in 2018.

Figure 3: Provincial growth rate in terms of GDP in 2018



Source: The figure is made by the author by using data collected from the CSMAR database (2020)

The average growth rate of GDP is about 6.7% in 2018. There are five eastern provinces that have a growth rate higher than the average level, accounting for 45% of the total number of eastern provinces. The growth rate of fourteen eastern and central provinces exceeds the national average growth rate, accounting for 70% of the total. Among provinces with growth rates lower than the average level, two provinces belong to the central region, four belong to the western region and seven belong to the eastern region.

Moreover, Xizang, Guizhou, and Yunnan are the three provinces with the highest GDP growth rates, and all of them are located in the western part of China. There are nine provinces with a growth rate of more than 8%, including one in the eastern part of China, two in the central part, and six in the western part. Therefore, it could be noted that the GDP growth rates of most central and western provinces are higher than those of eastern provinces. Such a result might be attributed to the "Western Development Strategy". A large amount of governmental investments in central and western regions may change the growth pattern of these regions, thereby allowing them to grow at a higher speed. Furthermore, regional differences might be eliminated if central and western regions could maintain the trend of accelerated growth. And economic policies may play an important role in this process. The following parts introduce two major policies that focus on different regions and illustrate the changes in regional development strategy with the implementation of these policies.

2.2 Development strategy at the stage of central planning (1961-1977)

The period after the establishment of the new Chinese government and before the economic reform in 1978 is usually regarded as a phase of planned economy (Helms, 1992). The core of the planned economy is that the government completely controls the economic patterns and market dynamics（Lin, 1999）. During this period, the central government regards industrial development as the most important part of promoting economic growth and invests most of the capital and labor into the secondary industry (Yusuf, 1994). Such a measure is inseparable from the economic condition of China during that phase. Firstly, the central government was worried about the potential threats of other nations since China just escaped from the war (Yang, 1990). In addition, regional inequality was also a significant issue at that time. According to Wei, Yu and Chen (2011), coastal areas have better economic conditions than inland areas because of geographic and historical reasons. Moreover, the main driving force of economic development was agriculture since rural residents accounted for nearly 90 percent of the total population (Li & Yang, 2005). However, unlike modern agriculture, agricultural production at that time mainly relied on manual workers. Therefore, the productivity of agriculture was limited. According to Helms (1992), the GNP per capita was no more than two thousand Chinese yuan for a long period of time before the economic reform in 1978. Therefore, promoting economic growth and increasing military strength became the main objectives of the central government. For these reasons, the central government planned to give priority to the development of heavy industry (Cai & Zhou, 1996). In order to achieve the goal as soon as possible, the central government adopted a planned economic system. The term planned economy means that resources and funds are allocated in a planned way (Van Brabant, 1990). Such a system could to some extent ensure the social stability since earnings will be equally distributed by the government. However, the planned economy also has a lot of shortcomings. For example, production efficiency is relatively low compared with the market economy because workers have no incentive to create more outcomes (Fan, 1997). The wage is the same no matter how many products a worker could produce. In addition, the government only focused on heavy industry but neglected agriculture, which led to a shortage of food supplies (Li & Yang, 2005). However, the regional gap was not very large under the influence of planned economy and governmental intervention. Thus, there might be a trend of regional convergence during this phase.

2.3 Development strategy at the stage of economic reform (1978-1999)

In 1978, considering the negative outcomes brought by the planned economy, the central government proposed an economic reform called the "Open Door Policy". The reform has a significant impact on the economic transition of China since it shifts the economy of China from a balanced development to an unbalanced growth (Lee, Peng, Li & He, 2012). After 1978, the government decided to classify four cities including Shenzhen, Zhuhai, Shantou and Xiamen as economic zones (Huan, 1986). The purpose of doing so is to test the effectiveness of the "Open Door Policy" in promoting economic development. In the four special economic zones, the central government conducts several management mechanisms and preferential policies that are completely different from those in other regions. For example, the government makes adjustments to the economic system. In economic zones, the market economy is the dominant economic system (Yueh, 2013). In addition, the government provides more favorable tax policies to domestic and foreign companies that are involved in international trade (Wen, 2007). Unlike the planned economy, the market economy allows enterprises to have a certain degree of autonomy, thus breaking the strict control of the government on enterprises (Huan, 1986). Furthermore, local governments also own greater power compared with the central planning period (Wu & Reynolds, 1988). The intention of these adjustments is to allow corporations in the economic zones to attract foreign investments and absorb advanced technology or experience without barriers, thereby driving the development of the urban economy. In 1984, the central government decided to expand the range of economic zones since the economic reform was found to positively influence the urban development. More than a dozen coastal areas including Shanghai, Guangzhou and other big cities were designated as experimental regions of the "Open Door Policy" (Huan, 1986). Moreover, the government adjusted the existing policies according to the difficulties that appeared after the implementation of economic reform.

A fact could be easily observed from the demarcation of economic zones. The country attempts to implement a regionally unbalanced policy. On the one hand, the primary beneficiaries of the "Open Door Policy" are coastal provinces located in the eastern part of China. The superior location of coastal regions makes them more convenient to connect with other nations (Wang, Cornelis van Kooten & Wilson, 2004). Consequently, the "Open Door Policy" may have a higher chance of success in eastern areas. On the other hand, the central and west regions still follow the original path of development. Thus, regional differences would increase and there might be a regional divergence in GDP per capita during this period.

2.4 Development strategy at the stage of western development (2000-2018)

Since the implementation of the economic reform, the regional imbalance has shown an increasing trend (Yao, Zhang and Feng, 2005). The disparity in regional development has also resulted in inequality in income level. There are more and more rich people in the eastern provinces, while some citizens living in western provinces are still worried about daily needs. Such a serious inequality in income generates a potential threat to social security (Yao, Zhang and Feng, 2005). Moreover, many young individuals prefer to find a job in eastern regions, which further deteriorate the economic development of the west (Wei, 1999). Taking into account the serious consequences of the sustained imbalances, in 2000, the central government put forward a policy named "Western Development Strategy" (Barabantseva, 2009). Like the "Open Door Policy" in 1978, the "Western Development Strategy" is still a regionally oriented policy. The focus of the policy is western part of China. From this perspective, "Western Development Strategy" is also an unbalanced development project. However, the main purpose of the "Western Development Strategy" is to balance the income level and regional development, so that impoverished districts could catch up with rich ones.

