High-technology Industry Agglomeration, Spatial Spillover Effects and Regional Economic Resilience Enhancement

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Abstract. This paper explores the impact of high-tech industrial agglomeration on regional economic resilience by constructing a two-way fixed-effects model based on the sample data of 31 provinces and cities in China from 2000 to 2021. The results show that the local economic resilience is strengthened with the increase of the level of industrial agglomeration. The results show that local economic resilience increases with the level of industrial agglomeration, and the findings remain reliable after a series of robustness tests. The heterogeneity test finds that the enhancement of regional economic resilience by high-tech industrial agglomeration is more obvious in the central region and at high marketisation levels. In order to further explore the spatial effect of high-tech industrial agglomeration on regional economic resilience, this paper chooses the spatial Durbin model for empirical research, and the regression results show that high-tech industrial agglomeration in this region will have a significant impact on the economic resilience of the neighbouring provinces.

Keywords: high-tech industrial agglomeration, regional economic resilience,entropy method, spatial spillover effect

1 Introduction

At present, the global political and economic landscape is undergoing deep adjustments, and economic downward pressure is compounded by multiple risks. From the international financial crisis in 2008 to the trade friction between China and the United States, to the impact of the new crown epidemic, China's economic development is facing increasing uncertainty. In this context, "economic resilience" as a strategic ability to cope with external shocks has become a key dimension of economic competition among countries[1]. This ability is not only reflected in the stability of the economic system to withstand shocks, but also includes the development momentum of innovation and transformation.

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As a knowledge- and technology-intensive industry, high-technology industries have become the core engine of economic growth by virtue of their high value-added characteristics and technological penetration advantages. The strategy of "winning the battle of key core technologies" put forward at the 20th Party Congress highlights the key role of high-tech industries in breaking through "neck-breaking" technologies. As an important development mode, the mechanism of industrial agglomeration on economic resilience is still controversial. This paper focuses on the following questions: Can high-tech industrial agglomeration enhance regional economic resilience? Is there any spatial spillover effect of this impact? The findings of the study will provide a decision-making basis for optimising the industrial layout and enhancing the risk-resistant capacity.

2 Literature Review

The study of economic resilience is still in the development stage, and the academic community has not yet formed a consensus on its connotation and measurement.Martin proposed a four-dimensional framework of "resistance-recovery-adjustment-evolution" which has become the mainstream analytical paradigm, and the measurement methods are divided into a single-indicator method of choosing the number of employment or GDP[2,3], and the other is a comprehensive evaluation system method[4].Existing studies have shown that factors such as industrial structure upgrading, technological innovation, and digital finance significantly enhance economic resilience[5-7]. As far as the industrial agglomeration perspective is concerned, there are three types of views on the mechanism of its role in economic resilience: the positive promotion theory[8], the U-shaped non-linear theory[9], and the theory of differences in agglomeration types[10].

High-tech industrial agglomeration research mainly focuses on the following aspects: firstly, spatial characteristics, presenting significant spatial autocorrelation characteristics[11]; secondly, there is a threshold characteristic of the economic effect, with diminishing marginal benefits after exceeding the threshold[12,13]; for the impact of innovation, it presents an inverted N-type curve or a bidirectional promotional relationship[14,15]; and its environmental externality is manifested in the improvement of the ecology through green technological innovation[16].

Existing studies have not yet systematically revealed the mechanism of high-tech industrial agglomeration and economic resilience. The innovations of this paper lie in: firstly, constructing an evaluation system to measure economic resilience from both market and government dimensions; secondly, using two-way fixed effect model to analyse the agglomeration effect and empirically test its spatial spillover characteristics.

3 Theoretical Analyses and Research Hypotheses

Studies have shown that industrial agglomeration has become a core driver of regional growth through economies of scale, factor concentration and innovation synergy[17].

