Does China’s green economic recovery generate a spatial convergence trend: an explanation using agglomeration effects and fiscal instruments

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Abstract
China’s urbanization process has entered a period of rapid development, and cities have become key to driving regional economic development. This paper uses data from 286 cities in China in the period 2005–2018 to construct an urban economic growth quality index system and examine the influence of spatial factors on the convergence trend of China’s urban economic growth quality. It is found that there is a β absolute convergence trend of economic growth quality in Chinese cities across the whole country. After controlling for the initial conditions of individual economies, spatial factors strengthen the spatial convergence trend of urban economic growth quality and significantly increase the corresponding convergence rate. Among the areas studied, the western region has the fastest convergence rate, followed by the central and eastern regions, and the convergence rates of both the central and western regions are higher than the national average. Agglomeration economies and fiscal policy tools are important for the promotion of the urban economic growth quality. The agglomeration of productive service industries significantly improves the spatial convergence rate of urban economic growth quality. This effect is mainly due to the spatial spillover of industrial agglomeration. The expansion of government fiscal expenditure also contributes to the spatial convergence trend of urban economic growth quality. Local economic growth quality is also affected by government fiscal expenditure in neighboring cities.

Keywords Green economic growth · Spatial convergence · Spatial spillover · Agglomeration economy · Fiscal expenditure
1 Introduction

Over the past 40 years since China’s reform and opening up, its economic development has achieved remarkable results that have caught the world’s attention. A period of high economic growth has emerged under the impetus of the globalized economy, especially since China became a member of the World Trade Organization (WTO) in 2001. However, behind this unprecedented growth trend is the factor-input type of ‘sloppy growth’. This process has brought about many hidden dangers, including the depletion of local resources, economic inefficiency, increased environmental pollution, economic structural imbalance, and unbalanced economic development, among others (Chen and Chen 2018; Zhang 2021). As China’s economy moves into a ‘new normal’, the past high-input, high-consumption resource-input-based approach to economic growth is no longer sustainable. The internal and external conditions that supported past economic growth have changed, and China’s economic development requires a change to its approach to growth (Zhao and Ge 2019; Zhang and Kong 2022).

High-quality development has become the main feature of contemporary China’s society and economy. It can be said that the relationship and focus between the quantity of economic growth and the quality of economic growth have begun to change, and the quality of economic growth has become a critical factor in determining economic development (Zhang 2022). At the same time, in a stage during which the quantity of economic growth in China is rapidly increasing, differences in the level of economic development between different regions are subsequently expanding due to differences in natural endowments, policy tilts, etc. There is obvious heterogeneity in both the quality of economic development and the growth rate, with both factors being higher in the eastern regions and lower in the western regions (Su and Guo 2021; Kong et al. 2021b; Wong et al. 2021a). Therefore, reducing regional disparity cannot be ignored when encouraging high-quality economic growth. The spatial correlation of regional economic growth indicates that the economic growth process of a region is closely related to the regions surrounding it. Spatial proximity, spatial accessibility, and knowledge spillover between regions are important mechanisms for convergence in economic growth clubs (Bin et al. 2016; Zhang et al. 2020).

The relationship between the urbanization process and the quality of economic growth is extremely close, and urban economic growth is a highly important component of China’s economic growth (Kong et al. 2021a; Zhang et al. 2021). China has also entered into a phase of rapid urbanization. According to statistics, China’s urbanization rate has increased by 50 percentage points from 1949 to the present and has exceeded 60% in 2019.¹ As the core space and important carrier of regional economic development, the economic growth of China’s cities is closely linked to the nation’s overall socioeconomic growth. It can be said

¹ Relevant statistics for 1949 are from ‘50 Years of New China Cities’, Xinhua Publishing House, December 1999. Data from 1978 onward are obtained from the China Economic Statistics Database. Data in the table are presented in current year prices.
that cities bear the burden of economic development, and urban economic growth is an important component of China’s economic growth (Jiang and Yang 2020; Kong et al. 2021c; Wong et al. 2021b). Improvements in the quality of China’s economic growth must therefore be specifically reflected in the quality of economic growth in cities. This begs the question, how can the quality of urban economic growth be understood? How can it be measured? Furthermore, how has the quality of China’s urban economic growth evolved over time? What kind of spatial dependence and heterogeneity do territorial units have at the microscopic scale? What development trends are likely to emerge in the future? And considering that the agglomeration economy is the source and driver of urban expansion and economic growth (Sun et al. 2015), what will the trend of urban economic growth influenced by the agglomeration economy be?

This paper intends to answer these questions by taking the following three approaches. First, this paper takes 284 Chinese cities of prefecture level and above as research objects and measures the quality of urban economic growth in these cities in four dimensions: economic growth dynamics, structure, mode, and outcome. On this basis, we attempt to generalize their spatial and temporal evolution characteristics to determine the spatial convergence trend of economic growth quality in Chinese cities. The results of this study can help to clarify the future trend of urban economic development quality and to objectively understand the source of the gap in China’s urban economic development quality; this study can also help to deepen understanding of the current situation of regional economies and provide a reference for future urban economic development quality.

Second, this study will identify the key factors affecting the spatial convergence of urban economic growth quality and their degrees of influence. Since this paper takes cities as the object of investigation, and considering that urban economic growth has distinctive spatial aggregation characteristics compared with traditional economic growth, it is necessary to focus on distinguishing urban economic growth from traditional economic growth in the study of urban economic growth quality. Since 1978, spatial shift and agglomeration of industries have occurred in China, and widening regional economic disparity in China is closely related to this phenomenon. Especially after 1995, industrial agglomeration has become the dominant factor affecting regional disparity and industrial structure (Geo 2020). Therefore, the second problem that this paper aims to solve is the identification of whether the effect of agglomeration economy on the spatial convergence of urban economic growth quality is a result of specialized agglomeration or diversified agglomeration.

Third, the balanced development of regional economic growth is a key concern of government macro-control, and fiscal policy plays an active role in coordinating the balanced development of regional economies. The reasonable selection and application of fiscal policy tools can effectively optimize the supply structure, transform growth dynamics, and promote the synergistic development of heterogeneous regional spaces (Bian et al. 2019; Zhang and Yang 2021). Therefore, this paper further introduces fiscal policy tools, which can be used to analyze the factors influencing the spatial convergence of urban economic growth quality, and examines the changes in impact brought about by changes in the scale of fiscal expenditure. The study’s results are used to analyze the relationship and path of influence between the
regional economic growth gap, the spatial convergence trend, and fiscal policy tools in China in order to provide reliable empirical evidence for policy makers.

2 Literature review

The study of spatial convergence of economic growth quality can be based on the relationship between economic growth and convergence (Lee and Yu 2012; Song et al. 2020). Early mainstream studies of economic convergence theory are mainly situated within the fields of neoclassical growth theory and endogenous growth theory. Early neoclassical economics assumed technology invariance as a premise, but neoclassical growth theory achieved a theoretical breakthrough by putting forward a theory of technological progress, arguing that total factor productivity has a role in economic growth and revealing the process by which economic growth converges to a long-term steady state (Solow 1956). However, due to the assumption of exogenous technology in neoclassical theory, it is difficult for it to explain differences in economic growth quality in the long run. Endogenous growth theory thus proposes the core concept of endogenous technology. It assumes that the factors involved have diminishing marginal returns and that the endogenous driving force of continuous technological progress lies in the exogenous accumulation of knowledge; this formulation better explains the external fact of differences in growth rates in the long run. In addition to these two mainstream theories, most scholars have combined new economic geography with the spatial convergence of economic growth quality. New economic geography assumes that individual economies operate with the same initial conditions and economic structure, and explores endogenous evolutionary divergence in the spatial dimension. Research in new economic geography finds that the systemic endogenous forces of two homogeneous individual economies, independent of other external influences, can contribute to regional evolutionary divergence, industrial agglomeration, and even the formation of core–edge structures. This finding has important implications for studying the spatial attributes of regional economic growth, which affect club convergence (Borsi and Metiu 2015).

