



Research on the Time-Space Impact Paths of Economic Convergence-Empirical Evidence from 30 Provinces in China

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Abstract. By constructing a geographical distance matrix and a technological distance matrix, a double-fixed spatial Durbin model empirical test was conducted using panel data of 30 provinces during 2002–2020 to explore the factors influencing the convergence of inter-provincial economic growth in China. The outcomes reveal that the economic discrepancy of neighboring provinces has a pragmatic effect on the economic discrepancy of a single province. Also, the construction level of infrastructure, technology absorption capacity, and the level of marketisation have adverse spillover effects in space while the proportion of tertiary industry and R&D expenditure in the previous period in neighbouring provinces have positive spillover effects. Characteristic to that, the government should enhance the interaction mechanism of "industry-university-research", further cross-sectional industrial division and cooperation, and boost marketisation reforms to aggrandize the realization of "common prosperity" and high-quality economic development in China.

Keywords: Economic convergence · spatial econometric analysis · spatial Durbin model · high quality development · technological absorptive capacity

1 Introduction

China's domestic and international environment has sustained momentous transformations in recent years, and economic development has entered a reproving period of transformation. While the country's economic development has attained fruitful outcomes, there is also an incomprehensible situation of widening discrepancies between provinces. In conformity with the statistics of the National Bureau of Statistics, in terms of regional GDP, the proportion of China's GDP in the eastern, central and western regions to the country will be 54.19%, 24.33% and 20.96% in 2021, 54.32%, 24.31% and 21.01% in 2020, and 54.19%, 24.61% and 20.77% in 2019, respectively. China's Eastern region's share of GDP has been unremittingly maintained at a magnitude of over 50%, whereas the central and western regions' total economic output share has been sustained at a level below 25%. The aforementioned statistics show that there are

variations in the economic development of the east, middle and west regions of China, and that the opposition of unstable economic development is more noteworthy.

Being the world's fastest developing nation, it is a common occurrence that there are certain regional variances in the economic development process (Hu and Zhou 2002). Nevertheless, the continuous existence of such disparities is not favorable for the transformation and extra improvement of productivity. Presently, three kinds of regions exist in China and all of them focus on a holistic policy. The economic differences between regions are indisputably disregarded. Accordingly, it is essential to reinforce the government's regional economic policies active intervention role, find new engines of economic development in the central and western regions, reduce the economic disparity between regions, and achieve coordinated development in the eastern, central and western zones to strengthen economic convergence and improve the overall economic level of the country.

2 Literature Review

In macroeconomic analysis, growth and convergence are the two main issues that receive much attention. Neoclassical economic growth theory points to absolute convergence, where economies with lower initial per capita income potentially grow faster in the future than economies with higher initial per capita income. This is because of the diminishing marginal returns to capital and technological progress (Solow 1956; Barro 1991). Nonetheless, the authentic circumstance differs from the theoretical prediction. The merging issue has received noteworthy attention from academia. Under the influence of interior economic development theory, habitually, technological variations are seen as the most probable factor of the economic growth gap among nations (Lin and Liu 2003). As per Barro (1996), early levels of GDP per capita, human capital, terms of trade are incorporated in the explanatory variables, and results designate that technological progress is an essential source of regional economic development gaps.

Recent research regarding the drivers of regional economic convergence in China suggest that technological progress has been designated as the key. In compliance with Zhu et al. (2014), the reason for the lack of convergence of economic growth in each province is the unbalanced regional development in China. Additionally, the scholars state that the inter-provincial technological barriers should be lowered to stimulate the flow of talent, technology, and capital. Another scholar, Jin (2018), claims that the power supply for China's high-quality economic development is innovation-led. Furthermore, Wang (2020) emphasizes that enhancing innovation capacity is the focus of building a new development pattern in China.

The technology factor is for the most part reflected as innovation drive. Technological innovation is divided into innovation input, innovation output and innovation environment. Scholars inspect the technology level gap from the stance of numerous factors including talent, capital and market, to better interpret the reasons of regional discrepancy.