High-tech industrial agglomeration is subject to the three major effects of MAR (specialised knowledge spillover), Jacobs (industrial diversity innovation) and Porter (competition-driven innovation), which enhance the system's risk-resistant capability by reducing production costs and accelerating technology diffusion. Weber's industrial location theory states that spatial concentration of firms creates a positive cycle of economies of scale through cost savings, while Schumpeter emphasises that agglomeration provides an innovation network that allows technological breakthroughs to be rapidly transmitted to associated industries. Accordingly, Hypothesis 1 is proposed.

Hypothesis 1: High-technology industrial agglomeration significantly enhances regional economic resilience.

In the spatial dimension, agglomeration effects follow the law of geographical proximity[18]. The first law of geography reveals the existence of factor flows and economic linkages in neighbouring regions[19], and Krugman points out that technological spillovers have spatial penetration[20]: on the one hand, agglomeration leads to the formation of economies of scale in the periphery through the diffusion of factors; on the other hand, inter-regional technological catching-up and policy imitation form a demonstration effect[21,22]. Based on this, the following hypothesis is proposed:

Hypothesis 2: There is a positive spatial spillover effect of high-tech industry agglomeration on the economic resilience of neighbouring regions.

4 Study Design

4.1 Sample Selection and Data Sources

This paper selects 31 provinces in China from 2000 to 2021 as the research sample for empirical testing. The raw data used in the analyses are obtained from China Statistical Yearbook, China Population and Employment Statistical Yearbook, High Technology Industry Statistical Yearbook, China Science and Technology Statistical Yearbook, regional statistical yearbooks, and the website of the National Bureau of Statistics, and missing values are filled in using linear interpolation.

4.2 Selection of Research Variables

4.2.1 Explained Variables

Regional economic resilience. This paper evaluates regional economic resilience from the dimensions of market resistance to shocks and government regulation and restoration ability, in which market resistance to shocks is expressed as the ability of the economic system to resist and absorb external shock perturbations; government regulation and restoration ability refers to whether the government will take a series of policy measures to disperse and reduce the risk and stabilise and restore the economy when the region is facing economic shocks. Subsequently, the entropy method was used to measure the regional economic resilience, as shown in Table 1.

Table 1. Construction of regional economic resilience indicator system.

Target level	Normative layer	Specific indicators	Definition of indicators	Orientations
Regional economic resilience	Market resilience to shocks	GDP per capita	Total GDP/total population	+
		industrial structure	Tertiary sector output/ secondary sector output	+
		External trade dependence	Total exports and imports/ total GDP	-
		Unemployment	Urban registered unemployment rate	-
		Urban-rural income gap	Income of urban residents/ income of rural residents	-
		Resident savings	Savings balance for urban and rural residents	+
		Urban and rural structures	urbanisation rate	+
		Engel's coefficient for urban residents	Food expenditure/ total consumption expenditure	-
		Spending power	Total retail social consumption/ total GDP	+
		Quality of financial development	Deposits from financial institutions/ loans from financial institutions	+
		Price level	Average annual sales price of commercial property/disposable income per capita	-
		Information level	Internet penetration	+
		Level of medical protection	Number of beds in health-care institutions	+
		Innovation level	Number of patents granted	+
		Proportion of people in tertiary education	Population with tertiary education/ total population aged 6 and over	+
	Government adaptive capacity	Tax burden level	Tax revenues/total GDP	+
		Transfer payment	Local public budget expenditure - local public budget revenue	+
		Investment support capacity	Total investment in fixed assets/GDP	+
		Structure of financial expenditure on education	Fiscal education expenditure/ local fiscal expenditure	+
		R&D investment intensity	Internal R&D expenditure/ total GDP	+
		Structure of health care expenditure	Fiscal health expenditure/local fiscal expenditure	+

4.2.2 Explanatory Variables

High-technology industrial agglomeration (Haggl). Industrial agglomeration is essentially the concentration of an industry in a geographic area, and the degree of industrial agglomeration can be measured by the growth of industrial scale expressed by the industrial output value per unit of land area or the number of industrial employees. Based on this, this paper refers to the study of Lin Boqiang and Tan Ruipeng for the measurement of high-tech industrial agglomeration[23], which is measured by the proportion of the number of people employed in regional high-tech industries to the regional land area.