The existence of convergence in neoclassical growth theory has been supported empirically by domestic and international scholars using country and regional samples. Initially, Baumol (1986), basing their work on Maddison’s (1982) data analysis, obtained a more pronounced productivity convergence in sample countries during the period 1870–1979, and Summers and Heston (1984) used output per capita data to find similar results. De Long (1988) argues against this. His study obtained convergence, indicating that the type of convergence is controversial, but convergence is unquestionable. Following these initial studies, studies on convergence have increased in number (Chen and Fleisher 1996; Jian et al. 1996). Sala-i-Martin (2002) has reconfirmed the relevance of neoclassical growth theory by using different country samples over different examination periods. Based on the availability of country-specific data and the consideration of excessive sample variation, scholars began to focus on the convergence of regional economic differences within countries. For example, Barro et al. (1992) used data from 48 US states. Based on the absolute convergence model, they concluded that there was significant absolute
convergence in per capita income or per capita output in each state. In 1995, Barro.
 applied the same method to study convergence in the US, Japanese, and European
regions and again confirmed the existence of absolute convergence. However, Young.
et al. (2008) conducted a distribution function analysis using 1970 and 1998 US
county-level cross-sectional data and found that both counties and states displayed a
single-peaked distribution; that is, growth is parallel between counties and between
states and there is no $\sigma$ convergence. Caggiano and Leonida (2009) find that eco-
nomic growth is conditionally convergent in OECD countries. Moreover, Caggiano
and Leonida (2013) argue that the presence of clustering and/or polarization may be
a common problem in regional models, but do not exclude the existence of absolute
convergence.

In the 1970s, Weeks and Yao (2003) found large differences between China’s
regional economies, but these differences narrowed after the agricultural reform.
When industrialization became widespread in different regions of China in the
1990s, economic disparity between regions reemerged as a result of the different
levels of industrialization in different regions. Due to the advantage of endowment
combined with policy inclination, the economic development of the eastern region
was far in advance of other regions. The inter-regional economic growth rate was
clearly higher in the east and lower in the west, and this gap continues to widen
(Démurger et al. 2002). However, club convergence and conditional $\beta$ convergence
are evident within the eastern region (Shen and Ma 2002).

Furthermore, to investigate whether there a trend of convergence was evident at
the region-wide level in China, Lin and Liu (2003) used economic growth data from
1978 to 1999 for different Chinese provinces, and Xu and Li (2004) produced the
first analysis of economic convergence in China using urban data. Both these studies
found that there was indeed a trend of convergence. Jiang (2012), on the basis of the
Solow growth model, found that labor productivity converges rapidly and condition-
ally across Chinese provinces. Wang et al. (2013) used non-stationary factor analysis
to find that the conditional convergence of China’s regional economies is extremely
weak. Using a static spatial panel data model, Chen et al. (2018) found absolute
and conditional convergence in urban economic growth in China, while Sun and
Cao (2018) found that club convergence can be observed in China’s urban economy
through a nonlinear time-varying factor model study.

With the development of spatial economics, the spatial convergence of economic
growth has received wide attention. The foreign scholars Seya et al. (2012), and
Ahmad and Hall (2017) used spatial error and spatial Durbin model empirical analy-
sis to examine spatial convergence. The Chinese scholar Ying (2000) was the first
to study the spatial correlation of economic growth. Following Ying, many schol-
ars such as Pan (2010), and Huang and Yuan (2014) explored the spatial conver-
gence of China’s economy at the provincial level, the city level and the three major
regional levels of east, central and west using spatial econometric models based
on the consideration of geographical factors. Their findings all suggest the exist-
ence of conditional $\beta$ convergence or spatial club convergence in China, but do not
support the existence of absolute convergence. Following the significant impact on
global economic growth of the outbreak of COVID-19 in 2020 (Nandan and Mal-
lick 2021), scholars have initiated a new discussion on the spatial convergence of
economic growth. Wang et al. (2020) established a spatial Durbin model to empirically test the spatial convergence of economic growth between provinces in China. They found that economic growth between provinces in China is congruent with the law of conditional convergence. Cartone et al. (2021) studied differences in the determinants of economic growth between 187 regions of 12 European countries and used spatial quantile regression methods to find differences in the rates of conditional convergence of investment, population growth, and human capital in these European regions.

In conclusion, research on the spatial convergence of economic growth quality can be divided into general economic growth convergence theory and spatial economic growth convergence theory. General economic growth convergence theory mainly revolves around neoclassical growth theory and endogenous growth theory. Neoclassical theory assumes that technology is exogenous, which can account for the convergence of economic growth to a steady state in the long run, to a certain extent. However, its assumption of technological exogeneity can hardly explain differences in economic growth quality in the long run. The endogenous growth model, which treats the dynamics of economic growth as resulting from technological progress, solves this difficulty precisely. With the rise of spatial economics, geographic factors have been given full attention in the study of economic growth convergence. The theory of spatial convergence of economic growth, with new economic geography theory as its core, was thus born. This theory holds that individual economies interact spatially, resulting in spillover effects in economic development.

3 Analysis of regional differences in the green economic growth of Chinese cities

3.1 Indicator system establishment

Drawing on the research of the scholar Guo et al. (2020) and combining the characteristics of urban economy and data availability, this section selects four dimensions (economic growth dynamics, structure, mode, and outcome) to construct an indicator system for urban economic growth quality. The index system includes 9 secondary indicators and 18 tertiary indicators. The specific content of the indicators is shown in Table 1.

3.2 Measurement process of urban economic growth quality index

In this paper, the entropy weighting and Delphi methods are applied to establish a comprehensive urban economic growth quality index. The entropy method of assigning weights is based on the amount of information reflected by the level of data evolution, which can objectively reflect the importance of each indicator in the evaluation system as a whole. This can reduce the influence of human subjective factors on the indicator weights. The Delphi method is an expert opinion survey method. Combining the advantages of subjective assignment and objective
Table 1  Index system of economic growth quality of Chinese cities

| Target                      | Primary indicators       | Secondary indicators                      | Tertiary indicators                          | Attributes |
|-----------------------------|--------------------------|-------------------------------------------|---------------------------------------------|------------|
| Quality of economic growth  | Economic growth dynamics | Technological progress                    | Number of inventions acquired                | +          |
|                             | Human capital            | Local financial expenditure on education  | +                                            |            |
|                             |                          | Number of higher education schools         | +                                            |            |
| Economic growth structure   | Industrial structure     | The proportion of tertiary industry to GDP | +                                            |            |
|                             |                          | Fixed asset investment as a proportion of GDP | +                                         |            |
|                             | Trade structure          | Total imports and exports as a proportion of GDP | +                                      |            |
|                             |                          | Share of foreign direct investment in GDP  | +                                            |            |
| Economic growth mode        | Resource conservation    | Electricity consumption of 10,000 Yuan GDP | −                                            |            |
|                             | Environmental protection | Water consumption of 10,000 Yuan GDP       | −                                            |            |
|                             |                          | Green space coverage rate of built-up areas | +                                            |            |
|                             |                          | Harmless treatment rate of domestic waste  | +                                            |            |
| Economic growth results     | Economic development     | GDP per capita                             | +                                            |            |
|                             | Public services          | Books in public libraries per 100 people   | +                                            |            |
|                             | Social security          | Basic pension insurance coverage rate      | +                                            |            |
|                             |                          | Basic medical insurance coverage rate      | +                                            |            |
|                             |                          | Number of hospitals and health centers per 10,000 people | +          |            |

Compiled by the author
assignment, this paper assigns equal weights to indicators of the four dimensions of economic growth dynamics, structure, mode and result: each dimension accounts for 25%. The specific measurement process is as follows.