The "Western Development Strategy" adjusts the development strategy of the central and western regions in many aspects. First, the central government increases fiscal expenditures to improve the infrastructure of western regions. According to Lu and Deng (2013), the state has invested more than two trillion Chinese yuan in fields such as transportation, public healthcare within several years after the implementation of the "Western Development Strategy". Moreover, considering the loss of talent, the government also proposed a series of employment policies to keep high-educated citizens and attract talents from other regions (Lu & Deng, 2013). Another significant issue of western provinces is the number of highly educated residents. Compared with eastern regions, western provinces own more less-educated citizens (Golley, 2007). Thus, one of the targets of the "Western Development Strategy" is to improve the overall education level in the western provinces, since human capital is a key driver of regional growth. Besides governmental supports, eastern provinces are also required to play a role in assisting central and western areas (Golley, 2007). The "Open Door Policy" in 1978 has required the eastern regions to support other regions as they have a better economic condition. But some western provinces are still poor, and it seems that they do not receive enough aid from the east. Thus, one of the main targets of the "Western Development Project" is to strengthen interregional cooperation. A series of governmental interventions allow western regions to develop at a faster speed, and regional gaps gradually decrease in the following years (Liu, Wang & Hu, 2009). Thus, a trend of regional convergence might be observed during the period after the implementation of the "Western Development Project".

3 Theory and empirical research

This chapter discusses the theoretical background of regional convergence. Furthermore, previous studies are reviewed based on the classification of convergence.

3.1 The neo-classical theory

Some studies state that the neo-classical theory is the theoretical basis of regional convergence (Fingleton, 1999; Petrakos and Artelaris, 2009). In the production function proposed by Solow (1956), labor and capital are considered to be driving factors of economic growth. In addition, the returns from the latter factor is considered diminishing over time, which means that the greater the inputs, the lower the returns. Therefore, economies with larger capital accumulation may have a lower growth rate. According to Barro and Sala-i-Martin (1992), the neo-classical theory predicts that the economic growth rate of a country is inversely correlated with the initial economic condition. This rule also suits regional development. Poor regions usually have worse initial conditions compared to rich areas. However, according to the neo-classical theory, their growth rate will exceed that of rich ones over time. Thus, the difference in growth rate will enable poor regions to catch up. This phenomenon is called convergence in academia (Barro and Sala-i-Martin, 1992). From a model perspective, the basic form of the Cobb-Douglas function proposed by Solow (1956) is as follows:

$$\mathbf{P} = \mathbf{T} * \mathbf{F}(\mathbf{Z}, \mathbf{L}) = \boldsymbol{Z}^{\boldsymbol{\alpha}} * (\boldsymbol{T} * \boldsymbol{L})^{\mathbf{1}-\boldsymbol{\alpha}}$$

Here **P** represents the total output value, and **T** indicates the technology. **Z** is capital, and **L** is the number of labors. The above equation could be transformed into per capita form by dividing each element by the total number of effective labors, namely **T * L**. In this way, the following equation will be obtained:

$$\mathbf{p} = \boldsymbol{z}^{\boldsymbol{\alpha}} = \mathbf{f}(\boldsymbol{z})$$

Where p = P / (T * L), z = Z / (T * L), these two variables represent the output and capital accumulation that each effective labor could generate. According to Barro and Sala-i-Martin (1992), the change of z could be expressed as follow:

$$\dot{\boldsymbol{z}} = \boldsymbol{f}(\boldsymbol{z}) - \boldsymbol{c} - (\boldsymbol{\partial} + \boldsymbol{\gamma} + \boldsymbol{g})\boldsymbol{z}$$

$\dot{z}$ represents the variation of capital accumulation, c is the consumption of each effective labor, ∂ indicates the depreciation rate, g represents the technological progress, and γ donates the growth rate of labor. Furthermore, the utility function is expressed as follows:

$$\mathbf{U} = \int_{\mathbf{0}}^{\infty} \boldsymbol{u}(\boldsymbol{c})\boldsymbol{e}^{\gamma \boldsymbol{t}}\boldsymbol{e}^{-\boldsymbol{\sigma t}}\boldsymbol{dt},\ and$$

$$\mathbf{u}(\mathbf{c}) = \frac{\boldsymbol{c}^{\mathbf{1}-\boldsymbol{\omega}} - \mathbf{1}}{\mathbf{1} - \boldsymbol{\omega}}$$

To maximize the utility function, the first-order condition should be as follow:

$$\frac{\dot{\boldsymbol{c}}}{\boldsymbol{c}} = \frac{\mathbf{1}}{\boldsymbol{\omega}}.\{\boldsymbol{f}'(\boldsymbol{z}) - \boldsymbol{\partial} - \boldsymbol{\sigma}\}$$

In a steady state, the value of capital accumulation has the following expression：

$$\boldsymbol{f}'(\boldsymbol{z}^*) = \boldsymbol{\partial} + \boldsymbol{\sigma} + \boldsymbol{\omega g}$$

As Barro and Sala-i-Martin (1992) stated, if **z** is less than the equilibrium value $\boldsymbol{z}^*$, then **z** will grow closer to $\boldsymbol{z}^*$. Barro and Sala-i-Martin (1992) claim that the growth rate of **z** is decreasing in this process, meaning that returns of capital are diminishing over time. In addition, the output also follows this pattern since the total output **p** is a function of capital **z**. Thus, the growth rate of output is also decreasing over time. Besides, the gap between **p** and the equilibrium value in poor regions is much larger than that of developed areas, and the growth rate of poor regions will be relatively higher. Therefore, the neoclassical theory predicts a regional convergence based on an assumption of similar technology.

3.2 The endogenous growth theory

In contrast to the neo-classical theory, the endogenous growth theory proposed by Romer (1986) and Lucas (1988) predicts a divergence rather than a convergence. This type of growth theory considers factors like human capital, technology as endogenous elements of economic growth (Petrakos & Artelaris, 2009). According to Martin and Sunley (1998), investments in human capital could increase the efficiency of labor and physical capital in promoting growth. Thus, these endogenous factors are actually increasing returns over time (Martin & Sunley, 1998). In this case, rich economies will maintain a high growth rate while poor economies are still poor. Therefore, differences between rich economies and poor ones will gradually expand and all economies will diverge over time (Petrakos & Artelaris, 2009).

3.3 The new economic geography theory

Like the endogenous growth theory, the new economic geography theory proposed by Krugman (1991) also predicts that regions tend to diverge over time (Petrakos & Artelaris, 2009). In the new economic geography theory, the diffusion of factor is considered to a driving force for regional specialization and spatial agglomeration (Krugman, 1991). Moreover, spillover effects will make these clusters own competitive advantages compared with other regions (Martin, 2001). Thus, capital and labor will gradually flow into these agglomerations because of the increasing returns of factor (Martin, 2001). As a result, different regions within a country are more likely to diverge over time.

3.4 Empirical studies

From an empirical point of view, convergence could be divided into several types. The first type of convergence is the σ-convergence, which captures the degree of dispersion in GDP per capita (Rey & Montouri, 1999). In addition, different studies have various techniques to measure the σ-convergence. Some research attempts to estimate σ-convergence by observing the changes in the standard deviation (Borozan, 2017). Other research prefers to observe the β value, which is the coefficient of per capita GDP in regressions (Bernard and Jones, 1996).

