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Article

# Analysis on the economic growth effects of industrial clustering in high-tech manufacturing and knowledge-intensive service industries

**Jiayu Ru, Lu Gan***

School of Economics and Management, Xinjiang University, Urumqi 830049, China
*** Corresponding author:** Lu Gan, ganluchn@163.com

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**Abstract:** High-tech manufacturing and knowledge-intensive service industries exert significant spatial spillover effects on economic growth, which arise from their close coupling in innovation-driven development, value chain upgrading, mutual complementarity and synergy, spatial diffusion and spillover, as well as policy guidance and regional competition. First, their collaborative agglomeration enhances regional innovation capacity and industrial competitiveness, directing industrial structures toward higher value-added and more technologically advanced levels. Second, it enables the cross-regional flow and exchange of knowledge, technology, and talent, thereby fostering broader coordinated development and narrowing regional disparities. Empirical evidence indicates that such collaborative agglomeration is substantially more pronounced in the relatively developed central and eastern regions, yet remains comparatively weak in the western region, resulting in a nationwide spatial pattern characterized by the coexistence of "high-high" and "low-low" clusters. Further analysis using the Spatial Durbin Model confirms a significant positive impact of the joint agglomeration of high-tech manufacturing and knowledge-intensive services on regional economic growth, underscoring the vital importance of inter-industry collaboration. Spatial heterogeneity analysis reveals notable discrepancies in industrial agglomeration across regions. Consequently, strengthening the collaborative agglomeration capacity of these two industries is pivotal for establishing a new agglomeration model that aligns with their developmental requirements. Such efforts not only promote knowledge and technology spillovers but also help mitigate resource misallocation caused by congestion, thereby contributing to a reduction in regional development disparities.

**Keywords:** high-tech manufacturing; knowledge-intensive service industries; industrial agglomeration; spatial spillover effects

## 1. Introduction

The traditional extensive economic development model has become unsustainable under the new normal of the economy. Therefore, promoting the transition from a labor-intensive development model driven by factors to an intensive development model driven by knowledge and technological innovation has become a necessary requirement for enhancing the quality of economic growth. Knowledge- and technology-intensive industries have become the main drivers of global economic growth, playing an increasingly significant role in the world economy. Unlike traditional manufacturing and service industries, Knowledge-Intensive Business Services (KIBS) represent an emerging industry segment separated from the service sector, based on knowledge. KIBS have gradually become a key component of competition among countries or regions, playing a crucial role in the knowledge economy era. Meanwhile, high-tech manufacturing, due to its high level of technological innovation and added value, reflects a country's technological strength and industrial competitiveness and has become a pillar industry second only to traditional manufacturing. High-tech manufacturing not only serves as a crucial engine for new economic growth but also stimulates foreign trade and drives economic restructuring. This indicates that the "dual-engine" approach of manufacturing and services is an important characteristic of modern economic development. To improve the quality of economic growth and achieve stable economic development, it is essential to effectively combine innovation-driven strategies with the dual-engine approach. The core force driving innovative economic development lies in knowledge- and technology-intensive industries. KIBS, characterized by high knowledge content, high technological content, high interactivity, and strong innovation capacity, can make significant contributions to the innovation system in terms of knowledge distribution and learning abilities. At the same time, the technological innovation in high-tech manufacturing, through the incubation and realization of technological achievements, drives the production process of products, overcomes core and critical technological bottlenecks, and leads industrial technological revolutions. Therefore, the synergistic agglomeration of the two not only meets the needs of modern economic development but also aligns with the goals of high-quality economic growth.

In the new historical context, exploring the economic growth effects generated by the synergistic agglomeration of KIBS and high-tech manufacturing is of great significance. This synergistic agglomeration can achieve efficient resource allocation, promote high-quality economic development, and enhance the overall competitiveness of countries and regions. In conclusion, the coordinated development of KIBS and high-tech manufacturing is a key pathway for driving modern economic restructuring and improving the quality of economic growth. In the context of evolving economic conditions, it is crucial to fully harness knowledge and technology as catalysts for innovation, thereby advancing a dual-engine development approach that fosters sustainable economic growth. This strategy not only addresses the challenges posed by the emerging economic landscape but also provides a robust foundation for long-term development.

## 2. Literature review

Both Chinese and international researchers have conducted extensive research on Knowledge-Intensive Business Services (KIBS) and high-tech manufacturing from diverse perspectives. Research on KIBS mainly focuses on three aspects: Wei Jiang et al. [1] reviewed the concept of KIBS, defined its connotation, and proposed a specific classification method. Cao and She [2] collected and classified the concept of KIBS, identifying their respective characteristics, analyzing the deficiencies and reasons, and elaborating on the connotation and extension of KIBS in China. They further provided a concept and classification suitable for China's national conditions.

Xiong et al. [3] studied the internal and external factors influencing innovation activities in KIBS, constructed a KIBS collaborative innovation system model, and analyzed its operational mechanism. Zhang et al. [4] summarized the role of KIBS in different innovation processes and established a regional innovation endogenous system based on KIBS. They proposed development strategies for KIBS to promote the effective and sustainable operation of the regional innovation system. Antonietti and Cainelli [5] explored the main drivers of KIBS outsourcing in Italy’s manufacturing industry, finding that labor cost savings, information and communication technologies, and R&D investment have positive impacts. Building on a systematic review of domestic and international geography-focused studies on Knowledge-Intensive Business Services (KIBS), and employing CiteSpace 6.2.R6 for visual analyses of research hotspots, Fang et al. [6] demonstrate that KIBS exhibits a high degree of agglomeration in economically advanced regions. Furthermore, its spatiotemporal distribution pattern is closely associated with regional innovation environments, market demand, and shifts in the global division of industrial labor.

Pereyra et al. [7] analyzed the integration of knowledge-intensive business services (KIBS) and manufacturing enterprises in Mexico, indicating that such integration can lead to higher local economic growth and competitiveness. Zou et al. [8] used various indices to quantify the spatial agglomeration of KIBS in the Yangtze River Delta and conducted a global spatial correlation analysis to identify the factors influencing KIBS spatial agglomeration in the region. Wan et al. [9] constructed a panel data model based on the location entropy index to empirically analyze the impact of KIBS agglomeration on economic growth in 24 provinces and cities in China. Zhou [10] measured KIBS across 28 Chinese provinces and employed complex network and QAP methods to analyze the resulting linkage network. Key findings include 257 interprovincial connections, characterized by robust connectivity and stability, and a fourfold categorization of provinces—“two-way spillovers,” “brokers,” “primary beneficiaries,” and “net spillovers.” Geographic adjacency, manufacturing agglomeration, human capital, economic development, and openness jointly explain 71.3% of these spatial linkages.

Research on high-tech manufacturing primarily focuses on: Feng et al. [11], who measured the R&D efficiency of China’s high-tech manufacturing industry, revealing significant differences in R&D efficiency across various industries. Li and Feng [12] mainly studied the relationship between industry concentration and technological innovation performance in high-tech manufacturing. Dai et al. [13] used a three-stage DEA model to confirm the relationship between technological innovation efficiency and the business environment, proposing a series of countermeasures. Shi and Bao [14] analyzed the operational mechanism of the coupling system between high-tech services and equipment manufacturing. Li and Guo [15] emphasized the importance of accurately grasping the agglomeration level and spatiotemporal evolution of high-tech manufacturing in the Yangtze River Economic Belt for scientific regional industrial policy formulation. Shen and Pan [16] found that industrial agglomeration accelerates regional economic growth, especially in high-tech intensive service industries, the information industry, and the financial industry. They suggested that policymakers should leverage the positive externalities of industrial co-agglomeration and accelerate this process to promote high-quality economic growth in China. Kang et al. [17] constructed static and dynamic panel models to study the relationship between high-tech industrial agglomeration and the upgrading of high-tech export products, delving into open innovation through industrial agglomeration for sustainable development. Cheng et al. [18] discussed the impact of co-agglomeration between productive services and high-tech manufacturing on regional innovation efficiency and proposed optimizing industrial spatial layout to enhance innovation efficiency. Drawing on panel data from 2010 to 2019 for the Yangtze River Delta urban agglomeration, Xu and Yu [19] employed a spatial econometric model to investigate the spatial spillover effects of high-tech industry agglomeration on urban innovation. Their findings suggest that direct innovation spillovers exhibit an inverted U-shaped pattern. Moreover, the optimization of industrial structures in neighboring cities generates an inverted U-shaped nonlinear spillover effect, thereby influencing innovation output in adjacent urban areas.

