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Research on the relationship between industrial agglomeration and regional innovation from the dynamic perspective: evidence from China

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Abstract

Purpose – The purpose of this paper is to reveal the paradox between diversification and specialization from a dynamic perspective. More precisely, this paper will analyze the impact of diversification and specialization as well as their interaction on regional innovation in different development stages.

Design/methodology/approach – Based on the principles of new economic geography and innovation geography, data from 30 provinces from 2001 to 2017 was used to explore the relationship. Least squares regressions with fix effect were used to examine the hypotheses.

Findings – The results show that both diversification and specialization have a significant and positive impact on regional innovation. The interaction of diversification and specialization also significantly and positively impacts regional innovation. The effect of industrial agglomeration is heterogeneity under different development stages.

Practical implications – This paper verifies the positive role of diversification and specialization and their interaction in promoting regional innovation. The impact of industrial agglomeration on innovation is dynamic and changes with the regional development process. Emerging economies should make appropriate industrial agglomeration strategies according to their development stages.

Originality/value – This paper introduces diversification, specialization and their interaction into the research framework at the same time to analyze their impact on innovation performance which deepened the research of industrial agglomeration. Taking China as an example, this paper also examines the impact of industrial agglomeration on regional innovation in different development stages that expands the dynamic perspective of industrial agglomeration.

Keywords Diversification, Regional innovation, Specification, Industrial agglomeration

Paper type Research paper

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Introduction

Innovation is an important force in promoting scientific and technological progress and economic development (Schumpeter, 1912; Filippopoulos and Fotopoulos, 2022; Li *et al.*, 2022). In many regions, industrial agglomeration plays an important role in regional development. The early Italian traditional industry clusters, German manufacturing industry clusters and later the high-tech industry clusters such as Silicon Valley, Route 128, Tsukuba Science City and Zhongguancun Industrial Park led to the continuous improvement of local innovation capability (Filatotchev *et al.*, 2011; Engel, 2015). New economic geography indicates that industrial agglomeration promotes regional innovation by increasing returns and capital (Krugman, 2011). Industrial agglomeration produces increasing returns to economies of scale through knowledge spillover, human resource flow and infrastructure sharing (Ning *et al.*, 2016; Li and Jian, 2022). Meanwhile, the incomplete competition formed by industrial agglomeration provides sufficient capital sources for regional innovation (Krugman, 2011; Li and Jian, 2022).

As industrial development is the main driving force for regional innovation (Li *et al.*, 2022), it is important to clarify the relationship between industrial agglomeration. There are two kinds of industrial agglomeration: specialization and diversification. Specialization agglomeration, which is also known as Marshall-Arrow-Romer (MAR) externality, argues that a single industry agglomeration in a certain region contributes to labor market sharing and technology spillover effect, thus improving regional innovation performance (Glaeser *et al.*, 1992; Beaudry and Schiffauerova, 2009). Whereas diversification agglomeration or Jacobs externality, suggests that the knowledge spillover and technology externalities formed by the agglomeration of different industries in a region are conducive to the integration and collision of complementary knowledge (Li, 2015; Glaeser *et al.*, 1992). Existing literatures hold different views on whether regions should develop specialization or diversification (Li and Jian, 2022; Lan *et al.*, 2021). Beaudry and Schiffauerova (2009) claim that around 65% of the studies on agglomeration support the diversification Jacobs externality, whereas 54% of them support the specialization.

The reason for this paradox may be that existing studies mainly focus on mature industrial systems in developed countries and lack analysis of the dynamic process of industrial agglomeration, especially heterogeneity of industrial agglomeration in different development stages. Unlike developed countries, most emerging countries such as China are experiencing industrial upgrading and structural adjustment, and industrial agglomeration is characterized by dynamic changes, which also provides opportunities for research on the innovation effect of industrial agglomeration. Since the past 40 years of opening and reform, China, as the largest emerging country, has already established a unique economic and innovation system (Liu, 2009), which contains a relatively complete range of industry categories. Due to the differences in resource endowment and geographical location, industrial agglomeration among regions shows apparent differences. Therefore, China is a perfect research object for studying industrial agglomeration and regional innovation.