4.2.3 Control Variables

The control variables in this paper include :(1) The level of transport infrastructure (Transp); (2) The size of state-owned industry (Nation); and (3)The share of foreign investment (FDI). The descriptive statistics of the main variables are shown in Table 2.

Table 2. Descriptive statistics of the main variables.

Variable	Description of indicators	N	Mean	SD	Min	Max
Resilience	entropy method	682	0.196	0.099	0.071	0.676
Haggl	Number of employees in high-tech industries/district land area	682	5.356	13.774	0.001	96.125
Transp	Public transport vehicles per 10,000 population	682	11.177	3.979	3.000	30.800
Nation	Percentage of local state-owned industrial scale enterprises	682	0.18	0.162	0.011	0.872
FDI	Foreign direct investment/total GDP	682	0.024	0.023	0.000	0.163

4.3 Modelling

This paper constructs a two-way fixed-effects model (1) controlling for time and province to empirically test the relationship between high-tech industrial agglomeration and regional economic resilience, with the following formula:

$$\mathrm{Resilience}_{it}=\beta_0+\beta_1\mathrm{Haggl}_{it}+\beta_2\mathrm{Controls}_{it}+\lambda_i+\delta_i+\varepsilon_{it} \quad (1)$$

Where i and t denote regions and years, respectively, Resilience represents regional economic resilience; Haggl represents high-tech industrial agglomeration; Controls represents control variables; β_0 is the intercept term; λ_i denotes the individual characteristics of the ith region that do not change over time; δ_t is the time-point fixed effect; and ε_{it} is the random error term.

5 Empirical Studies

5.1 Baseline Regression Analysis

The regression results of model (1) are shown in columns (1) and (2) of Table 3, which indicate that the inclusion of control variables does not affect the results, and the core explanatory variables are all significantly positive at the 1 per cent level. So far, hypothesis I is verified. It shows that the increase in the level of high-tech industrial agglomeration will positively promote economic resilience.

Table 3. High-tech industrial agglomeration and regional economic resilience: benchmark regression results.

Variable	Resilience	Resilience
	(1)	(2)
Haggl	0.00278*** (8.49)	0.00256*** (7.65)
Transp		0.00321*** (6.70)
Nation		0.11271*** (5.69)
FDI		0.18817** (2.19)
Constant term	0.08916*** (16.08)	-0.00268 (-0.23)
Regional effect	Yes	Yes
Time effect	Yes	Yes
R^2	0.883	0.899
Sample size	682	682

Note: ***, **, * indicate significant at the 1 per cent, 5 per cent and 10 per cent levels, respectively; standard errors in parentheses; same table below.

5.2 Robustness Tests

5.2.1 Endogeneity Test

5.2.1.1 Hysteresis Treatment.

The test results are shown in columns (1) and (2) of Table 4. After adding the control variables, it can be seen from the results that the estimated coefficient of the lagged period of high-tech industrial agglomeration is significantly positive, and the results of the study indicate that the core conclusion that high-tech industrial agglomeration has an uplifting effect on the resilience of the regional economy is relatively robust.

5.2.1.2 Instrumental Variable Method.

The results of the two-stage least squares test in columns (3) and (4) of Table 4 show that the coefficient of topographic relief in the first stage is significant at the 1% level, with an F-statistic of 19.83>10, which excludes the problem of weak instrumental variables; the coefficient of agglomeration in the second stage stays significantly positive, which proves that the baseline results are robust.

Table 4. Robustness test: endogeneity test results.