The contrast in the level of technological innovation inputs among regions impacts the economic gap. The "Matthew effect," which attracts more innovation resources, raises the level of regional technology innovation and productivity, strengthening the regional

advantage, and Wang and Fan (2004) stated that developed regions have a wealth of innovation resources that not only provide more innovation inputs but also have higher productivity. However, less developed regions can also absorb the same effect of capital and personnel.

It is clear how the production of innovation varies by region. Second, regional variations in innovation output have an impact on economic inequality. Lin and Zhang (2005) asserts that developed regions produce more scientific and technological outputs and implement technology more quickly, both of which foster rapid economic growth; conversely, less developed regions can accelerate the introduction of technology in accordance with their comparative advantages in resource endowment and support the integration of industry, academia, and research, both of which accelerate the conversion of technology into productivity and help them close the economic gap with developed regions.

The regional economic divide is impacted by the different innovation environments. Xu and Li (2005) demonstrate that there is a glaring disparity between developed and less developed regions in infrastructure construction and government investment, which may easily form economic differences; nevertheless, with the government's support for less developed regions, their innovation environment can be improved, the efficiency and quality of production factor allocation can be optimized, and economic development can be accelerated, eventually narrowing the inter-provincial economic gap.

Moreover, due to technical convergence and information spillover, technological innovation in one location affects its own economic development on the one hand, and surrounding regions on the other, hence generating geographical consequences (Han et al. 2015). Moreover, economic agglomeration enhances knowledge spillover, causing technological innovation to have spatial implications on the upgrading of regional industrial structures (Tan and Peng 2017). Zhang and Li (2022) discovered, in his study of the economic convergence of cities in the Yangtze River Economic Zone, that disregarding the spatial effect may result in an overestimate of the economic convergence rate. Due to the spatial influence of technological innovation, the standard approach of presuming that regions are independent of one another when evaluating economic convergence does not adequately reflect the actual situation.

Overall economic growth convergence in China lacks significant region-wide characteristics, but the quality of economic growth convergence is more evident; regional, stage, and heterogeneous characteristics are more significant, and the main convergence trends are reflected within and among major economic regions, such as the respective convergence rates and steady-state trends within the eastern, central, and western regions. Examining regional linkages and regional spatial characteristics can help researchers studying economic convergence produce more accurate results; doing so also brings the study's depiction of China's regional economic growth more in line with the country's actual circumstances and offers potential solutions for helping China achieve coordinated regional development and reduce inequality. It can offer ways to eliminate regional economic imbalances and create coordinated regional development.

Based on previous studies, this paper develops a bi-fixed spatial econometric model based on the three dimensions of technological innovation, with reference to Yuan et al.

(2017) and Zhao and Chang (2020), the evaluation index system of high-quality economic development, with a focus on the factors reflecting “economic efficiency” and “innovation development” as explanatory variables, and measures the degree of economic convergence using economic disparity as the explanatory variable. The following are the main marginal contributions: To begin with, the impact of technical innovation on China’s economic development is examined using spatial econometric methods, and the estimated results are more accurate since the geographical effects of technological innovation are under consideration. Additionally, the Moran index, Geary index, and LISA agglomeration diagram are used to study the auto-correlation between time and space, and the influence path of economic convergence in time and space perspectives is thoroughly studied. The spatial weight matrix is established by combining geographical distance and technological distance, while a time lag term is added to the model.

3 Model Setting and Variable Description

3.1 Model Building

$$\begin{aligned}
 \ln \frac{\max GDP_{it}}{GDP_{it}} = & \tau \ln \frac{\max GDP_{i,t-1}}{GDP_{i,t-1}} + \rho W_{ij} \ln \frac{\max GDP_{it}}{GDP_{it}} \\
 & + \beta_1 \ln edu_{it} \times \ln trad_{it} + \beta_2 \ln fin_{it} + \beta_3 \ln tran_{it} \\
 & + \beta_4 R \& D_{i,t-1} + \beta_5 \ln mark_{it} + \beta_6 \ln tert_{it} + \delta_1 W_{ij} \times \ln edu_{jt} \times \ln trad_{jt} \\
 & + \delta_2 W_{ij} \times \ln tran_{jt} + \delta_3 W_{ij} \times R \& D_{i,j-1} + \delta_4 W_{ij} \\
 & \times \ln mark_{jt} + \delta_5 W_{ij} \times \ln tert_{jt} + \mu_i + \gamma_t + \varepsilon_{it}
 \end{aligned} \tag{1}$$

τ represents the first order time lag coefficient of the explained variable, ρ represents the spatial lag coefficient of the explained variable, β_n represents the regression coefficient of the variables, δ_n represents the influence coefficient of the other provinces’ explanatory variables towards the explained variable in one region, μ_i represents the constant term under individual fixed-effects, γ_t represents the constant term under time-fixed effects, ε_{it} represents random errors. W_{ij} represents the spatial weight matrix.