Different development stages in the region present the dissimilation of industrial structure and development mode (Filippopoulos and Fotopoulos, 2022). Industrial agglomeration changes with the local development stage (Rodrik, 2007). The relationship between industrial agglomeration and regional innovation is also affected by the regional development stages. Due to the difference in resource endowment and policy implementation among regions, China's regional development is highly unbalanced (Yao and Liu, 1998). First, the spatial distribution of regional innovation capacity in China is more unstable than in the USA and other developed countries (Fan, 2014; Liu and Sun, 2009), where some regions are more specialized, and others are more diversified. Second, economic

development shows noticeable regional differences and club convergence effects. The economic development level in the eastern coastal regions is higher than that of the central regions and the western inland regions (Fu, 2008; Kim and Knaap, 2001; Tian *et al.*, 2016). Third, the unsynchronized process of regional marketization has resulted in differences in the institutional environment among regions (Fan *et al.*, 2019), which has an essential impact on economic development and innovation (Li *et al.*, 2020). The uneven development among regions also provides an opportunity for us to use Chinese data to analyze the relationship between regional industrial agglomeration and regional innovation from a dynamic perspective.

Here, we use provincial-level Chinese regions to explore the impact of industrial agglomeration on innovation performance, aiming to reveal the paradox between diversification and specialization from a dynamic perspective. First, this paper analyzes the impact of diversification and specialization on regional innovation performance and explores their interaction with regional innovation to clarify the synergy between diversification and specialization. Second, this paper explores the impact of diversification and specialization on regional innovation in different development stages. The main finding is that diversification and specialization in China have a positive impact on regional innovation, and their interaction also has a positive impact on regional innovation. The effects of diversification and specialization are various in different development stages.

The rest of this paper is structured as follows. The following section presents the theoretical background concerning uneven regional development and the impact of diversification and specialization on regional innovation. The third section describes data resources and empirical strategy. The empirical results show in the fourth section. The paper concludes with a discussion of theoretical contributions and management implications.

Theory and hypotheses

Diversification and regional innovation

Diversification refers to the aggregation of different industries in the local region. Diversification generated externalities through industrial exchanges and cooperation (Li, 2015; Gao *et al.*, 2021). Diversification in the local region may promote regional innovation performance. Based on the small business administration innovation database of the USA, Feldman and Audretsch (1999) explored the impact of diversification and specialization on regional innovation. The results show that specialization has a more significant and positive impact on regional innovation than diversification. Based on the data collected from 30 provinces of China, Wang *et al.* (2016) invested the relationship between diversification and regional innovation; the results show that diversification has a significant and positive impact on regional innovation capacity (Wang *et al.*, 2016). Besides, R&D investment and FDI play a moderating role in the relationship between diversification and regional innovation.

The influence mechanism of diversification on regional innovation includes providing complementary resources, scope economy, complete industrial chain and reducing path dependence. First, diversification means that multiple industries gather in the local region, and knowledge resources among different sectors accumulate to be a "public pool" in the region (Baptista and Swann, 1998). The essence of innovation is the combination and recombination of different knowledge elements (Gao *et al.*, 2021). Diversification provides opportunities for firms to combine and recombine knowledge elements and generate innovation. Diversification also promotes the convergence of talents. They interact with each other, forming an environment of knowledge sharing and exchange, enabling the cross integration of technology and improving the innovation performance of enterprises.

Second, diversification spurs the complete industrial chain in the local region, which has a significant innovation range economy (Takano and Okamuro, 2021). According to Teece's framework of profiting from innovation, the critical element of innovation is the appropriability regime and complementary assets (Teece, 2018). Diversification reduces the cost of searching and acquiring complementary resources for enterprises and guaran for enterprises' profits (Gao *et al.*, 2021), which also provides good capital sources for further innovation of enterprises. At the same time, the industrial chain formed by diversification also creates the demand for complementary assets. To embed into the regional industrial chain, local firms should develop more innovative behaviors to meet various needs through innovation (Kortum and Lerner, 2000).

