

## The Impact Mechanism of Innovation Agglomeration Spatial Distribution Patterns on Chinese Urban Economic Resilience (Postprint)

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### Abstract

Enhancing economic resilience constitutes a crucial component of achieving high-quality development. Utilizing panel data from 275 Chinese cities spanning 2004–2021, this study investigates the relationship between spatial distribution patterns of provincial innovation agglomeration and urban economic resilience. The findings reveal that: (1) A monocentric innovation agglomeration pattern exhibits an inhibitory effect on urban economic resilience enhancement, whereas a polycentric pattern demonstrates a promoting effect, with its marginal effect strengthening as the degree of polycentricity increases. (2) Compared with cities possessing stronger economic resilience, the enabling effect of the polycentric innovation agglomeration pattern is more pronounced for cities with weaker economic resilience. (3) Heterogeneity analysis by location indicates that the polycentric innovation agglomeration pattern has the strongest effect on enhancing economic resilience in eastern region cities, followed by central region cities, while its effect on western region cities is not significant. (4) Mechanism identification tests demonstrate that the polycentric innovation agglomeration pattern can enhance urban economic resilience through independent mediating channels of promoting innovation factor mobility and capital return rate improvement, as well as a chain mediating channel of “innovation factor mobility–capital return rate improvement.” The research findings provide valuable practical insights for optimizing the spatial distribution pattern of innovation to enhance urban economic resilience.

## Full Text

# Impact Mechanism of Innovative Agglomeration Spatial Distribution Patterns on Urban Economic Resilience in China

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## Abstract

Enhancing economic resilience constitutes a crucial component of achieving high-quality development. This study employs panel data from 275 cities to investigate the relationship between provincial innovation agglomeration spatial distribution patterns and urban economic resilience. The findings reveal that: (1) The monocentric pattern of innovation agglomeration exerts an inhibitory effect on urban economic resilience enhancement, whereas the polycentric pattern demonstrates a promotional effect, with the marginal impact strengthening as the degree of polycentricity increases. (2) Compared with cities possessing stronger economic resilience, the polycentric pattern of innovation agglomeration exhibits a more pronounced enabling effect on cities with weaker economic resilience. (3) The polycentric pattern of innovation agglomeration demonstrates the strongest effect on enhancing urban economic resilience in eastern China, followed by the central region, while its impact on western cities remains statistically insignificant. (4) Mechanism identification tests indicate that the polycentric pattern enhances urban economic resilience through independent mediating channels that promote innovation factor mobility and capital return rate improvement, as well as through a chain mediating channel of “innovation factor mobility → capital return rate improvement.” These conclusions provide valuable practical insights for optimizing innovation spatial distribution patterns to strengthen urban economic resilience.

**Keywords:** Innovation agglomeration; spatial distribution mode; monocentricity; polycentricity; economic resilience

## Introduction

In the post-pandemic era, the global economic environment has become increasingly severe, with the Russia-Ukraine conflict, China-U.S. trade friction, and cyclical economic fluctuations posing significant challenges to the healthy development of the macroeconomy. Consequently, exploring pathways to enhance urban economic resilience within this complex and volatile domestic and international context holds profound significance for achieving stable and sustainable economic development in China. In September 2020, General Secretary Xi Jinping proposed at the seventh meeting of the Central Financial and Economic Affairs Commission that building resilient cities should become an important com-

ponent of improving urbanization strategies. Subsequently, the term “resilient city” was incorporated into both the Outline of the 14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives Through 2035 and the report of the 20th National Congress of the Communist Party of China.

According to evolutionary theory, the essence of economic resilience lies in exploring the causal relationships between the functional attributes and actual performance of diverse economic agents during external shocks, emphasizing the economic system’s capacity to leverage external shocks to achieve continuous optimization of economic structure. The strength of economic resilience is primarily influenced by factors including infrastructure construction, industrial structure, knowledge structure, economic agglomeration, and social capital levels. As research has deepened, the impact of technological innovation on economic resilience has attracted widespread scholarly attention. Simmie’s research demonstrates that technological innovation injects powerful momentum into regional economic resilience enhancement by promoting industrial diversification. Hassink argues that continuous innovation in economic systems not only facilitates dynamic evolution of economic structures to adapt to shocks and disturbances but also expands new economic growth paths to withstand external economic shocks. Cheng Guangbin’s research, based on data at the prefecture-level city tier in China, similarly finds that improved innovation capacity contributes to strengthening urban economic resilience.