Variable	Hysteresis processing		Instrumental variable approach	
	(1)	(2)	(3)	(4)
Topographic relief			-2.06175*** (-4.45)	
L. Haggl	0.00260*** (7.90)	0.00246*** (7.27)		
Haggl				0.00769*** (4.14)
Control variable	No	Yes	Yes	Yes
Constant term	0.09428*** (16.98)	0.00695 (0.61)	-2.46173 (-1.49)	0.17222*** (11.45)
Regional effect	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes
R^2	0.880	0.895	0.181	0
Sample size	651	651	682	682
Weak instrumental variables test			19.8296	

5.2.2 Replacement of Explanatory Variables

The paper further accounts for the explanatory variables using principal component analysis. Column (1) (2) of table 5 shows that the regression coefficient of the core explanatory variable is 0.01229 and is significantly positive at the 1% level. The findings obtained after applying two different methods to account for the explanatory variables remain consistent.

5.2.3 Deletion of Municipality Samples

It is well known that municipalities directly under the central government are significantly different from ordinary provinces due to resource and policy advantages. Considering the level of high-tech industry agglomeration in municipalities, this study re-runs the regression test after excluding the sample of municipalities. The results are shown in column (3) (4) of table 5, and it is found that the results are still robust.

Table 5. Robustness test results.

Variable	Substitution of explanatory variables		Delete the sample of the municipality directly under the Central Government	
	(1)	(2)	(3)	(4)
Haggl	0.01418*** (10.50)	0.01229*** (8.58)	0.01070*** (16.78)	0.01058*** (14.96)
Control variable	No	Yes	No	Yes
Constant	-0.39543***	-0.69160***	0.08155***	0.02079*

term	(-17.27)	(-14.08)	(15.31)	(1.86)
Regional effect	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes
R^2	0.878	0.886	0.906	0.917
Sample size	682	682	594	594

5.3 Heterogeneity Test

5.3.1 By Geographical Location

Based on the test of regional heterogeneity in the east, middle and west, the regression results indicate that the positive effect of high-tech industrial agglomeration on economic resilience is significant in the whole region, but the intensity of the effect shows a gradient characteristic of central > west > east.

The central region constitutes a "golden triangle" for receiving transfers due to its location advantage, factor cost advantage and market potential, forming a virtuous cycle of agglomeration and resilience enhancement. On the contrary, in the eastern region, due to the level of agglomeration is close to saturation and market barriers and intellectual property protection lagging behind and other institutional constraints, the marginal benefits show a decreasing trend.

5.3.2 By Level of Marketisation in Provinces and Municipalities

In this paper, the marketisation level of each province and city is measured by Fanzang marketisation index, and divided into high marketisation level areas and low marketisation level areas for group test according to the average standard, and the results are detailed in Table 6.

From the regression results, the promotion of economic resilience by high-tech industrial agglomeration is significantly stronger in regions with high marketisation levels than in regions with low marketisation levels.

Table 6. Regression results grouped by geographical location, marketisation level.

Variable	Eastern part	Central section	Western part	High level of marketisation	Low level of marketisation
	(1)	(2)	(3)	(4)	(5)
Haggl	0.00146*** (3.28)	0.02664*** (10.97)	0.01218*** (4.03)	0.00177*** (3.76)	0.00422 (1.44)
Control variable	Yes	Yes	Yes	Yes	Yes
Constant term	-0.07363*** (-3.26)	0.05474*** (3.48)	0.03542*** (2.63)	-0.04059 (-1.54)	0.04491*** (7.81)
Regional effect	Yes	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes	Yes
R^2	0.923	0.972	0.924	0.916	0.962
Sample size	242	198	220	351	331

6 Analysis of Spatial Effects

6.1 Spatial Correlation Test

Global correlation analysis. In order to examine the spatial effect of high-tech industrial agglomeration on regional economic resilience, the Moran index of economic resilience is estimated for each province in this paper. The test results are shown in Table 7, and the Moran index of the research sample during 2000-2021 is significantly positive, indicating that the economic toughness among provinces in China has a strong positive spatial correlation. Hypothesis 2 is preliminarily verified.

Table 7. Morans' I and P Values.