Third, diversification improves regional innovation by reducing path dependence. The region with a single industry is easily bound by a specific industry trajectory due to the historical factors of technology and institutional development and ignores the development and innovation of external technology and market (Arrow, 2003; Takano and Okamuro, 2021). As time passes, the region is easily locked in a specific trajectory due to the inertia of technology and institution (Arrow, 2003). Diversification enables regions to introduce new technological elements, establish new social systems, create a better innovation environment and improve the overall innovation performance of regions while cultivating and developing different industries. In summary, we argue that diversification has a positive effect on regional innovation and propose the hypothesis:

H1. The more the diversification in a region, the better innovation performance the region has.

Specialization and regional innovation

Specialization refers to the aggregation of similar industries in the local region, represented by the concentration of enterprises and labor force of the same industry (Marshall, 1975; Li, 2015). Specialization usually forms a "core-periphery" structure. Previous literature suggests that specialization can promote regional innovation. Based on the UK manufacturing data from 1975 to 1982, Baptista and Swann (1998) explored the positive impact of specialization on regional innovation. Using the data of 30 provinces' 29 kinds of manufacturing industry in China, Li (2015) analyzes the impact of specialization agglomeration on regional innovation and the moderating role of the regional institutional environment.

Specialization promotes regional innovation through the externality of technology and knowledge, mainly manifested in scale effect, knowledge dissemination, reducing information asymmetry, monopoly market competition incentive and knowledge spillover.

First, based on the new economic geography theory, there is an increasing return on the scale (Krugman, 2011). With the expansion of the scale of specialization, industrial profits show an increasing trend. On the one hand, specialization can reduce costs through resource sharing (Beaudry and Schiffauerova, 2009). In a region, investment in infrastructure and human capital has specificity (Williamson, 1979). Specialization may enable enterprises to share these infrastructure and human resources and improve innovation efficiency. On the other hand, the network externality of specialization improves innovation capability. The important premise of increasing scale is network externality. The value of a network depends on the number of other people already connected to the network (Tanriverdi˙ and Lee, 2008) when there is specialization in the region, the organization exchanges with each other to promote the overall technical ability of the industry and then improve the regional innovation ability.

Second, preliminary competition is another crucial assumption for new economic geography. Specialization brings more substantial market power to enterprises (Marshall, 1975) and forms a market monopoly in the local region. The market barrier provided by technological innovation is the prerequisite of monopoly (Schumpeter, 1912; Abdel-Rahman and Fujita, 1993), and the excess profit brought by the monopoly has become an essential incentive for regional innovation. To gain a long-term monopoly position in the market, enterprises must continue to carry out technological innovation, strengthen technical barriers and prevent competitors from entering the market. At the same time, the excess profit obtained by market monopoly provides the necessary economic basis for innovation. Further it supports enterprises to gain more substantial market power through technological innovation to monopolize the market.

Third, specialization contributes to the spread and diffusion of technical knowledge, which promotes regional innovation. Technological innovation is a process of knowledge accumulation. The special mechanism of specialization provides the necessary foundation for knowledge dissemination and diffusion, especially for tacit knowledge. Unlike explicit knowledge, which can be transformed into language and acquired through training and learning, tacit knowledge is difficult to be standardized challenging and easy to distort (Baumann and Kritikos, 2016). So tacit knowledge exchange between organizations depends more on experience exchange and sharing. Therefore, specialization can improve regional innovation performance by promoting the spread of knowledge.

Finally, specialization reduces transaction costs, which will produce a crowding-out effect on innovation and encourage regions to invest more capital in innovation. Specifically, specialization reduces search cost. Specialization brings the agglomeration of innovation elements (Li, 2015), which convinces enterprises easier to search for and obtain relevant innovation elements in the region. Specialization also reduces enterprises' particular investment and communication costs in response to information asymmetry. Specialization promotes information flow. Besides, specialization reduces the cost of innovative elements through market power, improving the bargaining power of enterprises in the region. Based on these discussions, we propose the following:

H2. The more the specialization in a region, the better the regional innovation performance.