3.2 Construction of the Spatial Weight Matrix

To investigate spatial spillover effects, we need to construct spatial weight matrix and obey Tobler’s first law of geography.

3.2.1 Geographical Distance Matrix

In this study, we calculate the linear distance and create the inverse distance weight matrix W_d using the longitude and latitude of the capital cities in 30 provinces.

$$\begin{aligned}
 W_d = & \left\{ \frac{1}{d_{ij}^2}, i \neq j \right. \\
 & \left. 0, i = j \right.
 \end{aligned} \tag{2}$$

3.2.2 Technology Distance Matrix

The number of regional invention patents issued is used in this study to calculate the region's technological distance. First, the following formula is used to determine the correlation coefficient between the two provinces' technological levels within the same time period of the sample period.

$$S_{ij,t} = \frac{\sum F_{i,t} F_{j,t}}{\sqrt{\sum F_{i,t}^2} \sqrt{\sum F_{j,t}^2}} \quad (3)$$

Calculate the average correlation coefficient over the sample period by adding the estimated correlation coefficient. The method of calculation is as follows:

$$\overline{S}_{ij} = \frac{1}{t_1 - t_0 - 1} \sum_{t=t_0}^{t_1} S_{ij,t} \quad (4)$$

t_1 denotes the end of the sample period (2020), t_0 denotes the beginning of the sample period (2011). \overline{S}_{ij} represents the elements corresponding to the coordinates (i, j) in the spatial weight matrix W_s .

3.2.3 Construction and Standardization of Spatial Weight Matrix

The calculation is done by multiplying the two spatial weight matrices created by the aforementioned:

$$W_e = W_d \times W_s \quad (5)$$

The final spatial weight matrix is created by using a standardization technique in this paper.

$$W_{ij} = \frac{W_e}{\sum_{i=1}^n W_e} \quad (6)$$

The denominator of this equation is the sum of the spatial distance between one province and other provinces and the numerator is the spatial distance between provinces i and province j , n is 30.

3.3 Data Preparation

3.3.1 Data Sources and Processing

The information in this study includes data from 30 Chinese provinces and uses the years 2002 to 2020 as its sample period (without including the regions of Tibet Autonomous Region, Macao, Hong Kong, and Taiwan). The Fan Gang Marketization Index, the GDP per capita of each province, the intensity of R&D investment in each province, the proportion of tertiary industry, the balance of deposits and loans, the number of general undergraduate and college students per 10,000 people, the number of invention patents granted in each province, and all other indicators are obtained from the China Statistical Yearbook.

This study utilizes the natural logarithm of the technology market contract turnover and the proportion of general undergraduate and college students per 10,000 people. It performs the non-dimensional treatment for the infrastructure development level indicator to prevent larger values from producing scale effects and outlier drive.

3.3.2 Explanation of Variables

A. Explained Variable. Economic gap ($\frac{\max GDP_{it}}{GDP_{it}}$): The distance in economic value between the per capita GDP of region I in year t and the maximum value of this economic indicator in the same year. A comparison with the maximum value in the same year is more consistent with the economic gap research issue than a comparison with the minimum value in the same year.

B. Core Explanatory Variable. Technology uptake ($\ln edu_{it} \times \ln trad_{it}$): The human capital component of technology adoption was chosen as the ratio of general undergraduate and tertiary students per 10,000 people, and the value of technology market contract turnover was used as a measure of technology marketability.

C. Control Variables. The ratio of the balance of deposits and loans from financial institutions in province I to GDP is represented by the financial development index (fin_{it}). Economic growth will be aided by an increase in the balance of deposits and loans, which will in turn contribute to a surge in deposits and loans.