Another kind of convergence is called absolute β-convergence. Rey and Montouri (1999) state that the underlying logic of absolute β-convergence is to examine the relationship between initial GDP and the growth rate. If scholars observe a negative correlation between these two factors, then they could prove the existence of β-convergence. Some studies usually put σ-convergence and β-convergence together since both are techniques to test convergence. Furthermore, one might expect a clear connection between them. However, the relationship between β-convergence and σ-convergence is not that close, which is why scholars distinguish these two techniques. According to Quah (1993), it is possible to detect a β-convergence without observing a decrease in the degree of dispersion. Therefore, one cannot prove the existence of β-convergence by detecting a σ-convergence. When testing the absolute β-convergence, various studies tend to use different methods to measure the initial GDP, which is the main independent variable in the convergence model. One way is to capture the per capita GDP at the starting point (Martin, 2001; Coulombe & Tremblay, 2001; Dall' Erba & Le Gallo, 2008). Another approach regards the GDP per capita at time t-1 as the initial value, and takes the annual growth rate into account instead of using the average growth rate (Rey & Montouri, 1999; Arbia and Piras, 2013; Maynou, Saez, Kyriacou, & Bacaria, 2016; Celbis & Crombrugghe, 2018). At the national level, most studies fail to prove the convergence theory. A research conducted by Baumol (1986) investigates the economic growth of 70 countries within 30 years, and this research finds a trend of economic divergence. The β value is found to be greater than zero. Thus, poor economies are still growing slowly and, as a result, they are less likely to catch up with rich ones. Furthermore, a convergence appears when Baumol (1986) limits his research to industrial nations, meaning that economies with similar characteristics are more likely to convergence to the same level. However, a paper written by Long (1988) criticizes the study of Baumol from the perspective of sample selection. Long (1988) argues that convergence studies at the national level should not take all samples from countries that have shown a significant convergence but should consider nations that have the potential to converge. Otherwise, the results have no practical meanings. After excluding the influence of sample selection bias, this research still fails to discover an absolute convergence across 16 countries. However, this study does not completely reject the convergence theory. On the contrary, Long (1988) claims that convergence is likely to occur under the influence of external forces. Similarly, a research of Barro (1991) also denies the existence of absolute convergence when the sample is expanded to 98 countries. In addition, subsequent analysis of this study confirms the arguments of Long (1988). When human capital is introduced into the convergence model, a significantly negative value of β is found, which is the symbol of economic convergence. At the regional level, there is a debate about the existence of absolute convergence. Unlike country-level studies, some regional studies verify the absolute convergence theory in several countries. As Turganbayev (2016) mentions, policies and institutions are similar in different regions within a country. Therefore, the diffusion of technology, capital and labor is more likely to occur at the regional level. For instance, Barro and Sala-I-Martin (1992) study the economic convergence in 48 counties of the United States. They discover the evidence of absolute convergence and the convergence rate is about 2%, meaning that regional differences tend to decrease over time. A similar study done by Rey and Montouri (1999) also detects a regional convergence in the United States. Unlike the research conducted by Barro and Sala-I -Martin (1992), this work introduces a spatial weight matrix into the convergence model to capture the spread of factors like technology, capital, etc. According to Rey and Montouri (1999), estimated results would be biased if one neglects spatial effects.

There are also studies that do not find a convergence but observe a divergence at the regional level. Borozan (2017) uses a fixed effect model to test the regional convergence in Croatia from 2000 to 2011 and claims that rich regions still grow faster than poor regions. Furthermore, Borozan (2017) argues that the divergence is caused by the unique historical background of Croatia. The war results in population movements between regions, and the increase of talents in rich areas exacerbates the regional inequality. Turganbayev (2016) examines the regional convergence in Kazakhstan with considering the movement of labor and also concludes that regional differences do not seem to decrease over time. It seems that most national level studies agree with the regional divergence, but studies at the regional level have not reached a consistent conclusion. The inconsistency of empirical results makes some scholars doubt the reasonableness of absolute convergence theories.

In fact, σ-convergence and absolute β-convergence are considered to be defective because both theories predict that the economic development of different countries will converge to the same level (Ertur, Le Gallo, & Baumont, 2006). However, in empirical studies, researchers notice that some poor regions converge to a low steady state and some rich regions converge to a higher steady state (Lessmann & Seidel, 2017). There is a huge gap between poor groups and rich groups, and the gap does not seem to be eliminated over time. But σ-convergence and absolute β-convergence theories fail to explain such a phenomenon. Thus, Durlauf and Johnson (1995) propose a concept named "club convergence" in their research to describe this phenomenon. Club convergence theory classifies regions into several spatial clubs, and members in each club will converge to the same economic level. But there are still economic differences between convergence clubs. According to Ertur, Le Gallo, and Baumont (2006), the formation of a convergence club depends on the initial economic conditions of regions. Areas with similar characteristics and development patterns are more likely to form a convergence club. In other words, poor regions are unlikely to be in the same club with rich ones. After the concept of club convergence is proposed, lots of studies start to investigate different groups of countries. Among them, studies in the EU setting account for a large proportion because of geographical proximity and economic connections (Petrakos & Artelaris, 2009). A cross-sectional study conducted by Olejnik (2008) tests the absolute convergence of European countries in 2004 and proves the existence of economic convergence. Moreover, this work argues that spatial dependence is one of the major driving forces of economic convergence. Badinger, Müller, and Tondl (2004) confirm the findings of Olejnik (2008) by conducting a panel analysis during the period 1985-1999. This research concludes that adjacent areas would share the positive effects of spatial spillovers, and thus result in a club convergence. Therefore, it seems that spatial spillover is also an essential factor of forming convergence clubs. However, not all studies indicate a convergence in the EU setting. For instance, Petrakos and Artelaris (2009) adopt a weighted least square method to analyze the convergence of GDP per capita during the period 1990-2000 and concludes that there is a divergence rather than a convergence in the EU. Petrakos and Artelaris (2009) point out that most EU-level studies ignore the impact of regional size on convergence, so these findings may be misleading. A better way to measure convergence is to give a certain weight to each region and take the regional heterogeneity into account (Petrakos & Artelaris, 2009). Outside the European Union, studies on club convergence tend to conduct an analysis at the regional level. For example, Lin et al. (2013) verify the existence of club convergence in China by using a unit root test. However, they do not find a trend of convergence across the country. The gap between the eastern and western regions is still considerable. There is no evidence showing that western areas are growing faster than eastern ones. Cheong and Wu (2013) verify the findings of Lin et al. (2013) by conducting a county-level study. Several spatial groups are found to have a trend of convergence. But overall there is no regional convergence.

The last type of convergence is the conditional β convergence, which differs from absolute β convergence in that it introduces control variables into the model (Dall' Erba and Le Gallo, 2008). Therefore, the most important part of testing conditional convergence is the selection of control variables (Turganbayev, 2016). A common practice is to look for factors that may have an impact on economic growth based on economic theories. Thus, different studies tend to incorporate different control variables, such as public investment (Siebern, 2000; Turganbayev, 2016); human capital (Guastella & Timpano, 2016; Lessmann & Seidel, 2017; Ramos, Suriñach & Artís, 2010); FDI (Völlmecke, Jindra, & Marek, 2016); infrastructure (Celbis & Crombrugghe, 2018; Fageda & Olivieri, 2019); R&D (Guastella & Timpano, 2016; Peiró-Palomino, 2016); migration (Borozan, 2017). All studies mentioned above confirm the existence of conditional convergence. Consequently, compared with club convergence and absolute convergence, the conditional convergence is less controversial.