Vintages	Resilience			vintages	Resilience		
	Morans'I	Z-value	P-value		Morans'I	Z-value	P-value
2000	0.053	3.166	0.001	2011	0.083	3.418	0.000
2001	0.050	2.988	0.001	2012	0.085	3.460	0.000
2002	0.052	3.098	0.001	2013	0.084	3.414	0.000
2003	0.065	3.436	0.000	2014	0.079	3.256	0.001
2004	0.079	3.823	0.000	2015	0.063	2.784	0.003
2005	0.074	3.580	0.000	2016	0.060	2.713	0.003
2006	0.090	4.015	0.000	2017	0.043	2.230	0.013
2007	0.097	4.186	0.000	2018	0.042	2.192	0.014
2008	0.104	4.241	0.000	2019	0.041	2.154	0.016
2009	0.099	4.038	0.000	2020	0.046	2.328	0.010
2010	0.091	3.712	0.000	2021	0.053	2.528	0.006

Local correlation analysis. As shown in Figure 1, the sample points in the Moran scatterplot drawn for 2010 and 2021, for example, are concentrated in the first and third quadrants, revealing that the regional economic resilience is characterised by high and high clustering and low and low clustering. Both the Moran index value and the scatterplot illustrate that spatial geography cannot be ignored, indicating the necessity of adopting a spatial measurement model.

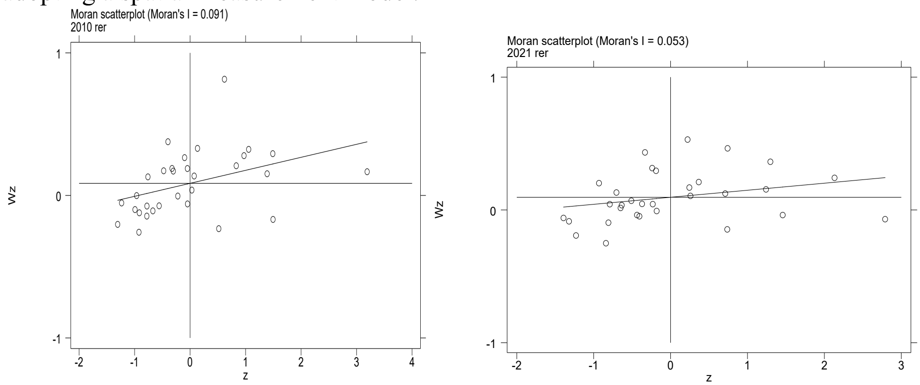

Fig. 1. Moran scatterplot of regional economic resilience in 2010 and 2021.

6.2 Spatial Measurement Models

In this paper, the geographic distance weight matrix is chosen to measure the geographic proximity between spatial entities; the higher the geographic proximity, the stronger the economic ties. The details are as follows:

Spatial geographic distance weight matrix $W_{ij}=\begin{cases} \frac{1}{d_{ij}} & i \neq j \\ 0 & i = j \end{cases}$

where dij is the distance between the two regions, calculated using the latitude and longitude coordinates of the provincial capitals of the two provinces; when i= j, w= 0.

To determine the econometric model, the LM Test Based on the geographical distance weight matrix is shown in Table 8. LM error, robust LM error, LM lag and robust LM lag all pass the test and initially support the spatial Dobbin model.Both the Wald and LR tests significantly confirmed at the 1% level that the spatial Durbin model (SDM) does not degenerate into the spatial lag model (SLM) and Spatial Error Model (SEM), and the Hausman test determined that a double-fixed Spatial Durbin Model was most appropriate (Equation 2).

$$Resilience_{it}=\rho \sum_{j=1}^{31} w_{ij}\, Resilience_{jt}+\alpha_1 Haggl_{it}+\alpha_2 Controls_{it}+ \beta_1 \sum_{j=1}^{31} w_{ij}\, Haggl_{jt}+ \beta_2 \sum_{j=1}^{31} w_{ij} Controls_{jt} + \lambda_i + \delta_t + \varepsilon_{it} \quad (2)$$

Where $Resilience_{it}$ is the dependent variable, $Haggl_{it}$ is the matrix of independent variables, the spatial autoregressive coefficient ρ represents the spatial spillover effect of high-tech industry agglomeration, α_1 is the vector of regression coefficients, β_1 corresponds to the spatial lag coefficient, which indicates the spatial spillover effect of neighbouring regions on the explanatory variables of the region, λ_i, δ_t correspond to the individual effect, time effect, and εit denotes the error term.