(1) Standardization. The indicators’ units and orders of magnitude are very different, and direct calculation will cause large errors, so the original data need to be invariant.

\[
x'_{ij} = \frac{x_{ij} - \min (x_{ij})}{\max (x_{ij}) - \min (x_{ij})} \quad \text{Positive indicators} \tag{1}
\]

\[
x'_{ij} = \frac{\max (x_{ij}) - x_{ij}}{\max (x_{ij}) - \min (x_{ij})} \quad \text{Negative indicators} \tag{2}
\]

In Eqs. (1) and (3), \(i\) represents the city, \(j\) represents the measured index, \(x_{ij}\) represents the value of the \(j\)-th index of the \(i\)-th city, and \(x'_{ij}\) is the result after data normalization.

(2) Calculate the share of the \(i\)-th city under the \(j\)-th indicator.

\[
S_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} \tag{3}
\]

(3) Calculation of the entropy value of the \(j\)-th indicator.

\[
e_j = -k \sum_{i=1}^{n} s_{ij} \ln(s_{ij}) \tag{4}
\]

where \(k = \frac{1}{\ln(n)}\), \(e_j \geq 0\) and satisfies \(e_j \geq 0\).

(4) Calculation of information entropy redundancy.

\[
d = 1 - e_j \tag{5}
\]

(5) Calculation of the weights of each indicator.

\[
w_j = \frac{d_j}{\sum_{j=1}^{m} d_j} \tag{6}
\]

(6) Measurement of the composite index of economic growth quality. This formula is calculated through a multiple linear weighting function, as follows.

\[
QEG_i = \sum_{j=1}^{m} w_j \times s_{ij} \tag{7}
\]

In Eq. 7, \(QEG_i\) represents the economic growth quality of city \(i\), \(QEG \subseteq [0, 1]\). The larger the \(QEG_i\) index, the higher the economic growth quality of the city.
Conversely, the smaller the $QEG_i$ index, the lower the economic growth quality of the city.

### 3.3 Measurement results and analysis

Based on the economic growth quality measured in the previous section, this section examines overall differences in the economic growth quality of 284 cities in China in terms of mean, standard deviation, minimum, median, and maximum values. The statistical information of the basic data is shown in Table 2. On this basis, the trend of growth rate of each indicator relative to 2005 was plotted, as shown in Fig. 1.
In general, China’s urban economy shows a fluctuating upward trend. Specifically, average urban economic growth quality rose from 0.2609 in 2005 to 0.2993 in 2018, an increase of 14.71%, implying an overall improvement in the quality of China’s urban economic growth. A more pronounced trough of fluctuation occurred in 2008, when urban economic growth quality dropped to 0.2550, a 2.26% decrease compared to 2005. The main reason for this trough is that the global systemic financial crisis affected the economic system in 2008, leading to a rapid economic decline and a consequent drop in the quality of economic growth. However, with the help of the ‘four trillion’ investment plan, China’s real economy recovered rapidly. At this time, investment differed greatly between different cities, leading to another divergence in the development of each city’s economy, and the differences between cities began to expand again. The growth curve of standard deviation shown in Fig. 1 always lies below the zero level and shows a fluctuating decline. It shrank from 0.0730 in 2005 to 0.0426 in 2018, an overall reduction of 41.65%, indicating a trend of narrowing differences in the quality of urban economic growth. The minimum value gradually increased from 0.1492 in 2005 to 0.1816 in 2018, while the maximum value expanded from 0.5113 in 2005 to 0.5240 in 2018. The average value across all years is higher than the median value of the maximum and minimum values, indicating that the difference in urban economic growth quality had a narrowing trend and balanced development.

Next, we used nonparametric kernel function estimation to empirically analyze urban economic growth quality distribution characteristics over the years. In this section, representative years at three-year intervals (2005, 2008, 2011, 2014, and 2017) were selected to plot the dynamic evolution of nonparametric estimations of urban economic growth quality in Fig. 2.

Overall, the basic shape of the size distribution curve of urban economic growth quality is consistent over the years. China shows a single-peaked state in the evolution of urban economic growth quality distribution during 2005–2018. There is a
significant narrowing of the wave width from 2005 onward. The wave width in 2017 is the narrowest among the representative years, which to some extent indicates a narrowing trend in absolute differences in the quality of urban economic growth. From the evolution of the crests, urban economic growth quality moves to the right and the height of the main crest increases over time, with the crest reaching its highest point in 2017. This indicates that the quality of urban economic growth has improved, which is consistent with the findings of previous studies.

According to the distribution characteristics of the density curve, cities with low levels of development of economic growth quality occupied a large proportion of this distribution before 2011 and gradually transitioned to medium–high levels of economic growth quality after 2011. In the early period, China’s economy pursued an increase in total economic volume by extensive and rough economic growth, ignoring the problems of environmental pollution, resource depletion, low economic efficiency and structural imbalance (Chen and Chen 2018). As China’s economic growth enters a ‘new normal’, the problem of non-synchronization of the quality of economic growth and the quantity of economic growth is gradually being exposed. A series of key measures for high-quality development emphasize quality as the core of development, and the Chinese economy is gradually entering a new stage in which quality is given primacy. Results at the city level also show that China’s urbanization level has been developing rapidly since 2011, indicating a highly agglomerated stage of economic development.

4 Research design

4.1 Model setup and data description

As a first step, a general convergence model was constructed. $\beta$ convergence is an important means for examining economic convergence among regions, and $\sigma$ convergence among regions will only hold if $\beta$ convergence exists among regions. Therefore, the general convergence model used here takes $\beta$ convergence as the initial measurement model. An absolute $\beta$ convergence model of economic growth quality was constructed.

$$d(\ln Q_{i,t}) = \ln Q_{i,t} - \ln Q_{i,t-1} = \alpha + \beta \ln Q_{i,t-1} + \epsilon_{i,t}$$ (8)

The economic growth quality condition $\beta$ convergence model is based on absolute $\beta$ convergence controlling for the initial characteristics of economic individuals, i.e., the absolute $\beta$ convergence is based on the introduction of control variables.

$$d(\ln Q_{i,t}) = \ln Q_{i,t} - \ln Q_{i,t-1} = \alpha + \beta \ln Q_{i,t-1} + \gamma X_{i,t} + \epsilon_{i,t}$$ (9)

where $\epsilon_{i,t} \sim N(0, \sigma^2)$. $Q_{i,t}$ denotes the economic growth quality of city $i$ in year $t$, and $Q_{i,t-1}$ denotes the economic growth quality of city $i$ in year $t-1$. $X_{i,t}$ in Eq. 9 is the set of control variables. If the coefficient $\beta$ is less than 0 and statistically significant, this means that there is absolute $\beta$ convergence and conditional $\beta$ convergence in the quality of urban economic growth, which eventually converges to the
steady-state $\gamma_0$. The convergence steady-state value $\gamma_0 = \frac{a}{1-\beta}$, the convergence rate $\theta = \frac{\ln(1+\beta)}{\beta}$, and the convergence half-life cycle $\tau = \frac{\ln 2}{\theta}$ can be calculated from the estimated value of the convergence coefficient $\beta$.