It is worth mentioning that none of the mentioned studies takes the effect of policies and structural breaks into account. A research conducted by Siebern (2000) investigates the regional convergence in Germany and emphasizes the importance of economic policies. Policies on promoting investments in East Germany play an important role in the process of regional convergence. Terrasi (1999) conducts a similar study in Italy and concludes that policies could lead to regional integration as well as regional disparity. The result depends on which regions will benefit from the policy. When coming to China, lots of studies take the impact of the "Open Door Policy" into account when analyzing regional convergence. For example, Yao and Zhang (2001) test the regional convergence after the economic reform in 1978 and states that the "Open Door Policy" does not make poor areas grow faster. On the contrary, the gap between rich and poor regions is further enlarged. A more recent study conducted by Andersson, Edgerton and Opper (2013) draws the same conclusion by investigating the regional convergence during the period 1978-2009. This study claims that the reform is an unbalanced policy which exacerbates the regional differences of China in the short term.

3.5 Hypotheses

It could be noted from previous research that convergence theories did not stop developing over the past few decades since scholars continuously discovered new issues. However, there is not a widely accepted conclusion. Differences in econometric methods, time spans and the selection of control variables will enable studies to reach various results. But it seems that most studies related to regional convergence of China fail to prove the existence of absolute convergence. In addition, major policy like the "Open Door Policy" is found to have an important impact on regional convergence. Therefore, this paper has the following hypotheses based on previous studies and our research questions:

H1: There is no absolute convergence across 27 provinces of China during the time period 1961-2018 with considering the spatial dependence.

To answer the second research question, this paper will divide the entire time span into three sub-periods, 1961-1977,1978-1999 and 2000-2018. By doing so, the relationship between economic policies and regional convergence could be well captured. And, in addition, this paper proposes the following hypotheses:

H2: There is a regional convergence before the economic reform in 1978.

H3: A regional divergence could be detected during the period after the implementation of the "Open Door Policy" in 1978.

H4: The regional divergence tends to disappear after the implementation of the "Western Development Strategy" in 2000.

4 Data and methodology

The purpose of this section is to introduce the method to collect data and explain the primary methodology used in this paper.

4.1 Data

The dependent variable of this article is the annual growth rate of per capita GDP. The independent variable is the initial GDP which is measured by the GDP per capita at time t-1. A lot of recent studies use such a method to enlarge the sample size (Ramos, Suriñach & Artís, 2010; Arbia & Piras, 2013; Borozan, 2017). All data comes from the CSMAR database. The full name of CSMAR is "China Stock Market & Accounting Research Database", which is a database for Chinese researchers to collect macro and micro data. The data in this database is the same as that in the Regional Bureau of Statistics. The only difference is that the data in CSMAR is integrated into one table. Thus, people do not have to spend much time merging the original data. In this database, this paper collects the annual GDP data for all provinces of China during the period 1961-2018. Besides, a total of 27 provinces are included in the sample. Among them, there are eleven provinces in the east, nine provinces in the middle, and seven provinces in the west. This article excludes Hong Kong, Macao and Taiwan from the sample because of geographical distance and differences in institutions. Besides, Qinghai province and Xizang province are excluded because of lack of data. Moreover, the data on the price index of each province before 1980 is not available. Thus, this paper applies the method proposed by Barro and Sala-I-Martin (1992) to deflate the nominal GDP. This method uses the consumer price index of the entire country instead of using the regional price index. As Barro and Sala-I-Martin (1992) claims, only constant terms would be influenced by using the same deflator for each region. In addition, this paper takes logarithm for the independent variable. **Table 1** provides a description of primary variables and some brief statistics.

Table 1: Variable description and descriptive statistics

Variable	Definition	Mean	Std.Dev	Min	Max
$G_{i,t}$	Real GDP per capita at time t	11842.63	21049.37	82.8596	137327.4
$G_{i,t-1}$	Real GDP per capita at time t-1	10731.46	19466.06	82.8596	126962.7
$Rate_{i,t}$	Annual growth rate of per capita GDP	0.096	0.108	-0.862	0.388
W	Row normalized weight matrix (27x27)	0.037	0.125	0	1

4.2 Spatial dependence

Spatial interaction is an important factor for investigating regional convergence. However, time series studies and cross-sectional analyses often neglect the spatial effects and regard each region as an independent unit (Rey& Montouri, 1999). As Jones (1997) mentions, the diffusion of factors is one of the most important elements to stimulate economic convergence. Thus, convergence studies should take spatial interactions into account. Otherwise, one may obtain a biased result and draw an unreliable conclusion (Dall' Erba & Le Gallo, 2008).

4.3 Spatial weighting matrix

One way of capturing spatial spillovers between regions is to introduce a spatial weight matrix into the convergence model. According to Ertur, Le Gallo and Baumont (2006), the spatial weight matrix is the most common technique to capture spatial interactions. (In this paper, the Geoda software will be used to generate a spatial weight matrix for 27 provinces of China.) Furthermore, this article replicates the method of measuring spatial effects in matrix form presented by Kosfeld and Lauridsen (2004). Here we define a 27×27 spatial weight matrix named **W**, and $W*_{a,b}$ represents the spatial effects between two provinces, the possible values of $W*_{a,b}$ are listed as follows:

$$W*_{a,b} = \begin{cases} 1 & \text{if two regions } a \text{ and } b \text{ are regarded as neighbors} \\ 0 & \text{if two regions } a \text{ and } b \text{ are far away from each other} \end{cases}$$

The values of $W*_{a,b}$ is equal to 1 or 0, which depends on the spatial relationship between two regions. If two areas are defined as neighbors, the spatial effect between them should be equal to 1. Otherwise, there may be no spatial effects between two regions and $W*_{a,b}$ equals 0. In addition, there are a lot of ways to define neighbors. Among them, the "Queen contiguity" and the "Rook contiguity" are the two commonly used ones (Getis & Aldstadt, 2004). This paper adopts the former technique. The queen contiguity matrix regards two areas as neighbors if they share a common boundary line or they are connected by a point. Two regions might interact with each other even if they are only connected by a point. Therefore, the queen contiguity matrix is superior than the Rook contiguity matrix in capturing the relationship between regions. Furthermore, a normal procedure after generating a weight matrix is to normalize the matrix through dividing every element by the sum of each row (Ertur et al, 2006).