Most studies on the agglomeration of KIBS and high-tech manufacturing and their economic growth effects focus on the relationship between the two. Lü and Jin [20] analyzed the impact of KIBS on innovation in high-tech manufacturing, concluding that the development of KIBS contributes to innovation in high-tech manufacturing and proposed policy recommendations. Ren et al. [21] found that KIBS has a synergistic growth effect on high-tech industries and argued that developing KIBS helps to overcome the middle-income trap. Li and Li [22] studied the impact of KIBS and high-tech manufacturing agglomeration, as well as their collaborative agglomeration, on innovation.

Through a review of the literature, it is found that research on the issue of collaborative agglomeration between KIBS and high-tech manufacturing mainly focuses on the degree of collaborative agglomeration and its influencing factors, with emphasis on the collaboration between high-tech services and high-tech manufacturing. However, studies on the effects of collaborative agglomeration are relatively limited, especially regarding high-tech manufacturing and KIBS. Czarnitzki and Spielkamp [23] pointed out that one of the main drivers of technological change and economic growth is KIBS, which will be the mainstream of future service industry development. As a product of the integrated development of modern services, KIBS plays an indispensable role in enhancing the competitiveness of high-tech manufacturing, and the collaborative agglomeration effect between the two should not be ignored. However, many scholars have not fully considered the spatial spillover effects that may arise from industrial collaboration. Therefore, this paper argues that the collaborative agglomeration of high-tech manufacturing and KIBS may result in nonlinear economic growth. To address this, the paper will explore the following aspects: first, it will establish a spatial panel model to examine the spatial spillover effects of the collaborative agglomeration of high-tech manufacturing and KIBS on economic growth; second, it will test the nonlinear relationship between collaborative agglomeration and economic growth by establishing a spatial autocorrelation model. Clarifying the complex relationship between the two is conducive to scientifically evaluating the development model of collaborative agglomeration between high-tech manufacturing and KIBS and provides a scientific basis for promoting the optimization and upgrading of regional industrial structures. Such analysis can achieve a “dual-engine” economic drive, improve the quality of economic growth, and promote the optimization and upgrading of regional industrial structures.

## 3. Mechanism analysis and hypothesis development

Knowledge-intensive service industries do not merely rely on knowledge but also generate it, functioning as both users and producers of expertise. In these industries, knowledge serves a dual role, operating as both an input and an output. Meanwhile, high-tech manufacturing, which is pivotal for advancing innovation-driven growth and transitioning from traditional to emerging economic drivers, is characterized by high levels of investment, innovation, and added value, alongside relatively low energy consumption. Consequently, the innovation-led momentum of economic growth significantly strengthens the spatial co-agglomeration of these two sectors. On this basis, the economic growth effects resulting from the co-agglomeration of knowledge-intensive service industries and high-tech manufacturing encompass spatial spillover effects and nonlinear benefits, which manifest in the following two dimensions:

(1) Both sectors share the commonality of innovation, and innovation is mobile.

Both high-tech manufacturing and knowledge-intensive service industries are centered on innovation, and the spatial co-agglomeration of these two sectors helps leverage the economic growth effects driven by innovation. On the one hand, knowledge-intensive service industries can realize the creation, transfer, and sharing of knowledge through enhanced interactions with their customers. By providing specialized problem-solving services to customers, and aligning their operations with client needs and industry development prospects, these industries can learn new technologies, absorb new knowledge, and thus produce or create new knowledge systems and resources. This new knowledge and resources can then be transmitted to customers through services, creating a beneficial feedback loop that forms a key cooperation mechanism between the two sectors. To promote the high-quality development of the manufacturing industry, not only are financial capital and highly skilled talent required, but also new knowledge as an input factor. By utilizing high-skilled talent and financial resources, knowledge can be transformed into new technologies and management methods, effectively applied in production activities to achieve innovation. On the other hand, high-tech manufacturing industries enhance the level of innovation by fostering the generation, transformation, and dissemination of technological innovations. These industries spread their technological innovation outcomes by providing advanced materials, instruments, core components, and transferring new technologies and management knowledge to other sectors. In improving the economy's innovation capacity, both high-tech manufacturing and knowledge-intensive service industries play central roles. Based on this, the first hypothesis is proposed:

Hypothesis 1: High-tech manufacturing and knowledge-intensive service industries exhibit a spatial correlation when they co-agglomerate.

(2) The economic growth effects of co-agglomeration are reflected in external economies and diseconomies.

The economic growth effects of co-agglomeration are reflected in the internal and external economies of scale. In terms of external economies, the adjacent co-location of these two sectors greatly helps reduce the costs of knowledge dissemination. With the increasing specialization in the technological innovation chains of high-tech manufacturing firms, companies need to obtain more knowledge or technical services externally, as internal service departments cannot fully meet their technological needs. Consequently, high-tech manufacturing industries are increasingly dependent on inputs from knowledge-intensive service industries. Their co-agglomeration contributes to improving resource allocation efficiency and productivity, facilitating the sharing and spatial flow of factor resources such as labor, technology, and capital, and creating complementary advantages. However, on the downside, the scale effect of their co-agglomeration may lead to external diseconomies, such as the siphoning effect of economic development, which attracts an influx of population into urban areas. The over-concentration of factors and industries in the same region may result in an imbalance in the allocation of resources, such as labor, resources, and technology, leading to issues like resource shortages and redundancies in labor and technology. These issues are likely to become more pronounced as more companies enter and the scale of industries expands. Excessive agglomeration may also exacerbate problems such as traffic congestion and environmental pollution, undermining the efficiency of market resource allocation. Based on external economies, the second hypothesis is proposed:

Hypothesis 2: The heterogeneity of industry co-agglomeration between high-tech manufacturing and labor-intensive service industries promotes regional economic growth and generates an “1 + 1 > 2” economic driving effect.

## 4. Research methods and variable descriptions

### 4.1. Research methods

Spatial autocorrelation assesses whether the observed values of a variable in one region are independent of those in neighboring regions. It can be examined from two distinct perspectives. Global autocorrelation analyzes the overall distribution, frequently exploring whether the pattern exhibits clustering. Local autocorrelation, in contrast, focuses on specific areas within the broader pattern to identify clusters or “hotspots” that may drive global clustering or reveal localized heterogeneity differing from the global trend.

Moran (1948) [24] proposed the first measure of spatial autocorrelation to study random phenomena distributed in two or more dimensions, which is defined as a method for measuring the correlation between neighboring observations in a pattern (Boots and Getis, 1988) [25]. The calculation Moran’s *I* is achieved by dividing the spatial covariance by the total variation.

The Moran’s Index formula is as follows:

$$Moran'sI = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}\left(Y_i - \overline{Y}\right)\left(Y_j - \overline{Y}\right)}{S^2 \sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}} \tag{1}$$

where $n$ represents the number of regions being observed, $Y_i$ and $Y_j$ represent the attribute values of geographic spatial units $i$ and $j$, respectively, $\overline{Y}$ denotes the mean of all observed values, and $W_{ij}$ represents the elements of the spatial weight matrix, indicating the spatial proximity or connection strength between geographic units $i$ and $j$. The index generally varies between −1 and 1. Values approaching +1 indicate positive spatial autocorrelation, where similar values cluster together. Values approaching −1 denote negative spatial autocorrelation, signifying that similar values are spatially dispersed. An index value of 0 implies a random pattern, reflecting no meaningful spatial autocorrelation.

#### 4.1.1. Spatial econometric model

Considering that regional economic convergence exhibits obvious characteristics of spatial correlation, this paper introduces a spatial panel model. Common spatial econometric models include the Spatial Autoregressive Model (SAR), the Spatial Error Model (SEM), and the Spatial Durbin Model (SDM). Among these, the Spatial Durbin Model is a generalized version of the Spatial Autoregressive and Spatial Error Models. Based on this, the spatial absolute convergence model can be expressed as follows:

In this model, $P_{it}$ denotes the level of economic growth, and $A_{it}$ is the core explanatory variable representing the co-agglomeration level of high-tech manufacturing and knowledge-intensive service industries. The term $\rho$ is the spatial autoregressive coefficient, while $W$ is the spatial weight matrix. $\lambda_0$ and $\lambda$ refer to the elasticity coefficients of the core explanatory variable and the control variables, respectively. $\mu_{it}$ and $\upsilon_{it}$ capture individual and time fixed effects, and $\varepsilon_{it}$ is the random disturbance term.