Interaction of diversification and specialization

Industrial agglomeration is a dynamic development process. Diversification and specialization may co-exist (Duranton and Puga, 2000; Abdel-Rahman and Fujita, 1993). Duranton and Puga (2000) noted that specialization is partly the result of economic interactions within a given sector, whereas economic interactions across sectors foster diversification. Besides, the specialization co-exists with diversification in most regions. So, the interaction between specialization and diversification also affects regional innovation.

First, there is complementarity between diversification and specialization. On the one hand, diversification is conducive to resource acquisition and product sales of specialization, reducing the cost of specialization. On the other hand, specialization is conducive to improving the overall competitiveness of diversification. In other words, specialization can be embedded in a diversified industrial chain and take advantage of its advantages to improve the region's overall competitiveness. Second, the interaction between diversification and specialization helps to break path dependence. Specialization may form path dependence because of a single industry (Arrow, 2003), whereas diversification may fall into path dependence because of the lack of endogenous innovation ability. The joint effect of the

two can simultaneously play the endogenous growth ability of specialization and the multi-industry synergy advantage. Based on these discussions, we suggest that there is synergy between specialization and diversification and propose the following:

H3. The interaction of diversification and specialization positively affects regional innovation performance.

Moderating of development stage

Industrial agglomeration changes with the local development stage (Rodrik, 2007). Imbs and Wacziarg (2003) study the evolution of sectoral concentration about the level of per capita income using various data sources. The results showed that the relationship between industrial agglomeration and regional development follows a U-shaped pattern. In other words, when a country becomes rich, the output and employment of various industries show less specialization and more diversification. This phenomenon will continue to the later stage of development. Only when a country's income catches up with Ireland, its industry will be specialization.

So, we argue that the development stage will moderate the relationship between industrial agglomeration and regional innovation. First, regional development guarantees the market's leading role in allocating factors (Katila and Ahuja, 2002), creating a fair competition environment for enterprises. The free flow of innovation elements based on market rules is conducive to the organization's acquisition of complementary assets (Teece, 1986), ensuring the smooth running of the organization's innovation activities. Second, regional development is also shown in a sound system of laws and a good level of enforcement. A sound legal system provides normative constraints for the innovation behavior of innovation subjects and reduces the cost of coordination between enterprises. The high level of enforcement has increased the illegal expenditure of the innovation subject (Fischer and Henkel, 2012), avoiding the opportunistic risk of the organization such as "hitchhiking". Third, regional development promotes the establishment of reciprocal mechanisms among enterprises. A good institutional environment is conducive to guiding innovation participants in the market to form good social norms such as trust and reciprocity (Gouldner, 1960), strengthening cooperation and trust mechanism among organizations, increasing the intangible cost of illegal and dishonest organizations and reducing the risk of innovation. In summary, we propose the following hypothesis:

H4. The relationship between industrial agglomeration and regional innovation performance changes with the regional development stage.

Research context

Characteristics of industrial clusters in China

In China's economic transformation, the formation of industrial clusters has a certain complexity. First, China established a planned economic system in the early days of founding the People's Republic of China and formed several industrial clusters on the state's initiative. For example, Northeast China has developed an industrial agglomeration relying on national policies, focusing on resource-bases and heavy industries. Second, with the reform and opening of China and the reform of the market economy, the private economy has been growing. It has formed several competitive industrial agglomerations, such as Zhejiang, relying on its geographical advantages through import and export trade to form industrial clusters. Third, at the same time, depending on China's cheap domestic resources

to attract foreign investment, introduce foreign advanced technology and then form an industrial agglomeration, such as the export-oriented processing industry cluster in Guangdong Province. Fourth, due to China's uneven distribution of natural resources, some regions rely on resource advantages to develop industrial agglomeration, such as the coal industry in Shanxi Province and the steel industry in Hebei Province. Fifth, industrial agglomeration is promoted by the government. The Chinese Government plays an important role in developing and constructing industrial clusters. It promotes the formation of industrial clusters by providing various preferential policies and establishing industrial parks. For example, Zhongguancun in Beijing relies on national support policies and high-tech resources to form a high-tech industrial cluster (Kang and Ma, 2021).