In the second step, a spatial convergence model was constructed. Cities are divided into artificial administrative divisions, cities are open in spatial scope, and there are economic interactions between different cities. In addition, the spatial correlation pattern of economic growth quality and the boundaries between cities may not be uniform, generating neighborhood measurement errors. The statistics in the research process are related to the sample space, and subsequently, the quality of economic growth in different cities may be affected by spatial correlation. If the spatial factor is ignored, large errors may result, so a spatial lag model (SAR) and a spatial error model (SEM) were constructed. The specific expressions of these models are given in Eqs. (10) and (11).

\begin{align*}
  d(\ln QEG_{it}) &= \ln QEG_{it} - \ln QEG_{it-1} \\
  &= \alpha S + \rho W_n (\ln QEG_{it} - \ln QEG_{it-1}) + \beta \ln QEG_{it-1} + \gamma X_{it} + \mu_{it} \\
\end{align*} 

\begin{align*}
  d(\ln QEG_{it}) &= \ln QEG_{it} - \ln QEG_{it-1} \\
  &= \alpha S + \beta \ln QEG_{it-1} + \gamma X_{it} + \varphi_{it}, \quad \varphi_{it} = \lambda W \varphi_{it} + \mu_{it} \\
\end{align*} 

where $\epsilon_{it} \sim N(0, \sigma^2)$. $S$ is the spatial unit column vector, and $W$ is the spatial autocorrelation weight matrix. Equation (10) is the spatial lag model, where $\rho$ is the spatial autocorrelation parameter. When $\rho$ is greater than 0, this indicates a positive spatial correlation of spatial economic growth quality among cities; when $\rho$ is less than 0, this indicates a negative spatial correlation of spatial economic growth quality among cities. $\beta$ is the convergence coefficient consistent with Eqs. (8) and (9). Equation (11) is the spatial error model, where $\lambda$ is the parameter measuring the spatial correlation between the regression residuals.

In the third step, the impact of the aggregation of economic and fiscal policy instruments on the spatial convergence of the quality of urban economic growth was examined. A specific model was constructed as follows.

\begin{align*}
  d(\ln QEG_{it}) &= \ln QEG_{it} - \ln QEG_{it-1} = \alpha S + \rho W_n (\ln QEG_{it} - \ln QEG_{it-1}) \\
  &+ \eta_1 SP_{it} + \eta_2 DV_{it} + \eta_3 FOS_{it} + \beta \ln QEG_{it-1} + \gamma X_{it} + \mu_{it} \\
\end{align*} 

\begin{align*}
  d(\ln QEG_{it}) &= \ln QEG_{it} - \ln QEG_{it-1} = \alpha S + \beta \ln QEG_{it-1} \\
  &+ \eta_1 SP_{it} + \eta_2 DV_{it} + \eta_3 FOS_{it} + \gamma X_{it} + \varphi_{it}, \quad \varphi_{it} = \lambda W \varphi_{it} + \mu_{it} \\
\end{align*} 

In Eqs. (12) and (13), $SP$ denotes the degree of specialization and agglomeration of productive service industries, $DV$ denotes the level of diversification and agglomeration of productive service industries, $FOS$ denotes the scale of government fiscal expenditure, and $X_{it}$ is the set of control variables.
4.2 Setting of spatial weight matrix

In spatial econometric analysis, the spatial weight matrix is a powerful tool for the conceptualization of spatial relationships, which reflects the structure and intensity of spatial effects and determines the degree of contribution of spatial units to neighboring units. In addition to geographical factors, studies have shown that spatial correlation among cities is also related to the level of economic development (Gu and Pang 2008). This paper therefore set the spatial weight matrix according to two sets of factors: geographical factors and economic factors.

4.2.1 Distance matrix of neighboring weights

If two cities are adjacent, then the weight is 1, and if they are not adjacent, the weight is 0.

\[
W_{ij}^n = \begin{cases} 
1, & i = j \\
0, & i \neq j 
\end{cases}, \quad W'_{ij}^n = \frac{W_{ij}^n}{\sum_j W_{ij}^n}, \quad i \neq j
\] (14)

In Eq. 17, \(i\) and \(j\) denote the \(i\)-th and \(j\)-th cities. To simplify the model and to easily interpret the empirical results, the spatial weight matrix is row normalized so that the sum of the elements in each row is 1, yielding \(W'_{ij}^n\).

4.2.2 Geographical distance weight matrix

According to the general rule of spatial correlation between regions, the shorter the distance interval between regions, the stronger the correlation between regions. As the distance interval expands, the correlation between regions will gradually weaken. Therefore, this paper assigns weights according to the inverse of the geographical distance between different cities, as shown in Eq. (15).

\[
W_{ij}^d = \begin{cases} 
1/d_{ij}, & i \neq j \\
0, & i = j 
\end{cases}, \quad W'_{ij}^d = \frac{W_{ij}^d}{\sum_j W_{ij}^d}, \quad i \neq j
\] (15)

where \(d_{ij}\) is the geographic distance between two places, the weight is assigned to 0 when the inverse of the geographic distance is infinite, and \(W'_{ij}^d\) is the normalized matrix.

4.2.3 Economic distance weight matrix

Given that competition and spillover effects are more likely to be triggered between cities with similar levels of economic development, an economic
distance weight matrix was constructed. This matrix combines both spatial and economic factors which lead to differences, as shown in Eq. (16).

\[
W^e_{ij} = W^d_{ij} \text{diag}\left(\frac{\bar{Y}_1}{\bar{Y}}, \frac{\bar{Y}_2}{\bar{Y}}, \ldots, \frac{\bar{Y}_n}{\bar{Y}}\right) W^e_{ij} = \frac{W^e_{ij}}{\sum_j W^e_{ij}} \quad i \neq j
\]

(16)

where \(\bar{Y}_i\) is the economic indicator of the \(i\)-th city, \(\bar{Y} = \frac{1}{n} \sum_{i=1}^{n} Y_i\), is the mean value of economic indicators for all cities in the total observation period, and the normalized weight is \(W^e_{ij}\).

### 4.3 Variable descriptions and data sources

In this paper, the quality of economic growth in Chinese cities was selected as the research target. The sample data were obtained from the China City Statistical Yearbook. The data of the number of invention indicators were obtained from the CNRDS database. Data processing was performed in three main steps, as follows.

1. Different processing methods were selected to process cases of missing values for individual indicators. Indicators with low levels of missing data were filled with the average value of the two periods before and after the missing value, or with the value of the previous and later periods. We chose the interpolation method for indicators with missing data in individual years for all cities. For indicators with high levels of missing data, we considered replacing the variables.

2. Some indicators required simple calculation. The relevant proportion indicators were measured, and the import and export data and foreign direct investment data expressed in US dollars were converted according to the exchange rate of US dollars to RMB in the relevant year.

3. Because there were serious missing data problems for Tibet, Bijie, Tongren and several other cities, these cities were excluded from the sample. After this processing, panel data for 284 cities from 2005 to 2018 were ultimately obtained.

The core variables included the concentration of productive service industries and the scale of fiscal spending. Production service industry agglomeration was divided into the degree of specialized agglomeration and the level of diversified agglomeration. Referring to Combes (2000), this paper expresses the production service industry specialization agglomeration (SP) indicator as:

\[
SP_i = \frac{\left(E_{is}/E_i\right)}{\left(E_s/E\right)}
\]

where \(SP_i\) is the degree of specialization and agglomeration of productive service industry in city \(i\); \(E_{is}\) is the number of productive service employment in city \(i\); \(E_i\) is the total employment in city \(i\); \(E_s\) is the number of people employed in productive services nationwide; and \(E\) is the overall number of people employed nationwide. The level of the diversification agglomeration (DV) indicator is tabulated as

\[
DV_i = \sum_s \left(\frac{E_{is}}{E_i}\right) \times \left[\frac{1}{n} \sum_{s'=1, s' \neq s}^n \left(\frac{E_{is'}}{E_i - E_{is}}\right)^2\right]^{1/2} \times \left[\frac{1}{n} \sum_{s'=1, s' \neq s}^n \left(\frac{E_{s'}}{E - E_s}\right)^2\right]^{1/2}
\]
where $E_{is}$ denotes the number of people employed in a particular productive service industry $s$ (in city $i$ and industry $s$); $E_{is}'$ is the number of people employed in a productive service industry $s'$ nationwide in addition to industry $s$; and $E_s$ represents the number of people employed in productive service industry $s$ nationwide. The fiscal expenditure size (FOS) is expressed using the ratio of local fiscal general budgetary expenditure to GDP, drawing on the methodology of Wu (2021).