However, as a spatially embedded interactive learning process, innovation is neither an isolated event nor randomly and uniformly distributed within regional systems; rather, it exhibits a certain spatial agglomeration trend. Currently, China’s regional development imbalance is prominent, particularly regarding the spatial imbalance of innovation agglomeration and innovation output. Optimizing the regional innovation spatial pattern has become a critical task in implementing innovation-driven development strategies. Spatial patterns reflect the distribution modes of factor resources and economic activities within specific spatial scopes, representing the outcome of the interplay between agglomeration economies’ benefits and costs during development, primarily manifesting as monocentric and polycentric patterns. Based on the “structuralist” logical paradigm, different spatial structures entail distinct connotations, functional agents, and operational channels, potentially yielding differential impacts on economic resilience. How, then, do provincial innovation agglomeration spatial distribution patterns affect urban economic resilience? What are the underlying mechanisms? Do regional differences exist? While existing literature has yielded fruitful research findings on the impact of technological innovation on economic resilience, explorations of the economic resilience effects of innovation spatial patterns remain insufficient. Compared with previous studies, this paper’s marginal contributions are: Based on panel data from 275 Chinese cities and from the perspective of external spatial structure, it examines the relationship between provincial innovation agglomeration spatial distribution monocentricity/polycentricity and urban economic resilience, expanding the theoretical

analysis framework for the co-evolution of urban external spatial structure and economic resilience, enriching and supplementing relevant mechanism research, and deepening practical explorations of cross-regional integration of innovation resources, thereby providing theoretical foundations and policy recommendations for facilitating the smooth implementation of provincial-scale collaborative innovation strategies and enhancing regional economic resilience.

## 1 Theoretical Analysis and Research Hypotheses

According to innovation geography theory, innovation agglomeration spatial distribution patterns constitute an organizational form emerging in specific spaces based on innovation linkages. When inter-city innovation linkages within a province are weak, innovation level gaps are relatively large, and innovation activities are primarily undertaken by the central city with the highest innovation level, the province exhibits a monocentric pattern of innovation agglomeration spatial distribution. Conversely, when inter-city innovation linkages are strong, innovation level gaps are relatively small, and innovation activities are jointly undertaken by multiple “sub-central” cities, the province presents a polycentric pattern of innovation agglomeration spatial distribution.

As an open organizational network form, the polycentric pattern of innovation agglomeration enhances urban economic resilience through a dynamic “prevention-reconstruction” mechanism. First, the polycentric pattern of innovation agglomeration can expand the diffusion scope and propagation speed of information, data, and knowledge technology within innovation networks, reducing information asymmetry and strengthening risk prediction capabilities. Second, under the “borrowed size” effect, the polycentric pattern of innovation agglomeration promotes complementary advantages and functional differentiation among cities, extending the time for economic systems to resist external shocks. Finally, after external shocks occur, the polycentric pattern strengthens inter-city specialized division of labor and collaboration, unblocks bottlenecks in production, distribution, circulation, and consumption, activates internal and external circulation dynamics, and continuously enhances urban economic vitality and capacity to adapt to external shocks. Notably, the polycentric pattern may also inhibit economic resilience by undermining agglomeration effects. During stages of weak provincial innovation capacity, the monocentric pattern can significantly enhance regional economic efficiency by strengthening central city agglomeration effects, while excessive dispersion in a polycentric pattern not only fails to promote inter-city collaborative innovation but may also weaken agglomeration economies. However, as provincial innovation levels continue to rise, the monocentric pattern risks causing excessive factor agglomeration and industrial path lock-in, leading to innovation fatigue, whereas the polycentric agglomeration pattern overall facilitates inter-city collaborative innovation, positively influencing urban economic resilience enhancement.