Uneven development and regional innovation in China

The uneven regional development has always been the focus of scholars' attention. The inverted U-curve hypothesis points out that the imbalance of regional development will continue to increase with economic growth and decline when it reaches the fixed point (Williamson, 1965). Developing countries should prioritize some regions and then gradually develop other regions through their external economy (Hirschman, 1958). As an emerging economy with a vast territory and obvious regional endowment differences, China used the regional advantages of the east to cultivate the growth pole of development under the principle of "efficiency first". But it has also led to an imbalance of development among regions in China (Yao and Liu, 1998; Crescenzi and Rodríguez-Pose, 2017; Fu, 2008). Liu and White (2001) analyzed the uneven development of the regional innovation system in China from 5 fundamental activities – R&D, implementation, end-use, education and land linkage. By summarizing the existing literature, we summarize the three main aspects of China's uneven regional development: innovation capability, economic development and institutional environment.

First, there are obvious regional differences in innovation capability and activities among regions in China. According to the latest results of the Regional Innovation Index of China, which has been tracking and evaluating the regional innovation capability of China for nearly 20 years, there is a huge gap in innovation capability between regions. For example, ranking first, Guangdong scored 59.49, while Tibet scored 17.58, a difference of 3.4 times between them.

Second, the uneven development of the economy is also the most concerning topic among scholars. Due to the superior geographical location of the eastern coastal regions of China, the degree of globalization and economic liberalization is relatively high, and the level of economic development is also significantly higher than that of the central and the western regions (Fujita and Hu, 2001). This uneven economic development stems from the regional gap in agriculture, industry, construction industry, transportation and other industries, rather than the regional policy differences (Kim and Knaap, 2001). Due to the "club convergence" feature in the economic regions (Tian *et al.*, 2016), the three regions form different economic development clubs and the internal convergence trend of economic growth.

Third, the institutional environment between regions is uneven. After 40 years of opening and reform, market reform in China has achieved an important breakthrough and significant progress. However, due to inter-regional institutional construction and law enforcement differences, there are still differences among regional institutional environments (Fan *et al.*, 2019). A significant institutional environment means that the market plays a vital role in resource allocation and promotes regional innovation and economic development (Fan *et al.*, 2019; Li *et al.*, 2020). In institutional transitions such as

China, institutional environment uncertainty significantly affects innovation (Yi *et al.*, 2012; Barasa *et al.*, 2017).

Data and empirical strategy

Data

Our study used a combined dataset of four data sources: CEnet Statistics Database, *China Labor Statistics Yearbook*, Report on Regional Innovation Capability in China (2003–2019) and Marketization Index of China's Provinces: National Economic Research Institute (NERI) report (2001–2017). CEnet Statistics Database belongs to the Chinese National Information Center, one of China's authoritative economic databases. The data sources includes *China Statistical Yearbook*, *National Economic Statistics Bulletin*, China Statistical Summary, etc. The data involved in this paper mainly include R&D investment, fixed asset investment (FAI), regional patent application, technical contract turnover, quantity of import and export, postal and telecommunications business volume, etc. The *China Labor Statistics Yearbook*, compiled by the National Bureau of statistics, is an information Yearbook that comprehensively reflects the labor economy of China. It is the primary source of employment-population in each province in this paper.

Regional Innovation Index of China compiled by the research group on the development strategy of science and technology of China is one of the earliest reports on the regional innovation capability in China. The report evaluates regional innovation capability from five aspects: knowledge creation, knowledge acquisition, enterprise innovation, innovation environment and innovation performance (Liu *et al.*, 2018). And the report is widely used in the literature on regional innovation (Chen and Guan, 2012). Marketization Index of China's Provinces: NERI report compiled by Fang Gang *et al.* have been widely used in the business and economics literature (Li, 2015; Wang *et al.*, 2013). The NERI indices measure the maturity of the market economy from five dimensions, namely, the relationship between government and market, development of product market, development of factor market and intermediary market organization and legal system environment.

Considering the missing data in Tibet and different statistical caliber in Hong Kong, Macao and Taiwan, these four provinces are not included in this study. Finally, we use panel data from 30 provinces from 2001 to 2017 conduct our empirical research.