Sive Model (SAR): $P_{it} = \rho W P_{it} + \lambda_0 A_{it} + \lambda X_{it} + \mu_i + \upsilon_t + \varepsilon_{it}$

Spatial Error Model (SEM): $P_{it} = \lambda_0 A_{it} + \lambda X_{it} + \mu_i + \upsilon_t + \varepsilon_{it}$ $\varepsilon_{it} = \eta W \times \varepsilon_t + \gamma_{it}$

In this model, $\eta$ is the spatial error elasticity coefficient, representing the impact of region *i* on neighboring regions, and $\gamma_{it}$ is the random error term. The meanings of other variables are the same as in the previous formula. The key to constructing a spatial econometric model and performing spatial econometric analysis is that the spatial weight matrix should reflect the degree of interconnection between regions. Selecting an appropriate spatial weight matrix is crucial. The closeness of the connections between regions is inversely proportional to geographic distance, which is derived from the First Law of Geography. In the construction of spatial econometric models, both geographic distance and economic distance are considered when building the spatial weight matrix.

Spatial Durbin Model (SDM): $Y = \rho WY + X\beta + \theta WX + \alpha l_n + \varepsilon$

In this framework, the Spatial Durbin Model (SDM) serves as a generalized extension of the Spatial Autoregressive Model (SAR) and the Spatial Error Model (SEM). By incorporating spatial lags for both the dependent and explanatory variables, it captures spatial dependencies across these variables.

In the Spatial Durbin Model (SDM), $\rho$ denotes the spatial autocorrelation coefficient, reflecting the degree of spatial dependence among regions. The spatial weight matrix $W$ represents the intensity of spatial interactions between adjacent areas. The terms WY and WX are the spatial lag terms of the dependent and independent variables, respectively, accounting for the influence of neighboring regions on the focal region. The constant term is α, while ln is the $n \times 1$ identity matrix. The regression coefficients $\beta$ and $\theta$ capture the effects of the independent variables and their spatial lags, respectively. Finally, is the random error term. Taken together, these elements form a comprehensive framework for analyzing both direct and indirect spatial effects, thus shedding light on spatial dependencies and spillover dynamics across regions.

#### 4.1.2. Variable description

This study employs panel data from 2010 to 2021 for 30 provinces, municipalities, and autonomous regions in mainland China, excluding Tibet due to incomplete and severely missing observations. Missing data are addressed through linear interpolation, following a widely used scholarly approach, resulting in a fully interpolated dataset. Drawing from the classification method proposed by Wei et al. [1], the knowledge-intensive service industries are categorized into four major sectors: information transmission, computer services and software, financial services, leasing and business services, and scientific research and technical services. Employment data for these sectors is sourced from the "China Population and Employment Statistics Yearbook." Following the approach of Li and Li [22], and based on the classification method in the "China High-Technology Industry (Manufacturing) Classification" (2013), this study selects four major sectors as representatives of the high-tech manufacturing industry: pharmaceutical manufacturing, aerospace and equipment manufacturing, medical instruments and equipment manufacturing, and computer and office equipment manufacturing. Employment data for these sectors comes from the "China High Technology Industry Statistical Yearbook."

### 4.2. Dependent variable

Economic growth (PGDP) is commonly used to gauge a country's level of development and encompasses indicators such as total GDP, per capita real GDP, and GDP growth rate. To control for price fluctuations, this study adopts per capita real regional GDP as the primary measure of economic growth, deflated to 2010 as the base year.

#### 4.2.1. Independent variables

Considering data availability, the agglomeration indices of knowledge-intensive service industries and high-tech manufacturing industries are measured using the Location Quotient (LQ) method. The advantage of the Location Quotient lies in its wide applicability, as it effectively reflects the specialization of an industry sector and can also illustrate the status and role of a particular region on a broader scale, providing significant reference value.

The specific method is as follows: $LQ_{ij} = \frac{q_{ij}}{q_j} / \frac{q_i}{q}$

The location quotient index $LQ_{ij}$ is used to measure the agglomeration of industry $i$ in province $j$. In this formula, $q_{ij}$ and $q_i$ represent the employment of industry $i$ in province $j$ and nationwide, respectively, while $q_j$ and q represent the total employment in province $j$ and nationwide. A higher $LQ_{ij}$ value indicates a higher level of agglomeration of industry $i$ in province $j$. Following the research of Wang and Sui [26], the relative differences in industrial agglomeration are employed to depict the co-agglomeration of knowledge-intensive service industries and high-tech manufacturing industries.

$$LQ_A = \left(1 - \frac{|LQ_{hti} - LQ_{kibs}|}{LQ_{hti} + LQ_{kibs}}\right) + |LQ_{hti} + LQ_{kibs}|$$

In the formula, $LQ_A$ is the indicator used to measure the degree of industrial agglomeration, specifically the co-agglomeration index of knowledge-intensive service industries within the high-tech manufacturing sector. $LQ_{hti}$ represents the agglomeration index of high-tech manufacturing, while $LQ_{kibs}$ represents the agglomeration index of knowledge-intensive service industries. This co-agglomeration index not only reflects the overall level of co-agglomeration between high-tech manufacturing and knowledge-intensive service industries, but also indicates the depth of the co-agglomeration between the two industries.

#### 4.2.2. Control variables

The indicator system is constructed as shown in **Table 1**.

**Table 1.** Indicator system.

| Variable Type | Variable Name | Variable Symbol |
|---|---|---|
| Dependent Variable | Economic Development Level | lnPGDP |
| Independent Variable | Industry Co-Agglomeration Level | lnLQ |
| Control Variables | Government Expenditure Scale | lnSGE |
| | Foreign Direct Investment | lnFDI |
| | Human Capital | lnKL |
| | Innovation Level | lnInnov |

Data classification: All data were collected personally by the author.

(1) Government Expenditure Scale (SGE)

Government expenditure scale (SGE) substantially affects both economic fluctuations and growth, yet the adverse influence of economic volatility on regional economic development can outweigh the effects of government spending, posing a significant policy challenge. As an indicator of government intervention in market resource allocation, SGE is measured—following Shen and Huang [27]—by the ratio of local government fiscal expenditure to GDP.

(2) Foreign Direct Investment (FDI)

China's experience in attracting foreign capital indicates that, under certain conditions, foreign direct investment (FDI) can facilitate economic growth through competition effects and technology spillovers. However, FDI may also introduce challenges such as technological protectionism, resource depletion, human resource pressures, and environmental pollution, potentially hindering sustainable economic development. Following Yu et al. [28], this study adopts the ratio of a region's actual utilized foreign capital to its GDP as the measurement indicator for FDI.

(3) Human Capital (KL)

As an endogenous driving force for economic growth, human capital directly influences economic growth in China. Additionally, the knowledge spillover effect is a key reason for regional economic growth differences. Drawing from Zhu et al. [29] this study uses the average years of education as the measurement indicator for human capital input. The specific calculation method involves multiplying the proportion of people at each educational level (primary school, junior high school, high school, college, and above) by the corresponding years of education (6, 9, 12, 16), and summing the products. The calculation formula is as follows:$hc = x_1 \times 0 + x_2 \times 6 + x_3 \times 9 + x_4 \times 12 + x_5 \times 16$.

(4) Innovation Level (Innov)

Innovation-driven growth refers to the use of independent design, research, development, and knowledge production as the driving force for sustainable economic development. Patents reflect innovation based on knowledge and technology [30]. Therefore, this study adopts the number of invention patent applications, which represents autonomous innovation capacity, as a proxy variable for the innovation level. The number of invention patent applications (measured in tens of thousands) is logarithmically transformed for quantitative analysis, following the method used by Li and Li [22].

### 4.3. Empirical results

(1) Current State of Co-Agglomeration in High-Tech Manufacturing and Knowledge-Intensive Service Industries

Drawing on the Location Quotient and industrial agglomeration index approaches, this study measures the agglomeration levels of high-tech manufacturing and knowledge-intensive service industries, as well as their co-agglomeration levels, across various provinces in mainland China from 2010 to 2021. **Figure 1** displays the average values of these three indicators over the study period, revealing significant regional disparities in co-agglomeration levels. Different provinces exhibit distinct competitive advantages in the development of industrial agglomeration.