Furthermore, in the process of polycentric innovation agglomeration empowering urban economic resilience enhancement, innovation factor mobility and capi-

tal return rate improvement play crucial roles. First, compared with traditional production factors, innovation factors carry more knowledge and technology and possess higher innovation potential. Cross-regional flow of innovation factors can inject strong momentum into regional innovation development. Under the polycentric pattern, node cities have relatively similar hierarchical statuses, with diversified factor flow directions, creating more convenient conditions for cross-regional flow, agglomeration, and application of innovation factors. Sufficient innovation factor mobility can stabilize factor market supply-demand relationships while strengthening inter-city collaborative production networks, deepening inter-industry cooperation and division of labor, and promoting new technology R&D and traditional industrial transformation, thereby enhancing urban economic resilience. Second, capital return rate reflects investment efficiency; regions with higher capital return rates have stronger financing demand, and total demand is expected to rebound rapidly after external shocks, enabling swift economic recovery, which implies stronger economic resilience. On the one hand, the polycentric pattern promotes coordinated development among cities of different scales, avoiding efficiency losses from excessive innovation factor agglomeration in large cities while activating idle resources in small and medium-sized cities, contributing to efficient macro-level factor resource allocation. On the other hand, the organizational form of the polycentric pattern enhances inter-city innovation cooperation and exchange, accelerating cross-city knowledge and technology spillovers, thereby promoting regional technological progress to improve capital return rates. Based on the above analysis, the following hypotheses are proposed:

**Hypothesis 1:** The polycentric pattern of innovation agglomeration spatial distribution promotes urban economic resilience enhancement, but the effect exhibits heterogeneity.

**Hypothesis 2:** Innovation factor mobility and capital return rate improvement constitute important pathways through which the polycentric pattern of innovation agglomeration empowers urban economic resilience enhancement.

## 2 Research Design

**2.1 Study Area Overview** When calculating the polycentricity index of innovation agglomeration, methodological constraints require a minimum of four cities with complete data within each province. Hainan Province, Qinghai Province, Xinjiang Uygur Autonomous Region, and Tibet Autonomous Region have substantial missing data at the prefecture level, while Beijing, Shanghai, Tianjin, and Chongqing are municipalities directly under central government jurisdiction. Consequently, these eight provinces/autonomous regions/municipalities fail to meet the prerequisite for calculating the polycentricity index. Meanwhile, to ensure statistical consistency, data from Hong Kong Special Administrative Region, Macao Special Administrative Region, and Taiwan Province were excluded. The final sample comprises 275 cities across 22 provinces. Specifically, North China includes 11 prefecture-level cities in Hebei,

Shanxi, and Inner Mongolia; Northeast China includes 34 cities in Liaoning, Jilin, and Heilongjiang; East China includes 76 cities in Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, and Shandong; Central China includes 36 cities in Henan, Hubei, and Hunan; South China includes 29 cities in Guangdong and Guangxi; Southwest China includes 42 cities in Sichuan, Guizhou, and Yunnan; and Northwest China includes 47 cities in Shaanxi, Gansu, and Ningxia.

**2.2 Data Sources and Processing** Economic data for each city were primarily obtained from the *China City Statistical Yearbook*, national economic and social development statistical bulletins, and the CSMAR database. Annual patent data for each city were sourced from the “China Patent Database” of the National Intellectual Property Administration. Missing data were supplemented using linear interpolation, and all price variables were deflated using 2004 as the base year. Currently, Chinese city data are available in three statistical scopes: entire city, urban districts, and built-up areas. To comprehensively reflect urban economic functions, this study employs entire-city data for all analyses.

### 2.3 Variables

**2.3.1 Dependent Variable: Economic Resilience** Following Martin and Sunley’s research, economic resilience is measured using the change rate of core economic indicators, calculated as:

$$Res_{ct} = \frac{\Delta Y_{ct}}{Y_{ct-1}} - \frac{(\Delta Y_t/Y_{t-1})}{(\Delta Y_{t-1}/Y_{t-1})}$$

where  $Res_{ct}$  represents the economic resilience of city  $c$  in year  $t$ ;  $\Delta Y_{ct}/Y_{ct-1}$  denotes the GDP growth rate of city  $c$  in year  $t$ ; and  $(\Delta Y_t/Y_{t-1})/(\Delta Y_{t-1}/Y_{t-1})$  represents the national GDP growth rate in year  $t$ . For application convenience, the data were standardized using the formula:

$$Res_{ct} = \frac{Res_{ct} - Res_{min}}{Res_{max} - Res_{min}}$$

where  $Res_{ct}$  is the standardized economic resilience of city  $c$  in year  $t$ , and  $Res_{min}$  and  $Res_{max}$  are the minimum and maximum original values of urban economic resilience, respectively.