In this paper, we selected the level of informatization (INF), city size (POP), physical capital ($K$), transportation accessibility (TRAV), degree of government intervention (GOV), economic policy uncertainty index (EPU), and industrial SO$_2$ emissions (SO$_2$) as control variables. The level of informatization was measured using postal service revenue per capita. City size was measured using the total year-end population of the municipality. Physical capital was measured by capital stock calculated by the perpetual inventory method, and the capital stock depreciation rate was borrowed from Zhang et al. (2004) (set at 9.6%). Transportation accessibility was measured by total freight transportation per capita. The degree of government intervention was expressed using the city’s fiscal revenue as a percentage of GDP. The Economic Policy Uncertainty Index was based on Baker’s et al. (2016) methodology, which first calculates the proportion of daily news articles in the South China Morning Post (published in Hong Kong, China) that contained the keywords “China”, “economy”, “policy”, and “uncertainty” to the total number of articles published by the South China Morning Post in that month. Baker’s methodology then uses the index of global economic policy uncertainty published on an economic policy uncertainty website$^2$ to measure the index. This paper construct enterprises’ pollution emission intensity index using industrial SO$_2$ emissions, which are typically used to represent air pollution.

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**Table 3** Test of absolute $\beta$ convergence of urban economic growth quality

|       | (1) National | (2) East | (3) Central | (4) West |
|-------|-------------|---------|-------------|---------|
| $\alpha$ | $-0.3763^{***}$ | $-0.3144^{***}$ | $-0.4691^{***}$ | $-0.5165^{***}$ |
|       | $(-29.76)$  | $(-15.48)$ | $(-19.92)$  | $(-19.09)$ |
| $\beta$ | $-0.3184^{***}$ | $-0.2833^{***}$ | $-0.3863^{***}$ | $-0.4118^{***}$ |
|       | $(-31.20)$  | $(-15.82)$  | $(-20.82)$  | $(-20.10)$ |
| Convergence speed | 2.949 | 2.562 | 3.756 | 4.082 |
| Convergence period | 23.51 | 27.05 | 18.46 | 16.98 |
| $R^2$   | 0.3800 | 0.3983 | 0.3568 | 0.4008 |
| $N$     | 3692  | 1313   | 1300       | 1079    |

*, **, *** represent passing the coefficient significance test at 10%, 5%, and 1% significance levels, respectively; $Z$ values in parentheses; convergence rate in % and convergence period in years

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$^2$ [http://policyuncertainty.com/global_monthly.html](http://policyuncertainty.com/global_monthly.html).
5 Empirical results and discussion

5.1 General convergence results

Table 3 shows the results of the estimation of the absolute $\beta$ convergence model of economic growth quality. To consider the possibility of club convergence in China, this section empirically analyzes absolute $\beta$ convergence at the national level and the three regional levels of east, central and west. The results show that the $\beta$ coefficient is significantly smaller than 0 in the national sample, indicating the existence of absolute $\beta$ convergence in China. Similarly, the eastern, central, and western samples show a trend of club convergence. The western region converges the fastest, followed by the central and eastern regions, while the central and western regions converge faster than the national average. However, the absolute convergence rate is still relatively slow for each sample.

5.2 Spatial convergence analysis

Table 4 shows the spatial conditional $\beta$ convergence results obtained using the maximum likelihood estimation method (ML). Columns (1)–(3) are the results of spatial lagged dynamic panel model estimation, and columns (4)–(6) are the results of spatial error dynamic panel model estimation. This paper uses a combination of Hausman and Lagrange multiplier (LM) tests to make judgments with regard to the choice of spatial model. The results of the Hausman statistical test tended to favor the empirical results of the fixed-effects model rather than the random-effects model. The LM test results indicated that the surface spatial lag model was more suitable for the empirical analysis in this paper. Therefore, this section mainly focuses on the results in columns (1)–(3). Although the spatial error model is slightly less reasonable than the spatial lag model, it still reflects the robustness of the results of this study.

The $\ln QEG_{i,t-1}$ coefficient is significantly negative, indicating that urban economic growth quality still eventually converges to a steady state after the inclusion of spatial factors; that is, there is spatial conditional $\beta$ convergence. For different spatial weight matrices, the coefficients of $\ln QEG_{i,t-1}$ differ. The absolute value of the convergence coefficient corresponding to the economic distance weight matrix is the largest, followed by the neighboring weight matrix, and the geographical distance weight matrix. This indicates that convergence is more significant between neighboring cities with similar economic development levels. In addition, the spatial effect coefficient $\rho$ is significantly positive for the neighboring weights, geographic distance weights, and economic distance weights. This indicates that, due to the positive spatial spillover effect, the convergence of economic growth quality in the sampled cities is accelerated and the convergence period is shortened.
### Table 4  Quality conditions for China’s economic growth \( \beta \) spatial convergence test

|          | SAR                                         | SEM                                         |
|----------|---------------------------------------------|---------------------------------------------|
|          | Adjacency weighting | Geographical distance weight | Economic distance weight | Adjacency weighting | Geographical distance weight | Economic distance weight |
| \( \rho \) | 0.5004*** | 0.6040*** | 0.6422*** | 0.3927*** | 0.2325*** | 0.0615*** |
|          | (42.84)    | (54.84)    | (42.53)    | (57.35)    | (47.77)    | (48.51)    |
| \( \lambda \) | 0.3691*** | 0.3638*** | 0.4117*** | 0.3393*** | 0.3172*** | 0.5024*** |
|          | (−43.83) | (−43.37) | (−39.42) | (−45.49) | (−48.68) | (−43.29) |
| \( \ln QEG_{it-1} \) | 0.4703*** | 0.4038*** | 0.2072*** | 0.3471 | 0.5221*** | 0.0530 |
|          | (6.41) | (7.27) | (7.02) | (6.3) | (2.22) | (1.32) |
| \( K \)   | 0.3528*** | 0.4914*** | 0.6469*** | 0.2872*** | 0.3180*** | 0.0492*** |
|          | (10.42) | (7.46) | (9.23) | (5.26) | (4.94) | (6.13) |
| \( \text{GOV} \) | 0.1426*** | 0.1139*** | 0.5269*** | 0.2552*** | 0.1977*** | 0.1157*** |
|          | (6.61) | (6.39) | (7.07) | (7.2) | (5.25) | (6.15) |
| \( \text{TRAV} \) | −0.2274 | −0.5266* | −0.3746* | −0.2186 | −0.2468 | −0.1456 |
|          | (−1.47) | (−1.83) | (−1.86) | (−0.6) | (−0.56) | (−0.95) |
| \( \text{POP} \) | 0.0441*** | 0.0429*** | 0.0384*** | 0.2520 | 0.3090 | 0.4103 |
|          | (6.52) | (6.31) | (6.56) | (5.4) | (1.07) | (1.16) |
| \( \text{EPU} \) | −0.3602*** | −0.4164*** | −0.5613*** | −0.6564*** | −0.3797*** | −0.0227*** |
|          | (5.66) | (6.10) | (5.36) | (4.97) | (2.27) | (2.19) |
| \( \text{SO}_2 \) | 0.3103** | 0.3343*** | 0.5224* | 0.2097*** | 0.2291*** | 0.3614*** |
|          | (2.01) | (2.15) | (1.71) | (4.10) | (6.61) | (4.73) |
|                  | SAR                      |                      | SEM                      |                      |
|------------------|--------------------------|----------------------|--------------------------|----------------------|
|                  | Adjacency weighting      | Geographical distance weight | Economic distance weight | Adjacency weighting  |
|                  | (1)                      | (2)                  | (3)                      | (4)                  |
| Convergence speed| 3.543                    | 3.479                | 4.081                    | 3.188                |
| Convergence period| 19.56                    | 19.92                | 16.99                    | 21.74                |
| LMlag            | 179.74                   | 155.43               | 137.16                   | 153.61               |
|                  | 0.0000                   | 0.0000               | 0.0000                   | 0.0000               |
| LMerr            |                          |                      |                          | 34.24                |
|                  |                          |                      |                          | 25.10                |
|                  |                          |                      |                          | 39.64                |
|                  |                          |                      |                          | 0.0000               |
|                  |                          |                      |                          | 0.0000               |
|                  |                          |                      |                          | 0.0000               |
| Hausman          | 125.17                   | 95.31                | 143.66                   | 153.61               |
|                  | 0.0000                   | 0.0000               | 0.0000                   | 0.0000               |
|                  |                          |                      |                          | 0.0000               |
|                  |                          |                      |                          | 0.0000               |
|                  |                          |                      |                          | 0.0000               |
|                  |                          |                      |                          | 0.0000               |
| $R^2$            | 0.4193                   | 0.3915               | 0.2507                   | 0.2745               |
|                  | 3692                     | 3692                 | 3692                     | 3692                 |
| N                |                          |                      |                          | 3692                 |