Table 8. Results of the spatial measurement model selection test.

Spatial panel model tests		Statistic	P-value
LM test	Moran's I	19.879	0.000
	LM-error	351.510	0.000
	Robust LM-error	229.990	0.000
	LM-lag	124.717	0.000
	Robust LM-lag	3.197	0.074
Wald test	Wald-SEM	27.02	0.000
	Wald-SAR	33.96	0.000
Hausman test	Hausman test	19.73	0.0197
LR test	LR-SEM	53.81	0.000
	LR-SAR	52.00	0.000
Spatio-temporal fixed effects test	LR individual fixed effects	69.48	0.000
	LR time fixed effects	627.20	0.000

6.3 Empirical Analysis of Spatial Effects

The partial differential decomposition based on the SDM model is shown in Table 9. The direct effect of local high-tech agglomeration to promote the economic resilience of the region is significantly positive, and hypothesis 1 is proved; the indirect effect is 0.01689 and significantly positive, revealing the existence of spatial spillover effect, and hypothesis 2 is established. The overall explanatory power of the model is strong, with R^2=0.503, and the spatial autocorrelation coefficient of 0.32296 confirms the spatial characteristics of "high resilience - high agglomeration".

Table 9. Spatial Durbin effect regression results.

Variable	Considerations		Decomposition of effect		
	Local effect	Spillover effect	Direct effect	Indirect effect	Aggregate effect
Haggl	0.00316*** (9.31)	0.01016*** (5.20)	0.00344*** (9.26)	0.01689*** (4.24)	0.02034*** (4.87)
control variable	Yes	Yes	Yes	Yes	Yes
spatial rho			0.32296*** (2.97)		
σ2			0.00068*** (18.35)		
R2	0.503	0.503	0.503	0.503	0.503
Sample size	682	682	682	682	682

7 Conclusions and Implications

In this paper, the entropy method is used to measure the comprehensive index of economic resilience of each region constructed based on two dimensions of market and government. Secondly, using the panel data of 31 provinces and cities in China from 2000 to 2021, we constructed two-way fixed effect model and spatial Durbin model to test the impact of high-tech industry agglomeration on regional economic toughness. The main conclusions are as follows: (1) High-technology industrial agglomeration can significantly improve regional economic toughness. (2) There is a positive spatial spillover effect of high-tech industrial agglomeration. (3) The impact of high-tech industrial agglomeration on regional economic resilience is most obvious in the central region and under the high marketisation level.

Taken together, the findings of the above studies, the policy implications of this paper are:

Firstly,Accelerating the spatial agglomeration of high-tech industries. Implementation of the "government and city dual-wheel drive" strategy: accelerating the construction of high-tech industrial clusters, strengthening basic research inputs through targeted support for scientific research institutes and stimulating the innovation momentum of enterprises, and constructing a resilient cultivation mechanism of "market screening + government escort".

Secondly, in the process of development, provinces and cities need to take into account their own development and that of their neighbouring regions, and pay attention to the geographical links and interactions of economic agents. Regional economic resilience requires interregional and even national synergy at multiple levels. Regions should break down administrative boundaries, strengthen regional cooperation, give full play to the agglomeration effect, promote the free flow and effective distribution of factors of production, and promote the transformation and upgrading of the kinetic energy of regional development.

Thirdly, locally tailored policies and measures should be formulated. In view of the diversity of regions in China, it is necessary to formulate locally tailored policies. It is recommended that the central region increase investment in industrial park infrastructure to attract innovation resources; the western region should give full play to its regional characteristics and enhance its economic resilience in combination with its industrial base. The government should promote market-oriented reforms, strengthen intellectual property protection, optimise the business environment, reduce enterprise costs, and promote the clustering of high-tech industries.

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