**2.3.2 Explanatory Variables (1) Monocentric Index of Innovation Agglomeration Spatial Distribution.** Following Wu Dianyuan et al.’s research, the monocentric index is calculated based on urban primacy share to reflect the provincial-level monocentric pattern of innovation agglomeration. Urban innovation level is measured using invention patent applications. The calculation formula is:

$$Mono_{it} = \frac{\max(ZL_{i1t}, ZL_{i2t}, \dots, ZL_{int})}{\sum_{j=1}^n ZL_{ijt}}$$

where  $Mono_{it}$  is the monocentric index of innovation agglomeration spatial distribution for province  $i$  in year  $t$ ;  $ZL_{ijt}$  represents the number of invention patent applications for the  $j$ -th city in province  $i$  in year  $t$  ranked by invention patent applications; and  $n$  is the number of cities in province  $i$ .

**(2) Polycentric Index of Innovation Agglomeration Spatial Distribution.** The essence of polycentric agglomeration lies in reflecting the development gap between the primate city and other cities. The urban index method is employed to calculate the polycentric index:

$$Poly_{imt} = \frac{1}{m} \sum_{j=1}^m \ln \left( \frac{ZL_{ijt}}{ZL_{i(j+1)t}} \right)$$

where  $Poly_{imt}$  is the polycentric index of innovation agglomeration spatial distribution for province  $i$  in year  $t$ . To enhance comparability, the innovation development levels of the top 2, 3, and 4 cities ( $m = 2, 3, 4$ ) are selected to calculate the 2-city polycentric index ( $Poly_{i2t}$ ), 3-city polycentric index ( $Poly_{i3t}$ ), and 4-city polycentric index ( $Poly_{i4t}$ ), respectively. The mean value yields the comprehensive polycentric index ( $Poly_{it}$ ). A larger index value indicates higher polycentricity in the province' s innovation agglomeration spatial distribution.

To address potential endogeneity issues, Lewbel' s methodology is adopted to construct instrumental variables for both indices:

$$Mono_{it}^{IV} = (Mono_{it} - \overline{Mono}_i)^2$$

$$Poly_{it}^{IV} = (Poly_{it} - \overline{Poly}_i)^2$$

where  $Mono_{it}^{IV}$  and  $Poly_{it}^{IV}$  are the instrumental variables for the monocentric and polycentric indices, respectively;  $Mono_{it}$  and  $Poly_{it}$  are the original indices; and  $\overline{Mono}_i$  and  $\overline{Poly}_i$  are their respective means. This approach constructs valid instrumental variables without requiring external factors.

**2.3.3 Mediating Variables (1) Innovation Factor Mobility.** Innovation factors primarily include R&D personnel and R&D capital. Following Bai Junhong et al., a double-log gravity model incorporating pull variables is used to measure inter-provincial R&D personnel mobility ( $\ln Pfl$ ) and R&D capital mobility ( $\ln Cfl$ ). Key factors affecting personnel mobility include average wages of urban unit employees and average residential housing prices, while factors

influencing capital mobility include average corporate profit levels and financial market development.

**(2) Capital Return Rate.** Following Li Meng et al., the capital return rate at the city level is calculated using the “increment-capital ratio” method:

$$R_{oct} = \frac{\Delta GDP_{ct}}{I_{ct}}$$

where  $R_{oct}$  is the capital return rate of city  $c$  in year  $t$ ;  $\Delta GDP_{ct}$  is the increment in regional GDP (in 100 million yuan); and  $I_{ct}$  is fixed asset investment (in 100 million yuan).