To test the significance of spatial dependence, this paper uses a technique named Moran's I test. The basic expression of the Moran's I tests is as follows:

$$I_t = \left(\frac{n}{R_0} \right) . \frac{O_t{}' \, . \, \boldsymbol{W} \, . \, O_t}{O_t{}' \, . \, O_t}$$

Where n is the number of provinces in our datasets. O_t is a vector that contains n spatial observations, and it captures the deviation from the mean for each year (Rey & Montouri, 1999). **W** is the spatial weighting matrix that we defined earlier. R_0 is the sum of each factor in matrix **W**. The aim of the Moran's I test is to investigate the residuals of the simple regression and thus it is usually conducted before running the spatial models (Ertur, Le Gallo, & Baumont, 2006). Furthermore, the spatial dependence could also be detected by estimating the spatial lag model (SAR) and the spatial error model (SEM). Both models contain a spatial coefficient, and thus, spatial effects could be detected by conducting a significance test. Another way of testing the spatial dependence is to perform a Lagrange Multiplier (LM) test. Moreover, the Lagrange Multiplier (LM) test could also be used to judge which type of spatial model fits better (Anselin, Bera, Florax, & Yoon, 1996).

4.4 Spatial autoregressive model (SAR) and spatial error model (SEM)

There are a lot of techniques to test the regional convergence. This research intends to adopt the method proposed by Rey and Montouri (1999) since we want to incorporate spatial interactions into the model. This method constructs two spatial models, namely the spatial lag/autoregressive model (SAR) and the spatial error model (SEM), to investigate both spatial effects and regional convergence. Moreover, Rey and Montouri (1999) use a cross-sectional data in their research, but this paper is going to use a panel data. The application of panel data could, to a certain extent, reduce omitted variable bias and enlarge the sample size. The SAR and the SEM model are proposed based on the convergence model of Barro and Sala-I -Martin (1992). The only difference between them is the application of spatial weight matrix. The basic form of the convergence model without considering spatial effects is as follows:

$$Rate_{i,t} = a_i + \beta . log_e\left(G_{i,t-1}\right) + e_{i,t} \tag{1}$$

Here, i refers to 27 Chinese provinces in the datasets. t represents the year, it shifts from 1960 to 2018. $G_{i,t-1}$ is the GDP per capita of province i at time t-1. The left side of the equation captures the growth rate of GDP per capita, while the right side of the equation could be considered as the initial value of GDP per capita. It is interesting to note that Barro and Sala-I -Martin (1992) use the average growth rate in their research. However, this paper adopts the annual growth rate. In this case, the sample size will be significantly expanded. Finally, $e_{i,t}$ is the error term, and a_i is the fixed effects that are unique for each province and does not change over time. Moreover, β is the coefficient that this study aims to estimate. As Baumol (1986) stated, a negative sign of β could prove the existence of regional convergence since it indicates a negative relationship between the annual growth rate of GDP per capita and the initial value of GDP per capita. That means poor regions with worse initial conditions will grow at a higher speed compared with rich areas. Therefore, there exists a trend of regional convergence.

In the next part, model (2) will be further transformed into a spatial format. Here this paper replicates the SAR and the SEM model used by Rey and Montouri (1999) but in a panel format.

1. The spatial lag model with fixed effects (SAR)：

$$Rate_{i,t} = a_i + \rho.\boldsymbol{W}.Rate_{i,t} + \beta.log_e\left(G_{i,t-1}\right) + e_{i,t} \qquad (2)$$

As Rey and Montouri (1999) mentioned, the basic logic of the SAR model is to add a spatial lag of GDP per capita on the right-hand side of the classic convergence model. Here, ρ is a coefficient to measure spatial effects. As mentioned before, testing the significance of ρ could detect the existence of spatial dependence. For the estimation of β and ρ, Elhorst (2003) recommends the Maximum Likelihood method since OLS will yield a biased result.

2. The spatial error model with fixed effects (SEM):

$$Rate_{i,t} = a_i + \beta.log_e\left(G_{i,t-1}\right) + e_{i,t} \qquad (3)$$

$$e_{i,t} = \lambda.\boldsymbol{W}.e_{i,t} + \epsilon_{i,t}$$

In this model, the independent variable is assumed to be limited in capturing all the effects on the dependent variable. Hence, the spatial effects are actually located in the error terms. In the second equation, λ indicates the significance of spatial effects. According to Rey and Montouri (1999), the estimated variance will be biased by using OLS when there are non-spherical errors. Therefore, the Maximum Likelihood method is still a better way to estimate the SEM model.

The biggest difference between the SAR and the SEM model is the basic assumption. The SEM model assumes that spatial effects are located in error terms when the independent variable could not completely capture effects on dependent variable. Moreover, the SAR and the SEM model also have shortcomings. For instance, dummy variables could not be included into the spatial panel model since researchers usually run the SAR and the SEM model with fixed effects. Dummies will be omitted when there is a fixed effect in the model. Moreover, least square dummy variables (LSDV) could not resolve this problem since OLS will result in a biased result when estimating spatial models. Therefore, spatial panel model is not a good choice if one aims to includes dummy variables.

5 Empirical results

5.1 Overall Convergence or Divergence during the period 1961-2018

First, this paper tests the regional convergence of 27 Chinese provinces during the period 1961-2018. The estimated results are listed in table 2. The equation 1A is a convergence model estimated by OLS method without considering the spatial effects. Equation 1B and 1C are spatial panel models which are estimated by a Maximum Likelihood (ML) technique.

Table 2: Regional convergence of 27 Chinese provinces during the period 1961-2018

	Model		
GDP growth rate	***1A OLS***	***1B SAR (FE)***	***1C SEM (FE)***
Initial GDP	0.0129***	0.00279***	0.00374
	(9.72)	(3.28)	(1.08)
Convergence rate (τ)	-0.0002	-0.00005	-
Spatial			
rho	-	0.775***	-
		(36.27)	
lambda	-	-	0.780***
			(33.94)
Variance	-	0.00345***	0.00346***
		(10.04)	(10.00)
Fixed Effects	No	Yes	Yes
No. of observations	1566	1566	1566
No. of provinces	27	27	27
Diagnostics			
Hausman test	-	0.0189**	0.0006***
		(7.94)	(14.96)
AIC	-2606.793	-4096.767	-4085.3
Spatial diagnostics			
	Moran's I	LM test (lag)	LM test (error)
Statistics	40.332	1638.675	1614.723
p-value	0.00***	0.00***	0.00***

1. t and z statistics are reported in parentheses
2.*p<0.10, **p<0.05, ***p<0.01
3.The convergence rate is calculated based on the equation proposed by Rey and Montouri (1999): $\tau = \ln(\beta+1)/(-T)$, where β is the coefficient of main independent variable and T is the length of the time span.

From Table 2, we could see that each model has 1,566 observations. In the OLS model, the coefficient of initial GDP per capita is equal to 0.0129, which is greater than 0, and is significant at one percent level of significance. Thus, there is no evidence of economic convergence during the period 1961-2018 without considering the spatial effects. On the contrary, the economic gaps between different provinces tend to expand over time. Moreover, in the study of convergence, researchers usually look at the convergence rate or divergence rate. These indicators could reflect the speed of regional dispersion or integration. The divergence rate during the period 1961-2018 is less than one percent, meaning that regional gaps are expanding at a relatively small speed.