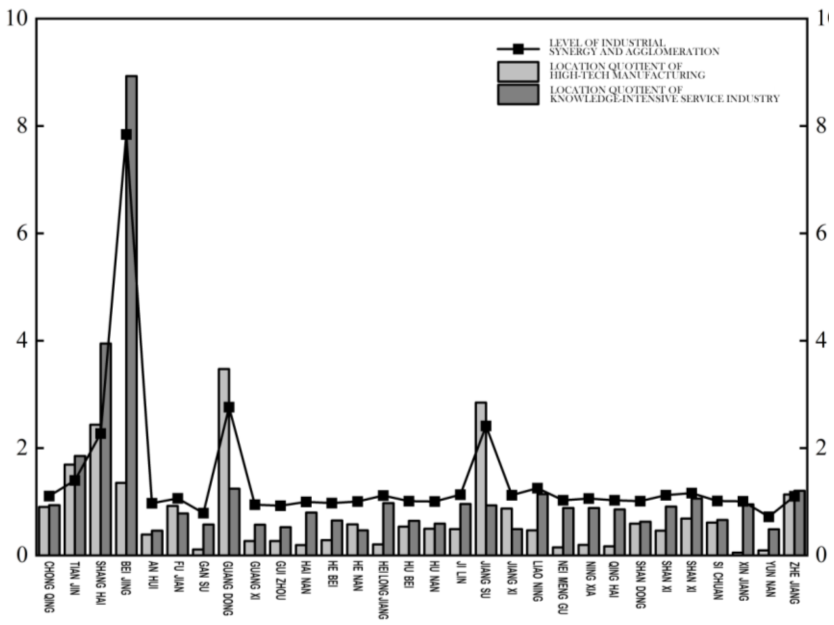



**Figure 1.** Average synergy and agglomeration levels between high-tech manufacturing and knowledge-intensive service industries across 30 Chinese provinces (2010–2021).

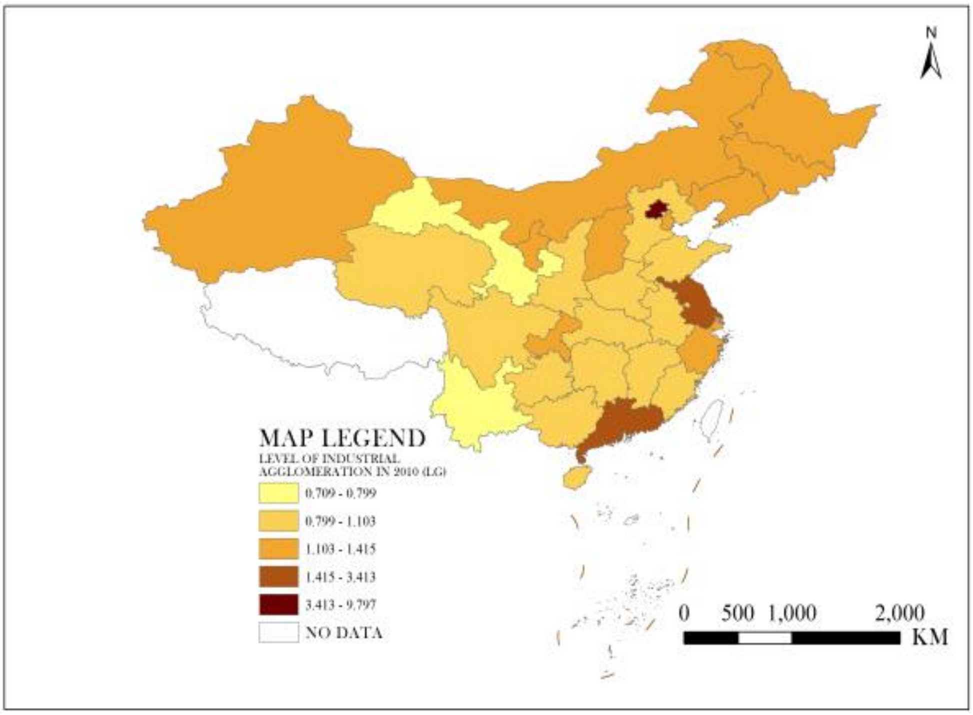
Data Source: The data was collected by the author and calculated independently.

In terms of high-tech manufacturing agglomeration, Guangdong and Jiangsu provinces show significantly higher levels of agglomeration compared to other regions, indicating that high-tech manufacturing has formed large-scale clusters in these two regions. In contrast, provinces like Gansu, Inner Mongolia, Qinghai, Yunnan, and Xinjiang show much lower agglomeration levels than the national average. These regions predominantly rely on primary industries due to their resource-based geographical locations, and their foundation for technology and knowledge-intensive industries remains weak.

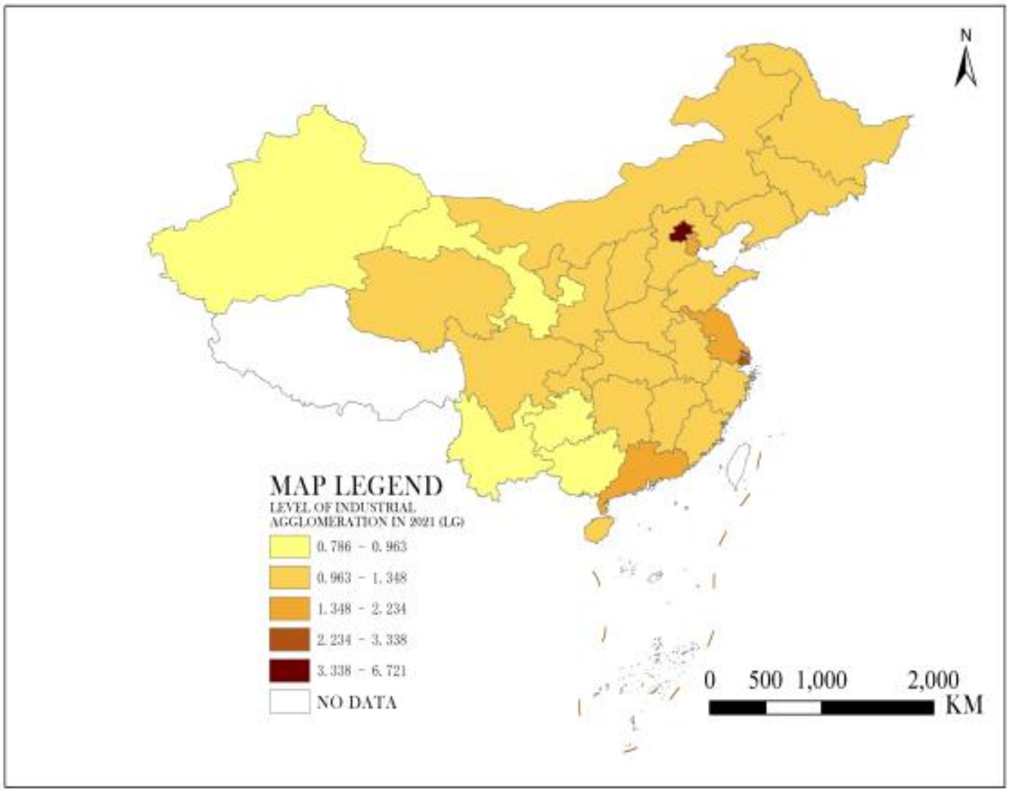
Regarding knowledge-intensive service industry agglomeration, Beijing ranks first in China, with its agglomeration level far exceeding that of other regions. This reflects Beijing's significant advantages as a geographical, economic, and technological center, with a notable edge in developing knowledge-intensive service industries. Most regions have agglomeration levels close to the national average, and compared to high-tech manufacturing, the regional differences in knowledge-intensive service industry agglomeration are smaller.

In terms of co-agglomeration between high-tech manufacturing and knowledge-intensive service industries, regions like Beijing, Guangdong, Shanghai, Jiangsu, and Tianjin exhibit much higher co-agglomeration levels than other regions, indicating an advantage both in the depth and quality of co-agglomeration. On the other hand, the co-agglomeration levels of high-tech manufacturing and knowledge-intensive service industries in Gansu and Yunnan are far below the national average. This suggests that not only are the levels of agglomeration for these industries low in these regions, but the differences in agglomeration are also significant.

**Figure 2** shows the changes in the regional distribution of co-agglomeration between high-tech manufacturing and knowledge-intensive service industries in 2010 and 2021. The figure reveals that regions such as Xinjiang, Inner Mongolia, Heilongjiang, Jilin, Liaoning, Jiangsu, Guangdong, Chongqing, Guizhou, Guangxi, Fujian, and Shaanxi experienced a decline in co-agglomeration levels, while Shanghai saw an increase. Overall, the co-agglomeration levels in 2010 are slightly lower than in 2021, indicating an upward trend in co-agglomeration. Regions with higher levels of co-agglomeration are mainly concentrated in the economically developed eastern coastal areas, while the western and southwestern regions exhibit lower levels. Generally, the pattern of co-agglomeration shows a "high in the east, low in the west" spatial distribution, gradually forming a distinct "east-high, west-low" agglomeration structure.