Empirical model specification

We consider regional innovation as the knowledge production function of industrial agglomeration (diversification and specialization) and other regional characteristics; the Cobb-Douglas production function is as follow:

$$\ln(INN_{it}) = \alpha + \beta_1 \ln(DIV_{it}) + \beta_2 \ln(SPEC_{it}) + \beta_i \sum_i^k CONTROL_{it} + \varepsilon \qquad (1)$$

Where i denotes region and t denotes year. INN_{it} is regional innovation performance. DIV_{it} is diversification. $SPEC_{it}$ is specialization. α is constant. $CONTROL_{it}$ are control variables. β_i are the estimation of output elastic coefficients of characteristics. k is the number of control variables. ε is residual error.

Variables

Dependent variable

This paper uses domestic patent applications to measure regional innovation. Patent-based variables may reflect the regional innovation activities more accurately than new product

sales from the technology perspective in a developing country such as China (Dang and Motohashi, 2015). Besides, the patent can provide some reliable and structural proxy such as patentee, application time, IPC and other information over time (Nagaoka *et al.*, 2010).

In addition, we argue that patent applications may be more suitable for our study than patent grants. First, compared with patent grants, the most significant advantage of patent applications is timeliness. Patent grant needs several processes such as preliminary examination, substantive examination and grant, which takes several years to be finally granted (Li, 2015). It cannot reflect regional innovation activities in time, but patent applications can reflect them in time. Second, patent applications can include innovation activities more complete. Because of strict examination procedures for the patent grant, some patents that do not meet the format and content standards will not be able to pass and thus cannot capture innovation activities more comprehensively.

Independent variables

We use Krugman specialization index as the measurement of MAR externalities (Ning *et al.*, 2016). The indicate is defined as follow:

$$SPEC_i = \sum_{j=1}^{n} \left| \frac{E_{ij}}{\sum_{j}^{n} E_{IJ}} - \frac{\sum_{i=1}^{m} E_{ij}}{\sum_{j=1}^{n}\sum_{i=1}^{m} E_{ij}} \right| \tag{2}$$

where E_{ij} is the number of employments in industrial j in region i, n is the total number of industries(max = 19) and m is the total number of regions(max = 30) which include all provinces in China except Tibet, Hongkong Macao and Taiwan.

The modified Herfindahl–Hirschman index is used to measure the regional specialization (Ning *et al.*, 2016), and the specific calculation formula is as follows:

$$DIV_i = \frac{1}{\sum_{j=1, j' \neq j}^{n} \left[E_{ij} / \left(E_i - E_{ij} \right) \right]^2} \tag{3}$$

We exclude the industry j that is considered when the diversity of the region and industry j is calculated ($j' \neq j$) to avoids the variety of an industry being linked with its specialization.

Moderating variables

In the Chinese context, there are many imbalances between regions. This paper introduces three moderating variables to test the relationship between industrial agglomeration and regional innovation in different development stages.

Innovation stages

We classify innovation stages according to the "Regional Innovation Index of China", which is evaluated by weighted comprehensive evaluation method. The primary indicators are dimensionless, the weights are obtained by experts. And then, the comprehensive utility value of innovation capability of each province is obtained. The utility value method is adopted in dimensionless treatment the specified value range of utility value is [0, 100].

In the report, the regional innovation capability is a relative ranking compared with other regions, instead of a direct measure of the focal region.

According to the report, Liu and Hu (2002) classified the 31 provinces in China into 4 groups. With the development of China, although there is still a gap between the first and second groups, the gap is constantly narrowing. Some provinces alternate between the first group and the second group. For this reason, we combined the first and second groups and divided the regions into three development stages: innovation leading region, innovation catching-up region and innovation backward region [1].

Economic development stage

There are obvious regional differences in China's economic development. The economic development level of the eastern coastal regions is higher than that of the middle and western inland regions (Fu, 2008). This difference is also reflected in the innovation ability (Sun, 2000). According to previous literature, China's economic regions are divided into eastern, central and western region [2].