**2.3.4 Control Variables** To mitigate endogeneity bias from omitted variables, the following city-level control variables are selected: (1) Human capital level, measured by the proportion of college and university students in the city’s average annual population; (2) Fiscal expenditure intensity, measured by the ratio of fiscal budget expenditure to GDP; (3) Financial development level, measured by the ratio of financial institution deposit and loan balances to GDP; (4) Industrial structure, measured by the ratio of tertiary industry output to secondary industry output; and (5) Economic development level, measured by per capita real GDP. Descriptive statistics for all variables are presented in Table 1.

## 2.4 Models

**2.4.1 Fixed Effects Model** Based on Hypothesis 1, the fixed effects model is employed to examine the direct effect of innovation agglomeration spatial distribution patterns on urban economic resilience, controlling for individual characteristics and temporal changes:

$$Res_{ct} = \alpha + \beta_1 Mono_{ct} + \beta_2 Poly_{ct} + \sum_k \beta_k Control_{ckt} + v_c + u_t + \varepsilon_{ct}$$

where  $Mono_{ct}$  and  $Poly_{ct}$  are the monocentric and polycentric indices of the province where city  $c$  is located in year  $t$ ;  $\beta_1$  and  $\beta_2$  are the estimated coefficients;  $\beta_k$  is the coefficient for the  $k$ -th control variable  $Control_{ckt}$ ;  $v_c$  denotes individual fixed effects;  $u_t$  denotes time fixed effects; and  $\varepsilon_{ct}$  is the random disturbance term.

**2.4.2 Chain Multiple Mediation Effects Model** Hypothesis 2 suggests that innovation factor mobility and capital return rate improvement may constitute important pathways through which the polycentric pattern enhances urban economic resilience, with potential interaction effects where innovation

factor mobility promotes capital return rate improvement. Therefore, a chain multiple mediation effects model is employed:

$$Flow_{ct} = \alpha_1 + \gamma_1 Poly_{ct} + \sum_k \beta_k Control_{ckt} + v_c + u_t + \varepsilon_{1ct}$$

$$Ro_{ct} = \alpha_2 + \gamma_2 Poly_{ct} + \delta Flow_{ct} + \sum_k \beta_k Control_{ckt} + v_c + u_t + \varepsilon_{2ct}$$

$$Res_{ct} = \alpha_3 + \gamma_3 Poly_{ct} + \zeta_1 Flow_{ct} + \zeta_2 Ro_{ct} + \sum_k \beta_k Control_{ckt} + v_c + u_t + \varepsilon_{3ct}$$

where  $Flow_{ct}$  represents innovation factor mobility (including  $\ln Pfl$  for personnel mobility and  $\ln Cfl$  for capital mobility);  $\gamma_1$  and  $\gamma_2$  are coefficients for the polycentric pattern in different models;  $\delta$  is the coefficient for innovation factor mobility; and  $\zeta_1$  and  $\zeta_2$  are coefficients for the mediating variables.

## 2.5 Preliminary Analysis

**2.5.1 Spatio-temporal Evolution Characteristics** To preliminarily explore the spatio-temporal evolution trends of provincial monocentric index, polycentric index, and urban economic resilience index, this study depicts their temporal development and spatial distribution differences using annual and individual means. At the temporal level (Figure 1), the polycentric index of innovation agglomeration shows an overall upward trend from 2004 to 2021, particularly rising sharply after 2012. Correspondingly, the monocentric index exhibits a declining trend, falling rapidly after 2012. This indicates that with the continuous evolution of the innovation-driven development strategy, innovation levels across cities have continuously improved, effectively alleviating the imbalance and insufficiency of innovation activities among cities. Urban economic resilience has generally increased from 2004 to 2021, though with considerable volatility, notably declining significantly in 2008-2009 and 2020-2021. This suggests that while China's economy demonstrates strong resilience and its long-term positive fundamentals remain unchanged, careful assessment of negative impacts from external economic shocks on macroeconomic development is necessary.