*, **, *** represent passing the coefficient significance test at 10%, 5%, and 1% significance levels, respectively; Z values in parentheses; convergence rate in % and convergence period in years.
5.3 Explanations for the spatial convergence of the urban economic growth quality

A scatter plot was drawn with the specialization agglomeration index and diversification agglomeration index as the x-axis and the quality of economic growth as the y-axis, respectively. As shown in Fig. 3, there is a linear relationship between specialization and diversification agglomeration and the quality of urban economic growth. Specialization agglomeration is positively related to the quality of urban economic growth, while diversification agglomeration is inversely related to the quality of urban economic growth.

Table 5 shows the estimation results of the spatially conditional convergence model, which reflect the effects of productive service industry agglomeration and fiscal expenditure. The specialized agglomeration of productive service industries plays a positive role in the spatial convergence of economic growth quality of cities. However, the higher the diversification agglomeration is, the more diffuse the economic growth quality is. After the agglomeration economy is factored in, the convergence speed of urban economic growth quality increases and the convergence period is shortened. The spatial lag model’s convergence speeds based on the neighborhood weight, geographic distance weight, and economic distance weight are 5.828%, 4.397%, and 9.702%, respectively. In the spatial condition β convergence model without considering industrial agglomeration, the convergence speeds corresponding to the three weight matrices are 3.543%, 3.479%, and 4.081%, respectively. The convergence speeds are increased by 64.49%, 26.39%, and 137.74%, respectively.

In terms of policy effects, the FOS coefficient is significantly positive, indicating that increasing the scale of fiscal expenditure can significantly promote the spatial convergence of urban economic growth quality. Therefore, fiscal policy instruments are important factors influencing the spatial convergence of urban economic growth quality. Finally, there is a significant positive spatial spillover effect among cities. This indicates that cities should consider the local industrial development level and the industrial development patterns of the surrounding areas when planning and designing industrial development.

![Fig. 3 Scatter plot of productive service industry agglomeration and urban economic growth quality](image)
Table 5 Results of considering productive services agglomeration and fiscal expenditures

|               | SAR               | SEM               |
|---------------|-------------------|-------------------|
|               | Adjacency weighting | Geographical distance weight | Economic distance weight | Adjacency weighting | Geographical distance weight | Economic distance weight |
| \( \rho \)   | 0.3076*** (32.56) | 0.3175*** (38.12) | 0.5930*** (44.27) | 0.6739*** (39.20) | 0.5719*** (34.71) | 0.4853*** (36.52) |
| \( \lambda \) |                   |                   |                     |                   |                   |                     |
| \( \ln QEGit-1 \) | −0.5312*** (−38.05) | −0.4354*** (−33.80) | −0.7167*** (−48.55) | −0.4892*** (−31.46) | −0.3242*** (−25.79) | −0.6385*** (−39.07) |
| SP            | 0.0013 (1.14)     | 0.0015* (1.85)    | 0.0036** (2.21)     | −0.0021 (−0.67)   | −0.0037 (−0.54)    | 0.0006 (0.37)       |
| DI            | −0.1937*** (−14.83) | −0.1539*** (−13.45) | −0.1706*** (−16.76) | −0.0587 (−0.53)   | 0.6062* (1.90)     | −0.0275 (−0.34)     |
| FOS           | 0.5378*** (6.64)  | 0.3533*** (5.25)  | 0.6676*** (6.58)    | 0.7772*** (5.41)  | 0.4467*** (6.78)   | 0.3706*** (2.16)    |
| CONTROLS      | YES               | YES               | YES                 | YES               | YES               | YES                 |
| Convergence speed | 5.828             | 4.397             | 9.702               | 5.168             | 3.014             | 7.827               |
| Convergence period | 11.89             | 15.76             | 7.14                | 13.41             | 23.00             | 8.86                |
| LMlag         | 156.31            | 214.23            | 111.48              | 0.0000            | 0.0000            | 0.0000              |
|                | SAR                      |              | SEM                      |              |
|----------------|--------------------------|--------------|--------------------------|--------------|
|                | Adjacency weighting      | Geographical distance weight | Economic distance weight | Adjacency weighting | Geographical distance weight | Economic distance weight |
| LMerr          |                          |              |                          | 65.24        |              |                          | 33.16        |              | 43.87        |              |
|                |                          |              |                          | 0.0000        |              |                          | 0.0000        |              | 0.0000        |              |
| Hausman        | 63.26                    | 75.69        | 98.18                    | 157.38       |              |                          | 98.27        |              | 231.40       |              |
|                | 0.0000                   | 0.0000       | 0.0000                   | 0.0000       |              |                          | 0.0369       |              | 0.0000        |              |
| $R^2$          | 0.3091                   | 0.2631       | 0.3700                   | 0.2784       |              |                          | 0.3236       |              | 0.2606        |              |
| $N$            | 3692                     | 3692         | 3692                     | 3692         |              |                          | 3692         |              | 3692         |              |

*, **, *** represent passing the coefficient significance test at 10%, 5%, and 1% significance levels, respectively; $Z$ values in parentheses; convergence rate in % and convergence period in years.
Robustness test

The spatial spillover effects obtained from the spatial lag model and spatial error model include local effects and indirect effects from other cities. In order to ensure the robustness of the above conclusions, and considering that in practice cases of spatial lag and spatial error may exist simultaneously, this section uses the spatial Durbin model for re-testing. In addition, considering the possibility of spatial correlation jumps due to the length of the examined period, the examined period is further divided into the sub-periods 2005–2012 and 2013–2018. The results are presented in Table 6. In Table 6, W1, W2, and W3 correspond to the adjacency matrix, geographic distance matrix, and economic distance matrix, respectively.

The results in Table 6 show that the specialized agglomeration of productive services is positive for the spatial convergence of the quality of urban economic growth, while diversified agglomeration increases the gap in urban economic growth quality. This is consistent with the results given in Table 5. Furthermore, from 2005 to 2012, specialization agglomeration is shown to be key to promoting the convergence of the urban economic growth quality gap; from 2013 to 2018, diversification agglomeration plays a major role in promoting economic growth quality. This result again proves that agglomeration economy is a key factor in the convergence of economic growth quality in cities. In addition, $W^{*}SP$ is significantly positive, while $W^{*}DV$ is significantly negative, indicating that specialized agglomeration in some cities can significantly contribute to the convergence of economic growth quality in other cities. Still, the specialized agglomeration of industries in neighboring cities contributes to the widening of regional differences. This situation is always present in both the short and long runs. Finally, we look at the impact of fiscal policy instruments. The coefficient of FOS is significantly positive, indicating that an increase in the size of fiscal spending can significantly contribute to the convergence of the quality of economic growth in cities. The estimated coefficient of $W^{*}$FOS also has a positive value, indicating that fiscal spending in some cities also affects the convergence of the quality of economic growth in other cities.