The second and third columns of Table 2 report the results of the spatial autoregressive model (SAR) and the spatial error model (SEM). According to the results of the Hausman test, this paper runs a fixed effect for both spatial models. Furthermore, the spatial lag model (SAR) seems to be more appropriate than the spatial error model (SEM) according to the result of LM test. In the SAR model, a positive β value could also be found, and it is statistically significant at one percent level. It is worth to note that the β coefficient estimated by the SAR model is lower than that estimated by the OLS model. The coefficient in the SAR model is 0.00279, and in OLS, this value is 0.0129. The difference in β value may prove the effect of spatial dependence. Moreover, all the spatial diagnostics indicate a strong spatial dependence since the results reject the null hypothesis of no spatial interactions. Similarly, a significantly positive value of spatial coefficient ρ also confirms the existence of spatial effects. Therefore, factors such as capital, labor, or technology that play an important role in promoting economic development will diffuse between rich and poor regions. The diffusion of factors allows poor areas to develop at a faster speed and thus forming a catch-up effect. This catch-up effect slows down the process of regional divergence. Consequently, the SAR model with including spatial effects reports a lower dispersed speed compared with the OLS model.

The estimated results in OLS model and spatial panel models do not indicate an obvious trend of regional convergence during the period 1961-2018. On the contrary, there only exists a slight divergence in GDP per capita. The reason might be that, in the long term, there still exist gaps between rich regions and poor regions. However, a small divergence rate may indicate that regional differences tend to decrease at some specific periods. According to Andersson, Edgerton and Opper (2013), governmental policies have a significant impact on regional convergence. Thus, the trend of regional convergence or divergence may change during different periods. The following parts of this paper will explore the relationship between economic policies and regional convergence. Unlike literature that only considers the "Open Door Policy", this article also takes the "Western Development Policy" into account. Thus, the overall time span is divided into three sub-periods, 1961-1977, 1978-1999, 2000-2018 based on the implementation time of mentioned policies.

5.2 1961-1977 The Period of Planned Economy

In the following section, this study investigates the regional convergence of 27 Chinese provinces during the period of planned economy. Table 3 shows the results of different models. The model 2A is an OLS estimation without considering the spatial dependence. Equation 2B and 2C are spatial panel models. Both spatial models are estimated by a Maximum Likelihood (ML) method. Moreover, this research runs a fixed effect for both spatial models based on the results of Hausman tests.

Table 3: Regional convergence of 27 Chinese provinces during the period 1961-1977

	Model		
GDP growth rate	***2A OLS***	***2B SAR (FE)***	***2C SEM (FE)***
Initial GDP	-0.0304***	-0.0794***	-0.223***
	(-2.61)	(-5.39)	(-4.59)
Convergence rate (τ)	0.002	0.005	0.015
Spatial			
rho	-	0.765***	-
		(22.59)	
lambda	-	-	0.792***
			(21.78)
Variance	-	0.00634***	0.00564***
		(8.09)	(7.69)
Fixed Effects	No	Yes	Yes
No. of observations	459	459	459
No. of provinces	27	27	27
Diagnostics			
Hausman test	-	0.000***	0.0004***
		(30.99)	(15.84)

AIC	-474.9557	-921.2755	-965.4214
Spatial diagnostics			
	Moran's I	LM test (lag)	LM test (error)
Statistics	21.849	469.278	468.512
p-value	0.00***	0.00***	0.00***

1. t and z statistics are reported in parentheses
2.*p<0.10, **p<0.05, ***p<0.01
3.The convergence rate is calculated based on the equation proposed by Rey and Montouri (1999): $\tau = \ln(\beta+1)/(-T)$, where β is the coefficient of main independent variable and T is the length of the time span.

As could be seen from Table 3, the coefficient of initial GDP per capita is less than zero in all the models. The β value estimated by OLS is -0.0304, it is equal to -0.0794 in the SAR model and -0.223 in the SEM model. A negative sign of major coefficient verifies the regional convergence of GDP per capita during the time interval of central planning. Thus, the economically behindhand provinces in 1961 have a higher growth rate in the following time compared to richer provinces. According to the calculation method proposed by Rey and Montouri (1999), this paper calculates the convergence rate in three models. The convergence speeds estimated by the SAR model and SEM are 0.5 percent and 1.6 percent. Compared with a convergence rate of 0.2 percent in the OLS model, these values are much larger. The results indicate that spatial spillovers enhance the exchange and spread of factors between regions and results in a higher convergence speed. Thus, it seems that the estimated results would be biased if spatial effects are neglected. A research conducted by Rey and Montouri (1999) also highlights this point. In general, there exists a significant trend of regional convergence during the period 1961-1977 and the result is consistent with the actual situation.

From the perspective of regional development, the central government adopted a balanced development strategy during the phase of central planning (Brun, Combes, & Renard, 2002). According to Yang (1990), the planned economy emphasizes two key points: fairness and priority. The priority means that all local governments invest resources and funds in heavy industry. Fairness means that the primary target of the central government was to eliminate regional disparities (Fan, 1997). Therefore, most of the fiscal expenditures go to inland areas with poorer economic conditions. As Yang (1990) mentions, more than one-half of the governmental investments are allocated to central and western regions. Moreover, local governments have a limited role in promoting regional growth because of the particularity of planned economy. Most economic activities are arranged by the central government. Therefore, there is an apparent convergence in GDP per capita before the economic reform in 1978. Obviously, the government's goal of decreasing regional disparities is achieved, although this result is at the expense of eastern development.

5.3 1978-1999 The period of Economic Reform

Table 4 reports the estimated results of regional convergence or divergence during the period of economic reform. The equation 3A is an OLS estimation. Equation 3B and 3C report the results of SAR and SEM models. Both are estimated by a Maximum Likelihood (ML) method. According to the outcomes of Hausman tests, this research runs a random effect for both spatial models.

Table 4: Regional convergence of 27 Chinese provinces during the period 1978-1999

	Model		
GDP growth rate	***3A OLS***	***3B SAR (RE)***	***3C SEM (RE)***
Initial GDP	0.0143***	0.0041**	0.00199
	(5.28)	(2.53)	(-0.44)
Convergence rate (τ)	-0.0006	-0.0002	-
Spatial			
rho	-	0.678***	-
		(21.23)	
lambda	-	-	0.699***
			(25.28)
Variance	-	0.00227***	0.00226***
		(9.24)	(9.50)
Fixed Effects	No	No	No
No. of observations	594	594	594
No. of provinces	27	27	27
Diagnostics			
Hausman test	-	0.2406	0.8362
		(2.85)	(0.36)
AIC	-1475.061	-1812.365	-1811.596
Spatial diagnostics			
	Moran's I	LM test (lag)	LM test (error)
Statistics	20.253	417.778	401.784
p-value	0.00***	0.00***	0.00***

1. t and z statistics are reported in parentheses
2.*p<0.10, **p<0.05, ***p<0.01
3.The convergence rate is calculated based on the equation proposed by Rey and Montouri (1999): $\tau = \ln(\beta+1)/(-T)$, where β is the coefficient of main independent variable and T is the length of the time span.