Regarding spatial distribution differences (Figure 1), cities in Fujian, Guizhou, Zhejiang, Jiangsu, and Inner Mongolia exhibit higher economic resilience than other provinces. Provinces with high monocentric indices and low polycentric indices include Jilin, Heilongjiang, Sichuan, Hubei, Shaanxi, Yunnan, and Shanxi in central and western regions. Conversely, provinces with high polycentric indices and low monocentric indices include Jiangsu, Anhui, Zhejiang, Shandong, and Hebei in eastern regions. This demonstrates that eastern provinces have achieved significantly improved innovation development balance, with a clear

polycentric innovation pattern, while central and western provinces maintain distinct non-equilibrium characteristics in innovation development, with significant innovation activity agglomeration in core cities.

[Figure 1: see original paper]

**2.5.2 Linear Characteristic Relationship** Building upon spatio-temporal evolution characteristics, this study further reveals the intrinsic relationship between innovation agglomeration spatial distribution patterns and urban economic resilience by depicting linear fitting distributions. Figure 2 shows a negative correlation between the monocentric index and urban economic resilience, and a positive correlation between the polycentric index and urban economic resilience. This preliminary evidence suggests that the polycentric pattern of innovation agglomeration promotes urban economic resilience enhancement, while the monocentric pattern exerts an inhibitory effect. However, this conclusion remains descriptive and requires further statistical validation through econometric models.

[Figure 2: see original paper]

### 3 Empirical Results

**3.1 Baseline Regression** Following Hausman test results, the fixed effects model is employed for baseline regression analysis of innovation agglomeration spatial distribution patterns' impact on urban economic resilience (Table 2). Regression (1) shows that regardless of whether control variables are included, the monocentric pattern coefficient is significantly negative, while the polycentric pattern coefficient is significantly positive. This indicates that the monocentric pattern inhibits urban economic resilience enhancement, whereas the polycentric pattern significantly promotes it. Considering potential differences among various polycentric patterns, regression (2) further reports the effects of 2-city, 3-city, and 4-city polycentric patterns on urban economic resilience. The results show that the 4-city polycentric pattern exhibits a larger absolute coefficient value than the 2-city and 3-city patterns, suggesting that as more cities enter the polycentric innovation spatial distribution framework, the spatial network effect of innovation agglomeration is further strengthened, thereby generating greater impact on urban economic resilience enhancement.

#### 3.2 Robustness Checks

**3.2.1 Endogeneity Analysis Dummy Variable Approach (Table 3):** Provincial fixed effects and province-time joint fixed effects are established to mitigate impacts from external macroeconomic systemic changes. Regression (3) shows that the monocentric pattern coefficient remains significantly negative, while the polycentric pattern coefficient remains significantly positive.

**Instrumental Variable Regression (Table 3):** Following Lewbel's methodology, the constructed instrumental variables for monocentric and polycentric indices are used for two-stage least squares estimation. The 2SLS results (regression 4) are consistent with baseline regression results.

**3.2.2 Robustness Tests Alternative Core Explanatory Variables (Table 4):** First, following Zhong Shunchang et al., the Herfindahl index is used to calculate the polycentric index. The Herfindahl index is an important indicator for measuring spatial distribution equilibrium, where larger values indicate higher concentration. The polycentric index is then calculated as 1 minus the Herfindahl index. Regression (5) shows that the polycentric pattern coefficient remains significantly positive at the 1% level. Second, since the previous polycentric index calculation was based on non-parametric estimation, the parameter estimation-based Zipf's Law is further employed following Meijers and Burger's research. Consistent with non-parametric estimation, the top 2, 3, and 4 cities are selected for regression analysis to obtain respective polycentric indices, with the mean value yielding the comprehensive polycentric index. Regression (6) confirms that the polycentric pattern's impact on urban economic resilience remains significantly positive.

**Alternative Dependent Variable (Table 4):** Following Du Zhiwei et al., employment change rate is used to measure urban economic resilience. Regressions (7)-(8) show that after changing the dependent variable, the monocentric pattern coefficient remains significantly negative while the polycentric pattern coefficient remains significantly positive, confirming baseline regression robustness.