Level of infrastructure development ($tran_{it}$): To calculate the density of roads and railways in each province, the number of kilometers of operating roads and railways are chosen and divided by the provincial area of each province.

$$tran_{it} = \frac{\text{kilometers of operating roads} + \text{kilometers of operating railways}}{\text{the provincial area of each province}} \quad (7)$$

R&D investment intensity ($R\&D_{i,t-1}$): R&D expenditure in each province's fiscal expenditure divided by the GDP per capita of each province in that year, which is used to measure the emphasis of each province in technological innovation.

Marketisation Index ($mark_{it}$): The Fan Gang Marketization Index is used in this study to assess the level of marketization in each province. Additionally, marketization processing helps each province's economy to thrive. One of the key causes of the expanding regional economic inequality is the lack of coordination of the marketization process.

Proportion of tertiary industry ($tert_{it}$): This is the ratio between the value added in the tertiary industry in region i during year t and the regional GDP. The tertiary sector is now the core driver of GDP growth.

4 Empirical Tests and Results

4.1 Spatial Correlation Test

Global Moran's Index (Moran's I):

$$I = \frac{n \sum i \sum j W_{ij} (y_i - \bar{y})(y_j - \bar{y})}{(\sum i \sum j W_{ij} \sum i (y_i - \bar{y})^2)} \quad (i, j = 1, 2, \dots, 30) \quad (8)$$

Table 1. Moran’s I and Geary’s C

Index	Variables	I	E(I)	sd(I)	z	p-value*
Moran’s I	lngdp	0.111 ***	-0.002	0.013	9.020	0.000
Geary’s C	lngdp	0.845 ***	1.000	0.019	-8.265	0.000

Notes: *** and ** denote statistical tests passed at the 1% and 5% levels respectively (same below)

Source: Authors’ calculations.

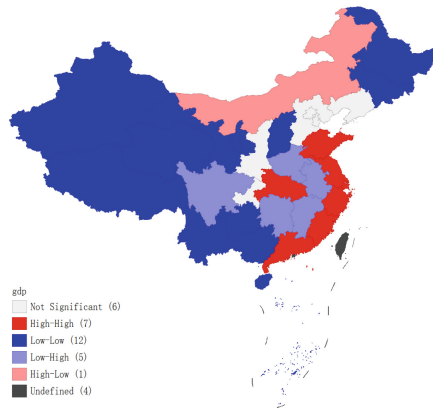


Fig. 1. LISA clustering of GDP per capita between provinces in China. Source: Mapped by the author using GeoDa.

Geary’s C Index:

$$C = \frac{(n-1) \sum_i \sum_j j W_{ij} (y_i - y_j)}{2(\sum_i i \sum_j j W_{ij}) [\sum_i i (y_i - \bar{y})^2]} \quad (i, j = 1, 2, \dots, 30) \quad (9)$$

y_i denotes the level of income disparity in province i . \bar{y} denotes the average of the economic disparities in the 30 selected sample provinces.

The nested matrix of technological and geographic distances used in this study to investigate the worldwide spatial correlation of economic disparities between the sample provinces is provided in Table 1: Indicating a strong positive geographical dependency of economic inequalities between the sample provinces during the period 2002–2020, the global Moran and Geary indices are significant at a level between 0 and 1%.

This study creates a LISA clustering diagram of GDP per capita in each province of China using the technological distance matrix as the weight matrix to confirm the spatial auto-correlation of GDP per capita in each province of China under the effect of technological distance (Fig. 1). The southeast coastal region exhibits “high-high agglomeration,” while the northwest region exhibits a strong “low-low agglomeration” characteristic. It is clear that GDP per capita even after accounting for technology weights still exhibits geographical regional agglomeration.