Institutional environment stage

According to the Marketization Index of China's Provinces: NERI report. The calculation of the primary index of the marketization index is based on the base period year. In the base period year, the relative scoring system of 0–10 points is adopted. The province with the highest marketization degree of the sub-item is 10 the province with the lowest marketization degree is 0. The score of other provinces is 0–10, which is calculated according to the relative gap between the index and the province with the highest and lowest scores. Therefore, the score reflects the relative situation of the marketization process between provinces. The higher score reflects the relatively higher degree of marketization. The score of subsequent years is still based on the base year it is allowed to be more than 10 points or less than 0 point. Based on the marketization score, the provinces is divided into three groups: market-oriented region whose score is higher than 8, market transformation region whose score is higher than 5 but lower than 8 government intervention region whose score is lower than 5. We also test the robustness through a grid search (at 0.2 increments) the results with other boundaries are consistent.

Control variables

We also control for several factors that might affect regional innovation. R&D input (RD), measured by regional R&D expenditure. On the one hand, R&D input improves the R&D intensity (Baumann and Kritikos, 2016), Wakelin, 2001). On the other hand, it increases the regional absorption capacity (Mukherji and Silberman, 2013). External knowledge spillover [foreign direct investment (FDI)], is measured by regional inward FDI (Ning *et al.*, 2016). FDI provides innovative capital elements for the region and brings some advanced technology for the region (Bajo-Rubio *et al.*, 2010), Driffield and Love, 2007). Regional labor force (EMP), is measured by the number of the urban employed population. The labor force is regarded as the basic factor in the knowledge production function (Romer, 1990). The labor force promotes the knowledge spillover of industrial agglomeration through the exchange and flow of the employed population. Investment in fixed assets (FAI) is measured by the total amount of investment in fixed assets completed by the whole society in each province. While promoting economic development, investment impacts regional innovation through technology transfer and spillover. Technology market activity (TMA) measured is by the regional turnover of technology contracts. As a platform for technology commodity transfer and exchange, the technology market plays an essential role in technology spillover and innovation. The level of foreign trade (TRADE) is measured by the total amount of imports and exports, reflecting regional foreign trade strength.

Foreign trade involves transferring and exchanging various knowledge and technology (Gokmenoglu *et al.*, 2015), Kim *et al.*, 2016). Infrastructure construction (INFR) is measured by the total volume of post and telecommunications business. Infrastructure construction is a significant foundation and platform for knowledge exchange and transfer among enterprises, universities and scientific research institutions. Infrastructure construction is conducive to promoting the collaborative innovation of all subjects in the region (Table 1).

Empirical results

Descriptive analysis

Table 2 shows the summary statistics and correlation matrix for all variables.

The correlation matrix shows a strong correlation between diversification and regional innovation. But the correlation between specialization and regional innovation is not significant. All the control variables correlated explained variable. We use variance inflation factor (VIF) to test the multicollinearity. The result shows that the highest VIF is only 3.78, far below the critical point of 10, suggesting that multiple collinearity is no longer a concern.

We map out the spatial distribution of diversification and specialization in Figures 1–2, visually represent our expected results across provinces in 2005, 2010 and 2015.

Table 1.
Presentation of description of the variables

Variable name	Acronym	Operationalization
Regional innovation	INN	Regional patent applications
Diversification	DIV	Improved Herfindahl-Hirschman Index
Specialization	SPEC	Krugman specialization index
R&D input	RD	Regional R&D expenditure
External knowledge spillover	FDI	Regional inward FDI
Regional labor force	EMP	The number of the urban employed population
Fixed asset investment	FAI	The total amount of fixed asset investment completed by the whole society
Technology market activity	TMA	Regional turnover of technology contracts
Foreign trade	TRADE	The total amount of import and export