Conclusions and policy recommendations

This paper takes 284 prefecture level and above cities in China from 2005 to 2018 as the research objects, constructs comprehensive indicators of urban economic growth quality using the entropy value method, and tries to summarize their spatio-temporal evolution characteristics to initially determine the convergence of urban economic growth quality in China. Given the possible spatial correlation of different cities, this paper examines the spatial convergence of urban economic growth quality by using a spatial econometric model starting from a general convergence trend. Furthermore, this paper also tries to explain the spatial convergence of urban economic growth quality in terms of both agglomeration economy and fiscal policy instruments.

The study draws the following conclusions. First, there is a general convergence trend in China across the whole territory. The western region converges the fastest,
|                | 2005–2018 |          | 2005–2012 |          | 2013–2018 |          |
|----------------|------------|----------|------------|----------|------------|----------|
|                | (1) (2) (3) | (4) (5) (6) | (7) (8) (9) |          |            |          |
| $W_1$          |            |          | 0.5880***  | 0.5398*** | 0.5576***  | 0.7033*** |
|                | (34.39)    |          | (30.59)    | (26.96)  | (25.00)    | (33.08)  |
|                |            |          |            |          | (30.82)    |          |
| $W_2$          |            |          | −0.6577*** | −0.4249***| −0.7327*** | −0.5761***|
|                | (−32.64)   |          | (−34.57)   | (−39.20) | (−27.01)   | (−31.46) |
|                |            |          |            |          |            | (−33.50) |
| $W_3$          |            |          | 0.0119*    | 0.0121***| 0.0172***  | −0.0032  |
|                | (1.75)     |          | (4.61)     | (4.16)   | (−0.51)    | (−0.46)  |
|                |            |          |            |          |            | (−0.62)  |
| $\ln Q_{EGi-1}$|            |          | −0.6577*** | −0.4249***| −0.7327*** | −0.5761***|
|                | (−32.64)   |          | (−34.57)   | (−39.20) | (−27.01)   | (−31.46) |
|                |            |          |            |          |            | (−33.50) |
| $SP$           | 0.0119*    |          | 0.0121***  | 0.0172***| −0.0032    | −0.0046  |
|                | (1.75)     |          | (4.61)     | (4.16)   | (−0.51)    | (−0.46)  |
|                |            |          |            |          |            | (−0.62)  |
| $DI$           | −0.0004    |          | −0.0008    | 0.0003   | 0.0005     | 0.0028** |
|                | (−0.23)    |          | (−0.56)    | (0.13)   | (0.24)     | (2.20)   |
|                |            |          |            |          | (1.16)     | (1.66)   |
| $FOS$          | 0.2558***  |          | 0.3296***  | 0.2853***| 0.0174**   | 0.5500***|
|                | (7.06)     |          | (8.90)     | (8.29)   | (2.03)     | (9.49)   |
|                |            |          |            |          | (8.52)     |          |
| $W^{\ln Q_{EGi-1}}$| 0.2664*** |          | 0.4339***  | 0.3475***| 0.3744***  | 0.3764***|
|                | (9.13)     |          | (8.36)     | (8.62)   | (8.64)     | (9.10)   |
|                |            |          |            |          | (8.35)     |          |
| $W^{SP}$       | 0.1520*    |          | 0.1118***  | 0.0042*  | 0.0063     | 0.1634***|
|                | (1.93)     |          | (4.64)     | (1.65)   | (1.01)     | (3.52)   |
|                |            |          |            |          | (1.81)     |          |
| $W^{DI}$       | −0.0321*** |          | −0.2131*** | −0.1981***| −0.3207*** | −0.2686***|
|                | (−6.52)    |          | (−6.71)    | (−5.31)  | (−6.21)    | (−4.65)  |
|                |            |          |            |          | (−7.21)    |          |
| $W^{FOS}$      | 0.4420***  |          | 0.3096***  | 0.2497** | 0.5224***  | 0.3691***|
|                | (6.12)     |          | (7.71)     | (2.14)   | (6.34)     | (5.12)   |
|                |            |          |            |          | (6.34)     |          |
| $CONTROLS$     | YES        |          | YES        | YES      | YES        | YES      |
| $W^{CONTROLS}$ | YES        |          | YES        | YES      | YES        | YES      |

Table 6 Results of spatial Durbin model
Table 6 (continued)

|               | 2005–2018 |       | 2005–2012 |       | 2013–2018 |       |
|---------------|-----------|-------|-----------|-------|-----------|-------|
|               | (1)       | (2)   | (3)       | (4)   | (5)       | (6)   |
|               | W1        | W2    | W3        | W1    | W2        | W3    |
| Convergence speed | 8.247     | 4.255 | 10.149    | 6.602 | 8.925     | 5.680 |
| Convergence period | 8.41      | 16.29 | 6.83      | 10.50 | 7.77      | 12.20 |
| Hausman       | 46.21     | 76.26 | 54.55     | 43.72 | 37.31     | 67.33 |
|               | 0.0000    | 0.0000| 0.0000    | 0.0109| 0.0000    | 0.0000|

*, **, *** represent passing the coefficient significance test at 10%, 5%, and 1% significance levels, respectively; Z values in parentheses; convergence rate in % and convergence period in years.
followed by the central and eastern regions, while the central and western regions converge faster than the national average. However, the absolute convergence rate is still relatively slow, regardless of the sample. Second, in terms of spatial convergence, the convergence between neighboring cities with similar economic development levels is more significant. Due to the existence of a positive spatial spillover effect, the speed of economic growth quality convergence among cities in China is accelerated and the convergence period is shortened. Third, an examination of the factors influencing the spatial convergence of urban economic growth quality reveals that the specialized agglomeration of productive service industries has a positive influence on the spatial convergence of urban economic growth quality, while the influence of diversified agglomeration is negative. After factoring in agglomeration economy, the convergence speed of urban economic growth quality increases and the convergence period is shortened accordingly. The empirical results of this paper also indicate that fiscal policy instruments are important factors affecting the spatial convergence of urban economic growth quality. The increase of fiscal expenditure scale can significantly promote the convergence of urban economic growth quality. The fiscal expenditure of other cities also significantly affects the spatial convergence trend of local urban economic growth quality.

The empirical analysis of this paper shows that the quality of China’s urban economic growth is currently converging spatially. However, there is still a problem in that there is a low level of convergence and a decreasing rate of convergence. Therefore, measures need to be taken to break this bottleneck. This paper recommends the following policies.

First, the spatial distribution of cities should be coordinated and the horizontal and vertical interactions between regions should be strengthened. This paper demonstrates a significant spillover effect on the convergence of economic growth quality in China’s cities and an obvious center-periphery pattern. The level of economic growth quality is unevenly distributed; this is related to the spatial distribution of cities to a certain extent. Therefore, the government should improve regional transportation structure, promote the construction of an inter-city rapid railroad network, and build a more rational urban spatial structure system to improve spatial accessibility and the degree of inter-regional knowledge spillover.

Second, inter-regional industrial sectors should be promoted; this will encourage regional industries to drive each other and encourage factor circulation. The government should focus on lowering technical barriers, promoting the flow of outstanding talents, capital and technology, and encourage in-depth cooperation between regions with similar technical structures. The advantage of doing so is that these policies can improve the regional linkage effect and avoid inter-regional policy fragmentation in order to adjust the disadvantages of regional economies and stimulate their growth.

Third, a city network system should be built and the city network structure should be optimized. A scientific and rational urban network system will be beneficial for the optimal allocation of resources by market players and will help to realize urban economies of scale and the benefits of agglomeration. Given the systemic characteristics of different regional areas, the government should implement active fiscal policies and accurately grasp the different functional characteristics and service levels of cities in multiple networks to realize the complementary development and
overall optimization of regional urban functions. The government should enhance network organization efficiency by improving the network resource domination ability of regional central cities and strengthening the support provided by node cities to the network system.