**(a)**




**(b)**

**Figure 2.** Level of industrial synergy and agglomeration between high-tech manufacturing and knowledge-intensive service industry in 2010 and 2021. **(a)** The industrial synergistic agglomeration level of high-tech manufacturing and knowledge-intensive service industries in 2010; **(b)** The industrial synergistic agglomeration level of high-tech manufacturing and knowledge-intensive service industries in 2021.

Data Source: The data was collected by the author and calculated independently.

## 4.4. Spatial analysis

Existing research indicates that economic development and industrial agglomeration exhibit spatial dependence. The flow of factors, industrial linkages, and trade exchanges can promote the coordinated development of regional economies. The effects of industrial spatial agglomeration, such as knowledge spillovers, technology diffusion, economies of scale, and resource integration, can significantly boost regional economic growth.

### 4.4.1. Spatial correlation analysis

Before applying spatial econometric models, it is essential to determine whether the study variables exhibit spatial dependence. Drawing on a distance-based spatial weight matrix, this study calculates the global Moran's I index for 30 provinces in China from 2010 to 2021, focusing on economic growth and the synergistic agglomeration of high-tech manufacturing with knowledge-intensive services. The results are shown in **Table 2**.

Throughout the observation period, the global Moran's I index for overall economic growth remains above zero at the 1% significance level, indicating a pronounced degree of spatial dependence in regional economic development. Except for 2011, the global Moran's I index for industrial synergy and agglomeration also exhibits positive values and shows a generally increasing trend, suggesting that the spatial correlation between high-tech manufacturing and knowledge-intensive services in China is gradually strengthening.

Based on these global Moran's I findings for the two core variables, employing spatial econometric models is appropriate. The significant spatial dependence observed in both China's economic growth and the co-agglomeration of high-tech manufacturing with knowledge-intensive services justifies the consideration of spatial effects in subsequent analyses.

**Table 2.** Spatial autocorrelation test results.

| Year | Economic Development Level | | | Industrial Synergy and Agglomeration Level | | |
|---|---|---|---|---|---|---|
| | **Moran`I** | ***z*-value** | ***p*-value** | **Moran`I** | ***z*-value** | ***p*-value** |
| 2010 | 0.705 | 6.860 | 0.000 | 0.038 | 0.821 | 0.206 |
| 2011 | 0.700 | 6.807 | 0.000 | −0.015 | 0.213 | 0.416 |
| 2012 | 0.703 | 6.832 | 0.000 | 0.053 | 0.996 | 0.160 |
| 2013 | 0.706 | 6.860 | 0.000 | 0.313 | 3.832 | 0.000 |
| 2014 | 0.705 | 6.844 | 0.000 | 0.387 | 4.574 | 0.000 |
| 2015 | 0.698 | 6.773 | 0.000 | 0.337 | 4.064 | 0.000 |
| 2016 | 0.688 | 6.689 | 0.000 | 0.410 | 4.870 | 0.000 |
| 2017 | 0.677 | 6.595 | 0.000 | 0.449 | 5.295 | 0.000 |
| 2018 | 0.669 | 6.525 | 0.000 | 0.476 | 5.595 | 0.000 |
| 2019 | 0.665 | 6.488 | 0.000 | 0.539 | 6.061 | 0.000 |
| 2020 | 0.665 | 6.501 | 0.000 | 0.529 | 6.068 | 0.000 |
| 2021 | 0.662 | 6.469 | 0.000 | 0.578 | 6.535 | 0.000 |

Data Source: The data was collected by the author and calculated independently.

#### 4.4.2. Spatial econometric model analysis

Further model selection tests are required. As presented in **Table 3**, both the LM-error and robust LM-error are significant at the 1% level, whereas the LM-lag and robust LM-lag are not significant, suggesting that the spatial error model outperforms the spatial lag model. Consequently, this study adopts the spatial Durbin model, which generalizes both approaches.

The Hausman test indicates that a fixed-effects specification is appropriate. Moreover, the Wald and LR tests show that the spatial Durbin model should not be simplified to either a spatial error or spatial lag model. These results confirm that the fixed-effects spatial Durbin model is the most suitable choice.

**Table 3.** Model selection tests.

| Test | Statistic | *p*-value |
|---|---|---|
| LM-error | 39.957 | 0.000 |
| Robust LM-error | 40.697 | 0.000 |
| LM-lag | 0.438 | 0.508 |
| Robost LM-lag | 1.178 | 0.278 |
| Hausman test | 42.28 | 0.000 |
| Wald-sem | 61.16 | 0.000 |
| Wald-sar | 36.05 | 0.000 |
| LR-sem | 55.44 | 0.000 |
| LR-sar | 34.96 | 0.000 |

Data Source: The data was collected by the author and calculated independently.

**Table 4** presents the regression outcomes for the three principal spatial econometric models. The Spatial Durbin Model (SDM) outperforms both the Spatial Error Model (SEM) and the Spatial Autoregressive Model (SAR) in terms of goodness of fit ($R^2$) and log-likelihood (LOG-L), confirming its superiority. At the 1% significance level, the collaborative agglomeration (LQ) of high-tech manufacturing and knowledge-intensive services has a significantly positive effect on regional economic growth, underscoring the role of heterogeneous-industry co-agglomeration in stimulating economic expansion.

From a micro-level perspective, collaboration between high-tech manufacturing and knowledge-intensive services deepens industrial specialization and raises production efficiency through inter-industry division of labor and cooperation. This process provides more specialized services for various stages of high-tech manufacturing, thereby promoting economic growth. At a broader level, bringing together industries with diverse attributes improves resource allocation efficiency by allowing resources to flow freely across sectors, reducing access barriers, and fostering industrial integration, innovation, and complementary advantages. Moreover, innovation, technology, and foreign investment circulate more readily between regions, enhancing talent exchange and technological interaction. These interregional linkages generate spatial spillover effects driven by knowledge, technology, and innovation, ultimately forming an economic agglomeration effect that propels regional development.

Turning to the model selection tests (**Table 3**), the LM-error and robust LM-error are both significant at the 1% level, whereas the LM-lag and robust LM-lag lack significance, indicating that the spatial error model is preferable to the spatial lag model. Consequently, the SDM—a generalized form of both—is adopted. The Hausman test identifies fixed effects as the appropriate specification. Furthermore, the Wald and LR tests confirm that the SDM should not be reduced to either an SEM or an SAR. Thus, a fixed-effects SDM is the most suitable model.

**Table 4.** Spatial econometric regression results.

| **Variable** | **SEM** | **SAR** | **SDM** |
|---|---|---|---|
| lnLQ | 0.0398** | 0.0158 | 0.1007*** |
| | (2.01) | (0.93) | (4.60) |
| lnSGE | −0.4583*** | −0.4272*** | −0.4456*** |
| | (−14.74) | (−14.15) | (−14.80) |
| lnFDI | 0.0201*** | 0.0226*** | 0.0152*** |
| | (4.27) | (4.88) | (3.26) |
| lnKL | 0.0129 | 0.0042 | 0.0015 |
| | (0.68) | (0.21) | (0.08) |
| lnInnov | 0.5221*** | 0.4641*** | 0.5433*** |
| | (7.98) | (7.33) | (8.47) |
| WxlnLQ | | | 0.1747*** |
| | | | (4.74) |
| WxlnSGE | | | 0.0348 |
| | | | (0.45) |
| WxlnFDI | | | −0.0451*** |
| | | | (−3.38) |
| WxlnKL | | | 0.0996** |
| | | | (2.44) |
| WxlnInnov | | | 0.2540 |
| | | | (1.57) |
| ρ/λ | 0.5860*** | 0.6348*** | 0.5308*** |
| | (11.05) | (10.37) | (8.02) |
| Year Fixed Effects | Yes | Yes | Yes |
| Province Fixed Effects | Yes | Yes | Yes |
| N | 360 | 360 | 360 |
| R2 | 0.523 | 0.310 | 0.765 |
| Log-l | 643.8835 | 654.1240 | 671.6045 |

Note: *z*-statistics in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

This table presents the spatial econometric regression results for three models: SEM (Spatial Error Model), SAR (Spatial Autoregressive Model), and SDM (Spatial Durbin Model). The SDM model shows a better fit with the highest $R^2$ and log-likelihood, supporting its selection as the preferred model.