In the OLS regression without including spatial effects, the estimated coefficient of initial GDP is significantly positive at the significant level of one percent. In the SAR model, the coefficient of initial GDP per capita is still greater than zero. The β value is not significant in the SEM model. However, the LM tests indicate that this study should adopt an SAR model rather than an SEM model. Furthermore, the β value estimated by OLS method is 0.0143, this value equals 0.0041 when it comes to the SAR model. Like the overall estimation results during 1961-2018, the estimated value of major coefficient in the spatial model is smaller than the estimated value in the OLS. The results of SAR model and OLS model prove that there is no economic convergence between Chinese provinces, but rather a regional disparity during the period of economic reform. The regional differences between poor provinces and rich provinces gradually expand under the influence of the "Open Door Policy". The divergence speed estimated by the SAR model is 0.02 percent, which is smaller than the 0.06 percent in the pooled OLS. Thus, although the central and western regions do not obtain strong policy supports, spillover effects still allow these areas to a certain extent share the positive impact of eastern development. Therefore, the speed of divergence becomes slower after introducing spatial dependence into the basic model. In addition, the estimation results are also consistent with previous expectations.

After the implementation of the "Open Door Policy", the central government increases investments in international trade and the construction of infrastructure in coastal regions (Yao and Zhang, 2001). According to Tsui (1996), more than 80 percent of the governmental funds are distributed to coastal areas, while investments in the central and western regions only account for a small proportion. As Wei (1999) stated, the speed of economic growth in coastal provinces has dramatically improved since 1978. On the contrary, the growth rate of interior regions maintains at a relatively stable level due to the lack of policy guidance and financial support. The difference in growth rate leads to the disappearance of regional convergence and the enlargement of economic disparity. However, such an unequal policy has a specific target when it is proposed. The goal of the "Open Door Policy" is to give priority to the development of some regions. Then these provinces could assist poor regions when they become stronger (Yao, Zhang and Feng, 2005). Therefore, in the long run, regional differences are expected to gradually disappear. This is one point that the "Open Door Policy" differs from other national policies (Golley, 2007). Besides, there is a debate about the effect of the "Open Door Policy". On the one hand, it widens the gap between regions and leads to an unbalanced development（Yao, Zhang and Feng, 2005）. On the other hand, the development of eastern provinces promotes the economic growth of the entire country (Lee, Peng, Li and He, 2012). China has rapidly strengthened its economic power in the past few years. But if one only evaluates the economic reform from the perspective of regional differences, it actually breaks the trend of regional convergence in the period of planned economy.

5.4 2000-2018 The Period of Balanced Development

Table 5 reports the regression results of regional convergence during the period 2000-2018. Like the previous tables, the equation 4A tests the convergence by using an OLS method. Equation 4B and 4C introduce a spatial weight matrix into the model, and both are estimated via Maximum Likelihood (ML). The Hausman tests indicate that the SAR model should run a fixed effect and the SEM model should adopt a random effect.

Table 5: Regional convergence of 27 Chinese provinces during the period 2000-2018

	Model		
GDP growth rate	***4A OLS***	***4B SAR (FE)***	***4C SEM (RE)***
Initial GDP	-0.0208***	-0.0070**	-0.02168***
	(-7.42)	(-2.10)	(-4.33)
Convergence rate (τ)	0.0001	0.0004	0.0012
Spatial			
rho	-	0.649***	-
		(13.62)	
lambda	-	-	0.652***
			(13.80)
Variance	-	0.00145***	0.00149***
		(4.95)	(5.11)
Fixed Effects	No	Yes	No
No. of observations	513	513	513
No. of provinces	27	27	27
Diagnostics			
Hausman test	-	0.000***	0.1049
		(22.67)	(4.51)
AIC	-1510.955	-1823.762	-1779.98
Spatial diagnostics			
	Moran's I	LM test (lag)	LM test (error)
Statistics	18.953	346.943	350.797
p-value	0.00***	0.00***	0.00***

1. t and z statistics are reported in parentheses
2.*p<0.10, **p<0.05, ***p<0.01
3.The convergence rate is calculated based on the equation proposed by Rey and Montouri (1999): $\tau = \ln(\beta+1)/(-T)$, where β is the coefficient of main independent variable and T is the length of the time span.

As can be seen from Table 5, all the values of β in OLS, SAR and SEM are negative and significant. Therefore, there exists a trend of regional convergence after the implementation of the "Western Development Strategy". However, the speed of regional convergence is not very fast. The estimated convergence rate is less than 0.5 percent in all the models, meaning that poorer regions still need to spend a long time to catch up with richer ones. Our results indicate that the "Western Development Strategy" may shrink the regional disparity of China, and weakens the shortcoming brought by the "Open Door Policy". But some criticisms claim that the effect of the "Western Development Strategy" is not that large. As mentioned by Golley (2007), a series of state investments do not fundamentally solve the problem of lagging development in the west. The key to the success of the "Western Development Strategy" lies in the "self-sustaining" development of the western region in the long term. However, the estimated results of this study verify that the policy does promote regional convergence. Thus, at least in the short term, the "Western Development Strategy" has a certain effect in reducing regional disparities.

5.5 Robustness tests

To test the robustness of the estimated results, this paper uses a different method to generate the spatial weight matrix and re-estimate the models for each period. Instead of using the contiguity matrix, new models adopt a geographic distance matrix. The test results are reported in Table 6. As can be seen from the results, the coefficient of independent variable in new models has a slight change compared with that in the original models. But the sign of the coefficient does not change, which proves the robustness of previous estimation results.

Table 6: Robustness test results

	Model	
Year	***6A Original Model (Contiguity matrix)***	***6B Robust Model (Distance matrix)***
1961-1977 (SAR-FE)	-0.0794***	-0.086***
	(-5.39)	(-5.49)
1978-1999 (SAR-RE)	0.0041**	0.005**
	(2.53)	(2.10)
2000-2018 (SEM-RE)	-0.0217***	-0.0191***
	(-2.10)	(-4.93)
1961-2018 (SAR-FE)	0.00279***	0.0264***

	(3.28)	(2.83)