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References

Ahmad M, Hall SG (2017) Economic growth and convergence: do institutional proximity and spillovers matter? J Policy Model 39:1065–1085
Baker SR, Bloom N, Davis SJ (2016) Measuring economic policy uncertainty. Q J Econ 131:1593–1636
Barro RJ, Sala-i-Martin X (1992) Convergence. J Polit Econ 100:223–251
Baumol WJ (1986) Productivity growth, convergence, and welfare: what the long-run data show. Am Econ Rev 76:1072–1085
Bian ZC, Zhao L, Ding H (2019) Transformation of China’s monetary policy regulatory framework, non-linear change of fiscal multipliers and the choice of fiscal instruments in China’s new era. Econ Res J 54:56–72
Bin YJ, Huang XY, Hong GZ et al (2016) The effect of transport accessibility on urban growth convergence in China: a spatial econometric analysis. Acta Geogr Sin 71:1767–1783
Borsi MT, Metiu N (2015) The evolution of economic convergence in the European union. Empir Econ 48:657–681
Caggiano G, Leonida L (2009) International output convergence: evidence from an autocorrelation function approach. J Appl Econom 24:139–162
Caggiano G, Leonida L (2013) Multimodality in the distribution of GDP and the absolute convergence hypothesis. Empir Econ 44:1203–1215
Cartone A, Postiglione P, Hewings GJD (2021) Does economic convergence hold? A spatial quantile analysis on European regions. Econ Model 95:408–417
Chen SY, Chen DK (2018) Air pollution, government regulations and high-quality economic development. Econ Res J 53:20–34
Chen J, Fleisher BM (1996) Regional income inequality and economic growth in China. J Comp Econ 22:141–164
Chen FL, Wang MC, Xu KN (2018) The evolution trend of China’s coordinated regional development: a spatial convergence analysis. Financ Trade Econ 39:128–143
Combes P-P (2000) Economic structure and local growth: France, 1984–1993. J Urban Econ 47:329–355
De Long JB (1988) Productivity growth, convergence, and welfare: comment. Am Econ Rev 78:1138–1154
Démurger S, Sachs JD, Woo WT et al (2002) Geography, economic policy, and regional development in China. Asian Econ Pap 1:146–197
Gu CL, Pang HF (2008) Study on spatial relations of Chinese urban system: gravity model approach. Geogr Res 1:1–12
Guo Y, Fan BN, Long J (2020) Practical evaluation of China’s regional high-quality development and its spatiotemporal evolution characteristics. J Quant Tech Econ 37:118–132
Huang WH, Yuan LS (2014) Has human capital “club convergence” clustered in China? China Popul Environ 24:123–132
Jian T, Sachs JD, Warner AM (1996) Trends in regional inequality in China. China Econ Rev 7:1–21
Jiang Y (2012) An empirical study of openness and convergence in labor productivity in the Chinese provinces. Econ Chang Restruct 45:317–336
Jiang AY, Yang ZL (2020) New urbanization construction and high-quality urban economic growth: an empirical analysis based on the double difference method. Inq Into Econ Issues 3:84–99
Kong QX, Chen AF, Peng D, Wong Z (2021a) Has the belt and road Initiative improved the quality of economic growth in China’s cities? Int Rev Econ Financ 76:870–883
Kong QX, Tong X, Peng D et al (2021c) How do factor market distortions affect OFDI: an explanation based on investment propensity and productivity effects. Int Rev Econ Financ 73:459–472
Kong QX, Peng D, Ni YH et al (2021) Trade openness and economic growth quality of China: empirical analysis using ARDL model. Financ Res Lett 38:101488
Lee L, Yu J (2012) Spatial panels: random components versus fixed effects. Int Econ Rev 53:1369–1412
Lin YF, Liu MX (2003) Growth convergence and income distribution in China. J World Econ 26(8):3–14
Maddison A (1982) Phases of capitalist development. Oxford University Press
Nandan A, Mallick H (2021) Do growth-promoting factors induce income inequality in a transitioning large developing economy? An empirical evidence from Indian states. Econ Chang Restruct 12:1–31
Pan WQ (2010) The economic disparity between different regions of China and its reduction: an analysis from the geographical perspective. Soc Sci China 1:72–84
Sala-i-Martin XX (2002) The classical approach to convergence analysis. Econ J 106:1019–1036
Seya H, Tsutsumi M, Yamagata Y (2012) Income convergence in Japan: a Bayesian spatial Durbin model approach. Econ Model 29:60–71
Shen KR, Ma J (2002) The characteristics of “club convergence” of China’s economic growth and its cause. Econ Res J 1:33–39
Solow RM (1956) A contribution to the theory of economic growth. Q J Econ 70:65–94
Song XJ, Li XN, Yu JH (2020) Estimation of short spatial dynamic panel data models: with application to growth convergence among Chinese cities. China J Econ 7:38–59
Su PL, Guo ZH (2021) Analysis of spatial differences and influencing factors of high-quality economic development. Stat Decis 37:123–125
Summers R, Heston A (1984) Improved international comparisons of real product and its composition: 1950–1980. Rev Income Wealth 30:207–219
Sun XD, Zheng YT, Zhang LL (2015) Chinese city scale based on the agglomeration economy rule. China Popul Environ 25:74–81
Sun GH, Cao Y (2018) Convergence of clubs for urban economic growth—identification methods and convergence mechanisms: an empirical test from 347 administrative regions in China. Mod Econ Sci 40:14–25
Wang LY, Qi TX, Li KP (2013) Geographical environmental differences, modernization process and economic convergence. Econ Sci 2:45–55
Wang QR, Liu JQ, Liu DY (2020) The convergence characteristics of China’s provincial economic growth and the test of spatial spillover effects. World Econ Pap 3:91–106
Weeks M, Yudong Yao J (2003) Provincial conditional income convergence in China, 1953–1997: a panel data approach. Econ Rev. 22:59–77
Wong Z, Li RR, Zhang YD et al (2021) Financial services, spatial agglomeration, and the quality of urban economic growth—based on an empirical analysis of 268 cities in China. Financ Res Lett 43:101993
Wong Z, Li R, Peng D, Kong Qi (2021) China-european railway, investment heterogeneity, and the quality of urban economic growth. Int Rev Financ Anal 78:101937. https://doi.org/10.1016/j.irfa.2021.101937
Wu YC (2021) Can smart city construction improve urban resilience? A quasi-natural experiment. J Public Adm 14:25–44
Xu XX, Li X (2004) Convergence in Chinese cities. Econ Res J 5:40–48
Ying LG (2000) Measuring the spillover effects: some Chinese evidence. Pap Reg Sci 79:75–89
Young AT, Higgins MJ, Levy D (2008) Sigma convergence versus beta convergence: evidence from US county-level data. J Money Credit Bank 40:1083–1093
Zhang D (2022) Are firms motivated to greenwash by financial constraints? Evidence from Global Firms’ Data J Int Financ Manag Account. https://doi.org/10.1111/jifm.12153
Zhang P, Yang X (2021) Fiscal policy tools’ optimization choice for the coordinated development of regional economy and Chinese logic. Soft Sci 35:29–34
Zhang J, Wu GY, Zhang JP (2004) The estimation of China’s provincial capital stock:1952–2000. Econ Res J 10:35–44
Zhang D, Kong Q (2022) Do energy policies bring about corporate overinvestment? Empirical evidence from Chinese listed companies. Energy Econ 105:105718
Zhang J, Xu HL, Wang HW (2020) A study on knowledge spillover and convergence of regional economic growth in China. Macroeconomics 4:71–84
Zhang D, Mohsin M, Rasheed AK et al (2021) Public spending and green economic growth in BRI region: mediating role of green finance. Energy Policy 153:112256
Zhang D (2021) Does the green loan policy boost greener production? Evidence from Chinese firms. Emerg Mark Rev. https://doi.org/10.1016/j.ememar.2021.100882
Zhao WJ, Ge CB (2019) Study on the influencing factors of China’s economic growth pattern: empirical analysis based on 248 urban data. Inq into Econ Issues 6:9–19

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