The impact of government spending scale (SGE) on economic growth, from the perspective of control variables, is evidently negative. Excessive government intervention leads to a decrease in resource allocation efficiency, thereby hindering economic development, a situation that improves with the gradual refinement of the market economy system. The positive effect of foreign direct investment (FDI) on economic growth is significant, indicating that the capital accumulation effect brought by foreign investment helps bridge funding gaps, while the technology spillover effect assists in reducing R&D costs and risks, thus promoting economic growth. Human capital (KL) and innovation levels (Innov) also have a significantly positive impact on economic growth, showing that their cumulative effects on knowledge and technological innovation generate notable agglomeration effects, contributing to the sustainable development of China's economy.

#### 4.4.3. Spatial heterogeneity analysis and robustness analysis

This paper further decomposes the Spatial Durbin Model into direct effects, indirect effects, and total effects. The results are presented in **Table 5**.

**Table 5.** Spatial Durbin model effect decomposition.

| Variable | Direct Effect | Indirect Effect | Total Effect |
| --- | --- | --- | --- |
| lnLQ | $0.1340^{***}$ | $0.4648^{***}$ | $0.5988^{***}$ |
| | (4.933) | (4.211) | (4.569) |
| lnSGE | $-0.4747^{***}$ | $-0.4022^{**}$ | $-0.8769^{***}$ |
| | (−13.837) | (−2.529) | (−4.820) |
| lnFDI | $0.0104^{**}$ | $-0.0745^{***}$ | $-0.0641^{**}$ |
| | (2.001) | (−2.764) | (−2.122) |
| lnKL | 0.0156 | $0.2090^{**}$ | $0.2246^{**}$ |
| | (0.811) | (2.513) | (2.457) |
| lnInnov | $0.6206^{***}$ | $1.0989^{***}$ | $1.7195^{***}$ |
| | (8.394) | (3.120) | (4.300) |

Note: *z*-statistics in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The decomposition of the Spatial Durbin Model reveals that the collaborative agglomeration of high-tech manufacturing and knowledge-intensive services (lnLQ) exerts both significant direct and indirect positive effects, culminating in a robust total impact. Government spending (lnSGE) demonstrates a markedly negative total effect, driven by a substantial negative direct effect and a moderately negative indirect effect. Foreign direct investment (lnFDI) presents a nuanced pattern, exhibiting a positive direct effect that is offset by a significant negative indirect effect, resulting in a slightly negative overall effect. Human capital (lnKL) shows a positive total effect, primarily attributable to its indirect influence. Innovation (lnInnov) exerts the most substantial positive impact, with significant positive direct and indirect effects, thereby contributing to a considerable total effect.

The direct effect analysis indicates that the collaborative agglomeration of high-tech manufacturing and knowledge-intensive service industries exerts a coefficient of 0.134 on local economic growth, which is significant at the 1% level. This finding demonstrates that industrial collaborative agglomeration substantially promotes local economic development. Moreover, the indirect effects reveal a significantly positive spatial spillover, suggesting that such agglomeration also spurs economic growth in surrounding regions. Consequently, the collaborative agglomeration of high-tech manufacturing and knowledge-intensive service industries in one region attracts and drives the economic advancement of neighboring areas.

Both the direct and indirect effects of government spending (SGE) are negative, indicating that government investment obstructs local economic growth and its spatial spillovers to other regions. As market mechanisms continue to evolve, excessive government intervention diminishes resource allocation efficiency and hampers economic development. In contrast, foreign direct investment (FDI) exhibits a positive direct effect but a significantly negative indirect effect: while substantial capital inflows from FDI enhance local economic performance by increasing investment levels, the resultant siphoning effect intensifies competition for local firms, leading to imbalanced economic development and suppressing growth in neighboring areas. Meanwhile, both human capital (KL) and innovation (Innov) show positive direct and indirect effects, suggesting that the accumulation of human capital and technological advancements fosters knowledge spillovers that benefit local and surrounding regions alike.

In terms of total effects, the collaborative agglomeration of high-tech manufacturing and knowledge-intensive service industries exerts a significantly positive influence on economic growth. This outcome aligns with China’s broader developmental achievements and confirms Hypothesis 2. Meanwhile, government spending and foreign investment both exhibit negative effects on economic growth. Excessive government intervention can distort market signals, leading to resource misallocation and hindering economic development. Additionally, certain foreign enterprises may form monopolies through mergers and expansions, thereby controlling prices and supply, suppressing the growth of local firms. Profits earned locally may be repatriated, depriving the domestic economy of capital accumulation and reinvestment opportunities, ultimately constraining long-term development. By contrast, human capital and innovation demonstrate significantly positive impacts on economic growth, reflecting the importance of interregional talent mobility and technological progress in China. This facilitates personnel exchanges and technical cooperation across regions, fostering broader development and creating an economic agglomeration effect that drives overall growth.

#### 4.4.4. Spatial robustness analysis

This paper uses two methods to conduct robustness checks. First, the economic geography matrix is replaced by an adjacency matrix for modeling analysis. Second, the dependent variable per capita GDP is replaced by GDP for robustness testing. The results show that the findings remain robust.

**Table 6.** Robustness test results.

| Variable | Replaced with Adjacency Matrix | | | Replaced Dependent Variable with GDP | | |
|---|---|---|---|---|---|---|
| | **Direct Effect** | **Indirect Effect** | **Total Effect Direct Effect** | **Direct Effect** | **Indirect Effect** | **Total Effect Direct Effect** |
| lnLQ | $0.0940^{***}$ | $0.3111^{***}$ | $0.4051^{***}$ | $0.1089^{***}$ | $0.4751^{***}$ | $0.5839^{***}$ |
| | (3.580) | (3.538) | (3.737) | (3.059) | (3.620) | (3.674) |
| lnSGE | $-0.4354^{***}$ | $-0.3029^{***}$ | $-0.7383^{***}$ | $-0.5160^{***}$ | −0.2073 | $-0.7233^{***}$ |
| | (−13.372) | (−2.827) | (−5.891) | (−11.401) | (−1.019) | (−3.096) |
| lnFDI | $0.0156^{***}$ | −0.0143 | 0.0013 | $0.0139^{**}$ | $-0.1194^{***}$ | $-0.1055^{***}$ |
| | (3.177) | (−0.950) | (0.071) | (2.023) | (−3.266) | (−2.593) |
| lnKL | 0.0318 | −0.0589 | −0.0271 | −0.0200 | $0.1993^{*}$ | 0.1792 |
| | (1.596) | (−0.942) | (−0.370) | (−0.788) | (1.872) | (1.531) |
| lnInnov | $0.4934^{***}$ | $0.4921^{*}$ | $0.9854^{***}$ | $0.7415^{***}$ | $1.0845^{**}$ | $1.8260^{***}$ |
| | (6.849) | (1.927) | (3.320) | (7.609) | (2.392) | (3.539) |

Note: *z*-statistics in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The robustness tests (see **Table 6**) show that the collaborative agglomeration of high-tech manufacturing and knowledge-intensive services (lnLQ) continues to have a significantly positive impact on economic growth, regardless of whether the economic geography matrix is replaced with the adjacency matrix or the dependent variable is replaced with GDP. Government spending (lnSGE) remains significantly negative, indicating that excessive government intervention still hampers economic development. The impact of foreign direct investment (lnFDI) is positive in direct effects but shows mixed results with negative indirect effects. Human capital (lnKL) shows no significant impact when the adjacency matrix is used, but presents a positive indirect effect when the dependent variable is GDP. Finally, innovation levels (lnInnov) consistently show strong positive effects on economic growth across both robustness tests.

#### 4.4.5. Spatial heterogeneity analysis

A comparison of high-tech manufacturing and knowledge-intensive service industries reveals significant regional variation in industrial agglomeration patterns. Evidence from **Table 7** indicates that in the central and western regions, the coefficients for the collaborative agglomeration of these industries on economic growth are 0.3893 and 0.1952, respectively, both significant at the 1% level. These findings suggest that industrial collaborative agglomeration markedly promotes economic growth in these areas. In terms of indirect effects, the spatial spillover is notably positive, indicating that collaborative agglomeration in the central, eastern, and western regions also stimulates economic expansion elsewhere. This further confirms that the collaborative agglomeration of high-tech manufacturing and knowledge-intensive services in one region attracts and propels the economic development of surrounding areas.