6 Conclusion

This paper adopts two spatial panel models, namely the spatial lag model and spatial error model to test the per capita GDP convergence in China at the provincial level during the period 1961-2018. First, this study only finds a slight divergence over the entire time period. Moreover, the value of the coefficient in the spatial model is lower than that estimated by the OLS method, which indicates the effects of spatial dependence. The diffusion of factors enables poor regions to catch up and thus slowing down the process of regional divergence. Therefore, the results verify the arguments proposed by Magalhães et al. (2005) and Rey and Montouri (1999) that the estimated outcomes are likely to be biased if the spatial effects are omitted in the study of convergence. Furthermore, the following research of this paper divides the overall time span into three sub-period based on two major economic policies named the “Open Door Policy” and the “Western Development Strategy”. The results indicate that regional convergence and regional divergence coexist in China and economic policies play a role in this process. During the time period 1961-1977, which is regarded as a period of the planned economy, this paper finds the evidence of regional convergence. During the period 1978-1999, the results indicate a slight divergence in GDP per capita, meaning than the “Open Door Policy” intensifies the regional disparities of China. Finally, the “Western Development Strategy” achieves its goal of reducing regional differences since this paper confirms the existence of regional convergence during the last time period 2000-2018. The mentioned outcomes are in line with the previous hypotheses and they also support the findings of some previous research. For example, Yao and Zhang (2001), Andersson, Edgerton and Opper (2013) examine the regional convergence before and after the “Open Door Policy” by using different techniques. The former one uses a panel analysis and concludes that the “Open Door Policy” does not make poor areas to catch up with rich ones. The latter study analyzes the regional convergence in China during the period 1978-2009 and claims that the economic reform exacerbates the regional disparities in the short term. Thus, the estimated results of this paper partly support their conclusions.

This study is valuable in that it combines the spatial panel model with major changes in economic policies, which fills the blanks in the previous study. Most convergence studies tend to conduct a cross-sectional analysis or use a fixed effect model. However, the former technique fails to explain regional heterogeneity and the latter method could not capture spatial interactions between regions (Arbia & Piras, 2013). This research combines the fixed effect model with a spatial weight matrix, and thus could to some extent avoid the mentioned limitations. Moreover, lots of studies do not consider changes in economic policies when investigating regional convergence. However, the results of this paper indicate a relationship between economic policies and regional convergence. Thus, further studies should take the transition of major policies into account when testing the regional convergence.

The policy implication is that regional-oriented policies have a strong correlation with regional convergence or regional divergence. Economic policies of China could both expand and narrow the regional differences, and the results depend on the characteristics of the policy. For instance, the “Open Door Policy” that favors eastern regions increases the regional differences of China, while the subsequent western-oriented policy enables western regions to catch up and stops the trend of regional divergence. Thus, policy makers should clear the purpose and balance the relationship between economic development and regional differences when formulating economic policies. Furthermore, from the perspective of convergence rate, this study only finds a slight convergence after the implementation of the “Western Development Strategy”. That means it will take a long time for western provinces to catch up with eastern ones. Therefore, it is necessary to implement a more powerful policy to accelerate the process of regional convergence. Finally, this study still has some limitations. For instance, this paper could only acquire provincial level data. So, the sample size is not very large. It may be better if one uses city level data or even county level data. In addition, this study only tests the absolute convergence and a conditional convergence with only considering spatial effects since the data of some variables is not available. Thus, further research could shorten the time span and take other factors into account when analyzing the economic convergence in China.

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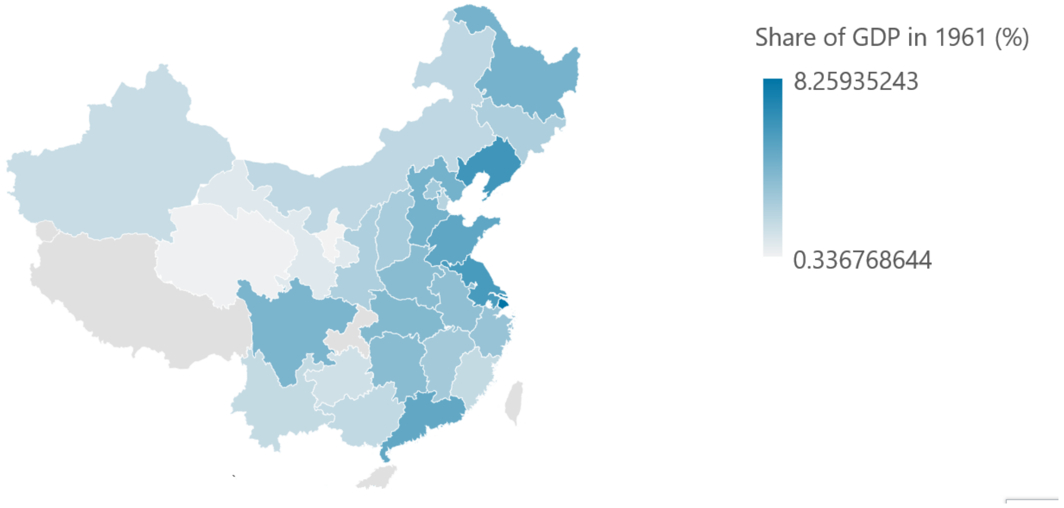
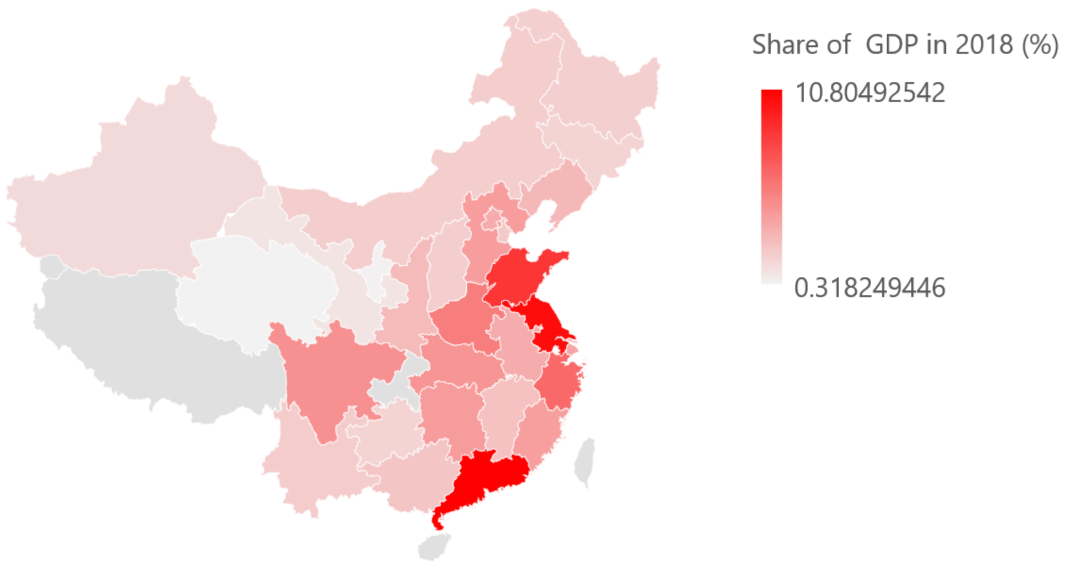
Appendices

Figure 1: ***Provincial GDP as a percentage of the total GDP in 1961***



Source: The figure is made by the author by using data collected from the CSMAR database (2020)

Figure 2: ***Provincial GDP as a percentage of the total GDP in 2018***



Source: The figure is made by the author by using data collected from the CSMAR database (2020)