Table 2. LM tests of the spatial econometric model

Diagnostics	Test	Statistic	p-value
Spatial error	Moran's I	11.458***	0.000
	Lagrange multiplier	112.525***	0.000
	Robust Lagrange multiplier	113.006***	0.000
Spatial lag	Lagrange multiplier	8.262***	0.004
	Robust Lagrange multiplier	16.729***	0.003

Table 3. LR test and Wald test for the spatial econometric model

Test		Statistics value	p-value
lrtest	sar nested in sdm	19.70***	0.0001
	sem nested in sdm	14.17***	0.0008
Wald	Spatial lag	29.59***	0.0000
	Spatial error	23.28***	0.0007
	Hausman	63.25***	0.0000
lrtest	ind nested in both	139.00***	0.0000
	time nested in both	1190.87***	0.0000

4.2 Spatial Model Selection and Robustness Testing

As shown in Table 2, the original hypothesis of “no spatial auto-correlation” was disproved in all three tests of spatial error and in both tests of spatial lag, demonstrating the greater significance of a spatial econometric analysis.

Next, the LR test was applied to select the best spatial econometric model. In Table 3 below, both the LR test and the Wald test reject the original hypothesis that the SAR and SEM models are better than the SDM model at the 1% significance level so the selection of the spatial panel Durbin model is reasonable. We further tested the specific form of fixed effects and the results rejected the original hypothesis at the 1% significance level, indicating that the choice of the time and individual dual fixed effects model is more robust. After the SDM model was chosen, the robustness test showed that the Hausman test had rejected the original hypothesis of selecting the random effects model.

4.3 Spatial Econometric Model Estimation Results

A dynamic geographic panel Durbin model with primarily time and individual double fixed effects is better appropriate for this study based on the aforementioned empirical tests and a comparison of the outcomes of the three fixed effects models, and the model estimate results are provided below (Table 4).

Table 4. Spatial econometric model estimation results

Variables	SAR		SEM		SDM	
	fe	re	fe	re	fe	re
lnet	0.001 (0.158)	−0.014*** (0.000)	−0.002 (0.427)	−0.002 (0.439)	−0.024*** (0.000)	−0.002 (0.362)
fin	−0.007** (0.041)	−0.019* (0.094)	0.047*** (0.000)	0.032*** (0.007)	0.158*** (0.000)	0.039*** (0.001)
tran	0.051** (0.014)	−0.545*** (0.000)	−0.494*** (0.000)	−0.576*** (0.000)	−0.293*** (0.000)	−0.568*** (0.000)
L.rd	−0.007 (0.172)	0.138*** (0.000)	0.172*** (0.000)	0.167*** (0.000)	−0.120*** (0.000)	0.163*** (0.000)
mark	0.001 (0.808)	−0.024*** (0.000)	−0.025*** (0.001)	−0.036*** (0.000)	0.002 (0.376)	−0.030*** (0.000)
tert	0.002*** (0.000)	0.009*** (0.000)	0.016*** (0.000)	0.015*** (0.000)	0.003*** (0.000)	0.015*** (0.000)
W*Intd	−	−	−	−	−0.365*** (0.000)	−0.007 (0.395)
W*fin	−	−	−	−	−0.014 (0.773)	−0.052 (0.177)
W*tran	−	−	−	−	−69.419*** (0.000)	0.340** (0.021)
W*L.et	−	−	−	−	6.912*** (0.000)	−0.354*** (0.000)
W*mark	−	−	−	−	−3.645*** (0.000)	0.034*** (0.001)
W*tert	−	−	−	−	0.584*** (0.000)	−0.007* (0.078)
L.lngdp	−0.512*** (0.000)	0.756*** (0.000)	−	−	0.673*** (0.000)	-
ρ	−0.512*** (0.000)				52.723*** (0.000)	
λ	−	−	−1.365*** (0.000)	0.928*** (0.000)	−	−
Constant	−	0.169 (0.118)	−	0.580*** (0.000)	−	0.439** (0.014)

Source: Authors' calculations

The findings of the SDM (fe) statistical analysis show that the explanatory variables have a large inter-provincial economic drive in space and a significant spatial auto-correlation impact, proving that China's economy has a propensity toward β convergence.

Table 5. Results of the econometric decomposition of the SDM model

Variables	LR_Direct	LR_Indirect	LR_Total
lnet	−0.014***	0.007***	−0.007***
tran	−0.586***	−0.018***	−0.604***
L.rd	0.080***	0.049***	0.129***
mark	−0.061***	−0.008***	−0.069***
tert	0.011***	0.000**	0.011***

The explained variable's first-order lagged coefficient is significantly positive at the 1% level, which reflects a province's economic catch-up trend during the sample period as a trend of linear growth. The proportion of tertiary industry and R&D spending over the previous period in spatially adjacent provinces have positive spillover effects, while the explanatory variables of technological absorptive capacity, level of infrastructure construction, and level of marketization have negative spillover effects in space. The spatial spillover effects of the explanatory variables cannot be fully captured by the basic regression results for the dynamic spatial panel Durbin model, so this paper further decomposes the model estimates into direct, indirect and total effects (Table 5) using the vector partial differential decomposition method of the spatial econometric model.