**Table 7.** Spatial heterogeneity analysis.

| | Variable | Eastern Region | Central Region | Western Region |
|---|---|---|---|---|
| Direct Effect | lnLQ | 0.0197 (0.94) | 0.3893*** (4.36) | 0.1952*** (3.41) |
| | lnSGE | −0.3119*** (−6.05) | −0.6996*** (−9.66) | −0.5733*** (−7.74) |
| | lnFDI | 0.0350*** (3.27) | 0.0029 (0.26) | −0.0111** (−2.16) |
| | lnKL | −0.0115 (−0.43) | 0.0347 (0.91) | −0.0012 (−0.05) |
| | lnInnov | 0.9113*** (6.38) | 0.3082 (1.61) | 0.0410 (0.48) |
| Indirect Effect | lnLQ | 0.1940*** (4.27) | 0.5823*** (3.05) | 0.8251*** (3.20) |
| | lnSGE | 0.1407 (0.81) | −0.1478 (−0.66) | −0.7979*** (−2.60) |
| | lnFDI | −0.0523* (−1.72) | 0.0451* (1.71) | −0.0826*** (−3.27) |
| | lnKL | −0.2359** (−2.11) | 0.3094** (2.47) | 0.1694 (1.37) |
| | lnInnov | 1.7770*** (3.46) | −0.0428 (−0.07) | −0.5469 (−1.26) |
| Total Effect | lnLQ | 0.2137*** (3.77) | 0.9715*** (4.59) | 1.0204*** (3.58) |
| | lnSGE | −0.1712 (−0.88) | −0.8474*** (−3.46) | −1.3712*** (−3.78) |
| | lnFDI | −0.0173 (−0.48) | 0.0479 (1.46) | −0.0937*** (−3.45) |
| | lnKL | −0.2474** (−2.12) | 0.3441** (2.31) | 0.1682 (1.24) |
| | lnInnov | 2.6883*** (4.95) | 0.2654 (0.36) | −0.5059 (−1.07) |

Note: *z*-statistics are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Examining the direct effects of the control variables reveals that government spending (SGE) exerts a negative direct impact in the eastern, central, and western regions, indicating that government investment curtails both local economic growth and its spatial spillovers. As market mechanisms mature, excessive government intervention reduces resource allocation efficiency, thereby impeding economic progress. By contrast, foreign direct investment (FDI) exerts a positive direct effect in the eastern and central regions, suggesting that foreign capital inflows stimulate economic growth in these areas. However, in the eastern region, FDI’s indirect effect is significantly negative, whereas in the central region it is positive, implying that foreign investment suppresses growth in neighboring areas of the east but fosters it in the central region. Although FDI increases local investment levels, the siphoning effect in the eastern region often intensifies competition for local enterprises, resulting in uneven economic development and slowing growth in surrounding areas. In the western region, both the direct and indirect effects of FDI are notably negative, indicating that foreign investment heightens economic strain rather than contributing to growth.

The direct effects of human capital (KL) are negatively correlated in the eastern and western regions but significantly positive in the central region. This suggests that the talent structure in the eastern region is saturated, with an oversupply that might lead to a decrease in wage levels, thus reducing overall consumption capacity and negatively affecting economic growth. In the western region, a mismatch between human capital and market demand may lead to rising unemployment or low-efficiency employment, further negatively impacting the economy. In the central region, the human capital structure aligns well with economic development levels, promoting regional economic growth. The direct and indirect effects of innovation levels (Innov) are both positive in the eastern region, indicating that the knowledge and technological innovation generated by innovation agglomeration brings more economic benefits to the region and its surroundings. In the central and western regions, the direct effect of innovation is positively correlated, indicating that innovation improves productivity and efficiency. The introduction of new technologies, products, and processes enhances the competitiveness of enterprises and drives industry growth, promoting regional economic development. However, the indirect effects of innovation in the central and western regions are significantly negative, suggesting that the innovation process may cause short-term economic pains, and the industrial agglomeration is still immature, leading to a slowdown in economic growth. External diseconomies, such as ecological problems and environmental pollution, may also hinder economic development.

In terms of overall impact, the collaborative agglomeration of high-tech manufacturing and knowledge-intensive service industries exerts a significantly positive influence on economic growth in the eastern, central, and western regions, consistent with achievements in China's regional economic development. However, government spending, foreign direct investment, and human capital in the eastern region collectively exert a negative total effect on economic growth. Excessive government intervention can distort market signals, leading to inefficient resource allocation and inhibiting development. Some foreign enterprises may establish monopolies through mergers and expansions, thereby controlling prices and supplies and suppressing local firms. Profits generated locally may be transferred abroad, depriving the domestic economy of capital accumulation and reinvestment opportunities and constraining long-term growth.

By contrast, innovation exerts a significantly positive total effect, indicating that the free movement of talent and technology within the eastern region fosters talent exchange and technological interaction, driving progress in neighboring areas. This dynamic creates an economic agglomeration effect that further propels overall economic development.

In the central region, foreign direct investment, human capital, and innovation levels all have significantly positive effects, indicating that these factors have effectively promoted economic growth in the region. In the western region, the total effects of foreign investment and innovation are negatively correlated, suggesting that these two factors have suppressed local economic development due to external diseconomies. However, the total effect of human capital in the western region is significantly positive, indicating that the human capital structure in the region can promote local economic development.

The spatial heterogeneity analysis for the Eastern, Central, and Western regions indicates that high-tech manufacturing and knowledge-intensive service industry agglomeration (lnLQ) exerts a significantly positive direct effect on economic growth in the Central and Western regions, whereas its influence in the Eastern region is not significant. Government spending scale (lnSGE) shows negative direct effects across all three regions, suggesting that it hinders economic growth. Meanwhile, foreign direct investment (lnFDI) has a positive direct impact in the Eastern region but negatively affects the Western region.

In terms of indirect effects, lnLQ exhibits significant positive spillover effects in all regions, promoting economic growth in neighboring areas. The indirect effect of lnSGE is significantly negative in the Western region, indicating that government investment also hinders economic growth in other regions. The total effects follow similar patterns, with lnLQ contributing positively to economic growth across all regions, and government spending (lnSGE) negatively impacting economic growth, particularly in the Central and Western regions. Finally, the innovation level (lnInnov) shows a strongly positive total effect in the Eastern region, reinforcing the importance of innovation for regional growth. However, in the Western region, lnInnov has a negative total effect, suggesting that innovation may still face obstacles in fostering economic growth.

## 5. Conclusion and policy implications

### 5.1. Conclusion

Drawing on panel data from 30 provinces and municipalities in China, this study employs a spatial panel model to investigate the spatial spillover effects of the collaborative agglomeration of high-tech manufacturing and knowledge-intensive service industries on economic growth. The principal findings are as follows:

(1) Significant Differences in Regional Industrial Agglomeration Characteristics: There are substantial variations in the agglomeration of high-tech manufacturing and knowledge-intensive service industries across different regions. High levels of collaborative agglomeration are primarily concentrated in the economically advanced central and eastern regions, while low levels prevail in the western areas. A “high–high” and “low–low” pattern of spatial agglomeration has gradually emerged nationwide. Overall, the eastern and central regions are witnessing gradual improvements in collaborative agglomeration, whereas the western region is experiencing a decline.

(2) Spatial Spillover Effects: Except for 2011, the levels of regional economic growth and the collaborative agglomeration of high-tech manufacturing and knowledge-intensive service industries demonstrate spatial autocorrelation throughout the observation period, underscoring significant spillover effects on neighboring regions. The Spatial Durbin Model (SDM) results indicate that the collaborative agglomeration of these industries exerts a significantly positive influence on economic growth, affirming that heterogeneous industrial agglomeration fosters regional economic expansion. Among the control variables, government spending (SGE) exerts a notable negative effect on economic growth, while foreign direct investment (FDI) exerts a significantly positive impact. These findings suggest that prudent government spending and foreign investment policies are vital for stimulating regional economic growth. Although the collaborative agglomeration of high-tech manufacturing and knowledge-intensive services notably promotes regional economic performance, its effects vary across different regions. Policymakers are advised to plan industrial layouts according to regional characteristics to optimize resource allocation and maximize the economic benefits of such collaborative agglomeration.

(3) Decomposition of Effects in the Durbin Model: The Spatial Durbin Model (SDM) partitions impact into direct, indirect, and total effects. The direct effects indicate that the collaborative agglomeration of high-tech manufacturing and

knowledge-intensive service industries significantly advances local economic growth. Meanwhile, the indirect effects confirm positive spatial spillovers, illustrating that such agglomeration also fosters economic development in neighboring regions. Among the control variables, government spending (SGE) imposes negative direct and indirect effects, whereas foreign direct investment (FDI) exerts a positive direct effect yet a markedly negative indirect effect. Both human capital and innovation levels benefit local and surrounding areas. Turning to the total effects, the collaborative agglomeration of high-tech manufacturing and knowledge-intensive service industries exerts a significantly positive impact on economic growth, validating Hypothesis H2. By contrast, government spending and foreign direct investment exhibit negative total effects, while human capital and innovation demonstrate notably positive overall influences.