### 3.3 Heterogeneity Analysis

**3.3.1 Quantile Regression Test** Considering that extreme values may affect regression results, quantile regression tests are conducted at the 25th, 50th, and 75th percentiles (Table 5). At the 25th percentile, the polycentric pattern coefficient is 0.121; at the 50th percentile, it is 0.098; and at the 75th percentile, it is 0.087. All coefficients are significant and gradually decreasing, indicating that the polycentric pattern's enabling effect is more pronounced for cities with relatively weaker economic resilience, while diminishing for cities with stronger economic resilience. The likely reason is that cities with weaker economic resilience have relatively lagging overall economic development and innovation capacity. Under the monocentric pattern, excessive siphoning of innovation factors by central cities is detrimental to these cities' economic development. In contrast, the polycentric pattern promotes inter-city innovation exchange and cooperation by enhancing innovation factor mobility, incentivizing cities with weaker resilience to actively participate in innovation R&D, thereby strengthening their capacity to respond to external economic shocks and enhancing economic resilience.

**3.3.2 Location Feature Difference Test** China's vast territory exhibits significant differences in economic environments, resource endowments, and policy preferences across regions, potentially generating location-specific heterogeneity in the effects of innovation agglomeration spatial distribution patterns on urban economic resilience. The full sample is therefore divided into eastern (Hebei, Liaoning, Jiangsu, Zhejiang, Shandong, Fujian, Guangdong), central (Shanxi, Inner Mongolia, Jilin, Heilongjiang, Henan, Hubei, Hunan, Jiangxi, Anhui), and western (Guangxi, Shaanxi, Gansu, Ningxia, Sichuan, Yunnan, Guizhou) sub-samples to examine regional heterogeneity (Table 6). Results show that both monocentric and polycentric patterns have more significant effects on urban economic resilience in eastern and western regions. Notably, the polycentric pattern's effect on eastern cities is strongest, followed by central cities, while its effect on western cities is not significant. This phenomenon may occur because western regions have relatively weaker scientific and technological innovation capacity, where innovation agglomeration in central cities can fully leverage agglomeration economies; excessive dispersion of innovation activities may instead undermine urban economic resilience. For eastern and central regions with relatively higher overall innovation capacity, excessive innovation agglomeration in central cities may cause diseconomies of agglomeration, whereas the polycentric pattern can generate positive externalities while avoiding such problems.

**3.4 Mechanism Identification Test** Following Hypothesis 2, the chain multiple mediation effects model is used to test the mechanisms through which the polycentric pattern influences urban economic resilience (Table 7). Regression (9) uses R&D personnel mobility and R&D capital mobility as dependent variables, yielding polycentric index coefficients of 0.089 and 0.076, respectively, both significant at the 1% level, indicating that the polycentric pattern promotes innovation factor mobility. Regression (10) uses capital return rate as the dependent variable, showing significantly positive polycentric index coefficients, with R&D personnel mobility and R&D capital mobility coefficients also significantly positive, demonstrating that the polycentric pattern promotes capital return rate improvement and that innovation factor mobility significantly drives capital return rate enhancement. Regression (11) uses urban economic resilience as the dependent variable, with both innovation factor mobility and capital return rate improvement showing significantly positive coefficients, while the polycentric pattern coefficients are 0.041 and 0.038, respectively, significant at the 1% and 5% levels. This indicates that the polycentric pattern not only enhances urban economic resilience through independent mediating channels of innovation factor mobility and capital return rate improvement but also through the chain mediating channel of "innovation factor mobility  $\rightarrow$  capital return rate improvement." Innovation factor mobility thus exerts both independent and chain mediating effects, while capital return rate improvement plays an independent mediating role.

## 4 Discussion

A region's economic resilience depends not only on its local innovation capacity but also on close spatial technological linkages between regions. As medium-sized cities continue to grow in scale and number, polycentric urban network layouts have gradually become typical characteristics of China's urbanization process. Chen Shuping et al. find that provincial polycentric agglomeration overall promotes urban innovation capacity enhancement but exhibits significant regional differences. Zhong Shunchang et al. demonstrate that the monocentric pattern of innovation agglomeration induces haze pollution, whereas the polycentric pattern significantly improves haze pollution. Building upon these studies, this paper further reveals that urban economic resilience enhancement more significantly depends on the network economic effects of polycentric structures rather than the agglomeration economic effects of monocentric structures. This finding has dual significance for developing urban network economic theory. First, it breaks through the traditional monocentric agglomeration research paradigm. While conventional urban economics emphasizes the enabling effect of monocentric agglomeration on economic efficiency, as China's overall economic development level and innovation capacity continue to rise, the network economic effects of polycentric structures better meet economic resilience demands in complex environments. Second, it deepens the theoretical connotation of urban network economics. Existing research suggests that polycentric spatial structures inhibit economic performance and innovation output by undermining agglomeration effects. This study demonstrates that while polycentric structures avoid diseconomies from excessive monocentric agglomeration, they can significantly obtain agglomeration externalities, compensating for traditional agglomeration theory's insufficient explanation of dynamic network mechanisms.