According to the results of the econometric decomposition, the region's economy has a technology absorption capacity impact of −0.014 units, while the technology absorption capacity of spatially nearby regions has a positive spillover effect on the region's ability to catch up economically. It suggests that successful application of scientific and technological advancements might encourage the closing of the economic gap between developing and developed regions, but we must also take into account the economic competitiveness among provinces. Therefore, the realisation of economic convergence cannot exclusively rely on external spillover; rather, it is essential to independently strengthen the external technical spillover's capacity for learning and reconfiguration. The positive synergy brought about by technology interchange has a higher overall impact than the rise in domestic economic inequality brought about by aggressive rivalry. The level of infrastructure development is conducive to the province's economic catch-up. In terms of spatial spillover, the increase in the construction of transport networks in neighboring regions will lessen the economic gap between the province and the more developed province, reflecting the important role of infrastructure for synergistic economic development. The turnover rate of science and technology innovation needs to be increased because there is also a certain "Matthew's effect" in the relationship between investment intensity in science and technology and economic development. Besides, both the direct and indirect effects of the degree of marketization are noticeably negative, demonstrating how much the gradual creation of a "national unified market" and the coordinated development of domestic marketization have contributed to economic convergence.

5 Policy Recommendations and Conclusions

5.1 Improve the Interaction Mechanism of “INDUSTRY-University-Research” to Realize the Transformation of High-Quality Human Capital into Productivity

In order to ensure high-quality economic development, the government should act as a coordinator. To start, policymakers should continue to expand the strategy for prioritizing education development and increase coordination between higher education and vocational education. Second, we should create national policies that give economically underdeveloped regions preferential treatment for talent, changing the distribution of talent across China as a result. Thirdly, we should strengthen the interaction mechanism of “industry-university-research” and encourage enterprises to cooperate with research institutions in depth and uses their comparative advantages.

5.2 Promote Cross-Regional Industrial division and cooperation

The Chinese government should aggressively assist technologically underdeveloped regions in importing and absorbing cutting-edge technology used in growing industries, and it should place an emphasis on industry connections from a spatial perspective. Additionally, we should encourage more social capital-beneficial sectors to invest, rationally continue the industrial transfer from frontier regions, knowingly accept the associated risks, and offer associated favorable policies when introducing investments.

5.3 Improve the Level of Marketization, Reform and Enhance the Relationship Between Government and the Market

The government should support increased government spending on the national economy and improving people’s standard of living. It should also strengthen the system for protecting property and foster the growth of the private sector. Additionally, China should reinforce weak connections in the transportation infrastructure in developing regions and strongly promote multi-modal transport in developed regions while adapting measures to local conditions for the construction of transportation facilities in the future.

5.4 Deepen Structural Reform on the Supply Side of Finance and Improve the Quality and Efficiency of Financial Resource Allocation

Using big data, cloud computing, and blockchain, among others, the People’s Bank of China should first make a reasonable adjustment to our monetary policy to increase the effectiveness of financial services to a significant economy, strengthen financial supervision, and prevent systemic financial hazards. Additionally, China needs to strengthen inter-provincial capital mobility and encourage the movement of capital between the various provinces. The amount of Chinese financial openness should also be increased, as should global collaboration in financial technology, financial innovation, and payment and settlement, as well as China’s capacity to engage in global financial governance.

5.5 Optimize the Industrial Structure and Transform the Mode of Economic Development

Provinces should combine their natural resources to build industrial chains that are appropriate for their environment, take advantage of comparative advantages to enhance regional development models, and create distinctive supporting industries. The development of industry toward “high-end, intelligent, intense, and green” should be accelerated, especially in weaker provinces, which should also minimize reliance on resource-based and highly polluting industries.

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