(4) Spatial Heterogeneity: Industrial agglomeration patterns differ considerably across regions. The direct effects indicate that the collaborative agglomeration of high-tech manufacturing and knowledge-intensive services significantly boosts economic growth in the central and western regions, alongside a notably positive spatial spillover effect. Government spending (SGE) consistently exhibits negative direct influences in the eastern, central, and western regions. Foreign direct investment (FDI) exerts a positive direct effect in both the eastern and central regions, yet its indirect effect is significantly negative in the east and positive in the center. In the west, both the direct and indirect effects of FDI are negative. Human capital (KL) shows a negative direct effect in the eastern and western regions but a significantly positive one in the central region. Innovation (Innov) generates positive direct and indirect effects in the east, whereas it has positive direct but significantly negative indirect effects in the center and west.

(5) Turning to total effects, the collaborative agglomeration of high-tech manufacturing and knowledge-intensive services exerts a significantly positive impact on economic growth in the eastern, central, and western regions alike. In the east, the total effects of government spending, foreign investment, and human capital on economic growth are negative, while innovation is significantly positive. In the central region, foreign investment, human capital, and innovation all have significantly positive total effects on economic growth. In the west, foreign investment and innovation exhibit negative total effects, whereas human capital has a significantly positive influence, indicating its role in promoting local economic development.

## 5.2. Policy implications

The findings offer significant policy insights for advancing economic growth, especially through the collaborative agglomeration of high-tech manufacturing and knowledge-intensive service industries:

(1) Enhance the collaborative agglomeration capacity of high-tech manufacturing and knowledge-intensive service industries. Key industries such as new energy, new materials, advanced manufacturing, and cultural tourism should be prioritized. For the western region with low agglomeration levels, regional resources, location advantages, and economic foundations should be considered

comprehensively. By scientifically planning industrial parks and economic development zones, resources can be concentrated to enhance regional competitiveness and sustainable development, thereby promoting industrial agglomeration. Additionally, leveraging the agglomeration advantages of knowledge-intensive service industries can help foster high-tech service industry clusters with modern business models. For the central and eastern provinces, optimizing the spatial layout of high-tech manufacturing and promoting automation in service and manufacturing sectors through stronger industrial linkages will create new collaborative agglomeration models. Policymakers should focus on mechanism innovation to drive the synergistic development of these industries, encouraging knowledge and technology spillovers.

(2) Strengthen the spatial role of high-tech manufacturing and knowledge-intensive service industries. Spatial econometric analysis shows that the collaborative agglomeration of these industries has significant spatial spillover effects. First, enhancing inter-regional collaboration platforms can facilitate information exchange, enabling the collaborative agglomeration of high-tech manufacturing and knowledge-intensive service industries across neighboring regions. Second, through regional industrial interaction, collaborative industrial development can be promoted. Finally, optimizing industrial layouts by adopting industry transfer models can reduce resource imbalance caused by crowding effects and narrow regional development gaps.

In summary, fostering the collaborative agglomeration of high-tech manufacturing and knowledge-intensive service industries not only enhances resource allocation and production efficiency but also facilitates the sharing and spatial circulation of labor, technology, capital, and other resources. Through effective policy planning and institutional innovation, regional industrial structures can be optimized and upgraded, ultimately advancing high-quality, sustainable economic development.

## 5.3. Future research outlook

Building upon the imperative of high-quality economic development and the shift toward new growth drivers, this study investigates the mechanisms and effects of collaborative agglomeration between high-tech manufacturing and knowledge-intensive service industries on economic growth. The findings indicate that such collaborative agglomeration substantially promotes economic performance within the focal regions and their neighboring provinces, although excessive agglomeration may produce crowding effects that constrain further growth. In light of these results, this study proposes corresponding policy measures. Nevertheless, given the relatively limited research in this field and certain constraints in research capacity, this paper still faces some limitations. Future work may be expanded in the following directions:

(1) Future research could employ more refined statistical metrics to classify high-tech manufacturing and knowledge-intensive service industries by sector or technological level. By distinguishing among different types of sub-industries,

scholars can investigate their locational choices, collaborative innovation models, and integration with local industrial chains, thereby identifying the heterogeneous effects of each sub-industry's collaborative agglomeration on economic growth.

(2) Future research could further examine how collaborative agglomeration influences the transformation and upgrading of industrial structures—for example, by assessing how the coupling of industrial chains among different sub-industries affects regional economic structures. Another direction involves investigating the impact of collaborative agglomeration on employment structures or job quality, such as whether the agglomeration of high-tech services and manufacturing creates more high-skill positions and thereby enhances regional human capital. Additionally, the role of collaborative agglomeration in fostering technological innovation deserves attention, particularly with respect to knowledge sharing and collaborative R&D among firms, which holds significant potential for regional innovation ecosystems.

(3) Although this research confirms the overall positive effect of collaborative agglomeration on economic growth, variations in industrial foundations, resource endowments, and market environments across different regions may yield distinct optimal levels or ranges of such agglomeration. Insufficient agglomeration may fail to generate significant economies of scale, whereas excessive agglomeration can lead to congestion effects, environmental pressures, or increased factor costs, thereby hindering economic development. Future research could employ methods such as threshold regression or quantile regression to examine how varying degrees of high-tech manufacturing and knowledge-intensive service agglomeration—under different conditions (e.g., land-use intensity, environmental capacity, and human resource availability)—affect economic growth, ultimately identifying the optimal agglomeration range or threshold value.

(4) Refining the "1 + 1 > 2" Framework: Conceptual Definitions, Dynamic Interactions, and Policy Implications Future research should focus on refining the "1 + 1 > 2" framework by addressing the conceptual and empirical definition of the "1" effect, with emphasis on its baseline characterization and quantification. This can involve constructing counterfactual baselines through methods such as synthetic control or difference-in-differences to isolate the intrinsic contribution of the local area absent collaborative agglomeration effects. Dynamic analysis is also necessary to explore the temporal evolution of these effects, such as the initial dominance of local impacts in early stages of agglomeration and the increasing importance of spillover effects over time. Scenario-based studies could extend the framework by exploring optimal balances between local and surrounding contributions in various regional contexts. Moreover, integrating the framework with policy analysis could identify strategies to strengthen local effects to achieve or exceed the "1" baseline while simultaneously enhancing spillover effects to benefit surrounding areas. These research directions aim to enhance the theoretical rigor and empirical relevance of the "1 + 1 > 2" framework for regional economic development strategies.

(5) The Impact of Collaborative Agglomeration on Regional Economic Resilience Collaborative agglomeration serves not only as a key driver of economic growth but also as a mechanism for enhancing regional economic resilience and long-term sustainability. In the face of economic fluctuations or external shocks, collaborative agglomeration can mitigate negative impacts by fostering industrial collaboration, strengthening innovation capacity, and enhancing factor mobility. For example, agglomeration may improve regional economic stability and risk resistance through diversification of industrial structures and optimization of employment structures. Moreover, collaborative agglomeration holds potential for promoting green development by facilitating the growth of resource-efficient and environmentally friendly industries, thereby reducing the environmental costs of economic growth. Simultaneously, agglomeration can create high-skill job opportunities, contributing to the accumulation of regional human capital, which is essential for sustained economic growth. Future research should investigate how different types of industrial agglomeration, such as high-tech manufacturing and knowledge-intensive services, contribute to these dimensions in a differentiated manner, thus providing targeted insights for policy-making.

(6) Dynamic and Nonlinear Effects of Collaborative Agglomeration While collaborative agglomeration has significant positive impacts on regional economic development, its effects may exhibit dynamic and nonlinear characteristics. Studies indicate that agglomeration within an optimal range can generate economies of scale, while excessive agglomeration may lead to congestion effects, environmental stress, or rising factor costs, thereby hindering economic growth. To address this complexity, future research should examine the optimal range or thresholds of agglomeration under varying regional conditions, such as land-use intensity, environmental capacity, and human resource availability. Threshold regression or quantile regression methods could be particularly useful in identifying how different levels of agglomeration in high-tech manufacturing and knowledge-intensive services influence economic growth across regions and development stages. Dynamic analysis methods could further explore the temporal evolution of agglomeration effects. For instance, local effects may dominate in the early stages of agglomeration, while spillover effects to surrounding areas become more pronounced as the scale of agglomeration expands. By uncovering the dynamic and nonlinear nature of collaborative agglomeration, future research could provide more precise theoretical guidance for regional economic planning and policy optimization.

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