Nevertheless, given China's regional variations in resource endowments, economic structures, and urban development levels, the enabling effect of provincial polycentric innovation agglomeration patterns on urban economic resilience also exhibits significant differences. This study only uses eastern, central, and western regions to represent location heterogeneity, overlooking impacts from provinces with similar resource endowments and economic structures. Future research should further deepen heterogeneity analysis of the relationship between innovation agglomeration spatial distribution patterns and urban economic resilience to obtain more detailed and comprehensive conclusions.

## 5 Conclusions and Recommendations

**5.1 Conclusions** This study investigates the impact mechanism of provincial innovation agglomeration spatial distribution patterns on urban economic resilience using panel data from 275 Chinese cities during 2004-2021. The main conclusions are:

- (1) Baseline regression results indicate that the monocentric pattern of innova-

tion agglomeration negatively affects urban economic resilience, while the polycentric pattern overall promotes urban economic resilience enhancement, with the enabling effect strengthening as the degree of polycentricity increases. Instrumental variable regression and robustness tests using alternative core explanatory and dependent variables confirm the reliability of these findings.

- (2) Heterogeneity analysis reveals that as urban economic resilience strengthens, the enabling effect of the polycentric pattern gradually diminishes. Regarding location-specific differences, the polycentric pattern demonstrates the strongest effect on eastern cities, followed by central cities, while its effect on western cities is not significant.
- (3) Mechanism identification tests show that the polycentric pattern enhances urban economic resilience not only through independent mediating channels of promoting innovation factor mobility and capital return rate improvement but also through the chain mediating channel of “innovation factor mobility → capital return rate improvement.”

## 5.2 Recommendations

- (1) **At the municipal level**, deepen collaborative innovation development models to fully stimulate urban innovation vitality. Specifically, relying on innovation entities such as universities, enterprises, and research institutions, and leveraging information and communication technologies including the Internet, big data, and artificial intelligence, establish municipal collaborative innovation alliances to broaden and deepen inter-city industry-university-research cooperation. Continuously promote exchange and sharing of scientific R&D and management experience, fully leverage each city’s comparative resource advantages for industrial division of labor and collaboration, and form a complementary high-quality innovation development system that compensates for individual cities’ development shortcomings and drives coordinated leapfrog development across large, medium, and small cities.
- (2) **At the provincial level**, adopt differentiated spatial development models based on local conditions. For eastern and central provinces with relatively higher innovation capacity, support qualified sub-central cities to develop preferentially, shaping a polycentric innovation spatial pattern with relatively dispersed innovation activities to fully stimulate innovation potential among diverse innovation agents. For western provinces with relatively weaker innovation capacity, avoid excessive dispersion of innovation activities, adhere to compact innovation spatial distribution patterns, maximize scale economies from innovation agglomeration, improve industrial development resilience while achieving efficient utilization of innovation resources, and establish an efficient transmission mechanism between innovation ecosystems and economic resilience enhancement.

- (3) **In response to national strategic decisions**, continuously improve the institutional framework and system design for factor market operations to promote efficient allocation of innovation resources. Unlike traditional production factors, innovation factors such as talent and technology with innovation potential are critical forces determining economic systems' capacity to respond to external shocks and achieve economic transformation. Therefore, oriented by improving urbanization construction, advance inter-city infrastructure development, particularly by continuously narrowing gaps in information and communication facilities, promote unified large market processes, and enhance the speed and rational allocation of cross-regional innovation factor mobility. Additionally, local governments should actively guide the development of patient capital to support regional innovation R&D, based on government investment funds, injecting sustained momentum into regional economic structure optimization and economic resilience enhancement.

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