Table 2.
Summary statistics and correlation matrix

Variables	1	2	3	4	5	6	7	8	9	10
1INN	–									
2DIV	−0.28***	1.80								
3SPEC	0.07	0.28***	1.86							
4RD	0.69***	−0.12*	0.23***	3.32						
5FDI	0.83***	−0.32***	0.04	0.58***	3.23					
6TRADE	0.46***	−0.36***	0.44***	0.63***	0.52***	3.78				
7EMP	0.52***	0.15***	0.13**	0.3***	0.42***	0.12*	2.21			
8FAI	0.16***	0.38***	−0.01	−0.07	−0.01	−0.42***	0.4***	1.79		
9CTR	0.83***	−0.15***	0.11	0.78***	0.69***	0.50***	0.39***	0.04	3.65	
10INFR	0.86***	−0.2***	0.04	0.50***	0.76***	0.38***	0.64***	0.11*	0.67***	3.73
Mean	9.35	5.96	1.32	0.76	12.13	0.24	13.61	0.46	12.66	5.9
S.D.	1.69	2.29	0.14	0.37	1.74	0.24	3.39	0.15	1.82	1.04

Notes: *$p < 0.1$; **$p < 0.05$; ***$p < 0.001$, similarly hereinafter. The diagonal is the VIF value of the variables

Figure 1 shows the three snapshots of the distribution of diversification, which is uneven spatial distribution. The degree of clustering in central and western regions is prominent such as Inner Mongolia, Qinghai and Heilongjiang. Overall, the level of diversification is on the rise. In Figure 2, the maps show an uneven spatial distribution of specialization. The provinces with specialization are distributed in the eastern coastal regions such as Guangdong, Fujian and Zhejiang. But the provinces with specialization moved to the central and western regions over time. Combining the results of Figures 1 and 2, diversification and specialization may co-exist in the same region, such as Heilongjiang and Hainan.

Main results

Table 3 presents the result from regressions of the number of patent applications. Column (1) shows the base model which only includes the control variable. The specification of Column (2) introduces diversification and Column (3) introduces specialization. We present their interaction item in Column (4) to test the interaction effect between diversification and specialization.

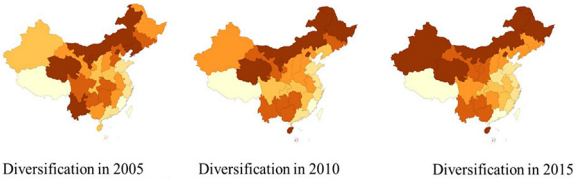

Figure 1. Distribution and change of diversification level in China

Figure 2. Distribution and change of specialization level in China

	(1)	(2)	(3)	(4)
DIV		0.054*** (0.02)		−0.024 (0.02)
SPEC			1.405*** (0.30)	1.379*** (0.30)
DIV*SPEC				0.332*** (0.08)
RD	2.138*** (0.16)	2.253*** (0.16)	2.167*** (0.15)	2.282*** (0.16)
FDI	0.148*** (0.03)	0.143*** (0.03)	0.144*** (0.03)	0.121*** (0.03)
TRADE	0.094 (0.26)	0.243 (0.27)	0.121 (0.25)	0.259 (0.26)
EMP	−0.005 (0.01)	−0.007 (0.01)		−0.007 (0.01)
FAI	2.191*** (0.21)	2.123*** (0.21)	2.193*** (0.21)	2.085*** (0.21)
CTR	0.395*** (0.02)	0.392*** (0.02)	0.371*** (0.02)	0.372*** (0.02)
INFR	0.142*** (0.05)	0.130*** (0.05)	0.073* (0.04)	0.100** (0.04)
Cons.	−0.873** (0.36)	−1.105*** (0.36)	−2.063*** (0.43)	−1.776*** (0.46)
N	510	510	510	510
R^2	0.899	0.900	0.903	0.908

Notes: *$p < 0.1$; **$p < 0.05$; ***$p < 0.001$

Table 3. Regression of the number of patent applications

The results in Column (1) show that the control variables on innovation are plausible and consistent with the previous literature (Ning *et al.*, 2016; Wang *et al.*, 2016; Li, 2015). The coefficients of R&D input, FDI, TRADE, FAI, CTR and INFR are positive and statistically significant. But the coefficient of EMP is not statistically significant. The results in Column (2) show that the coefficient of diversification is positive and statistically significant ($\beta = 0.054$, $P < 0.05$). This suggests that the regional innovation performance rise with diversification. *H1* is supported. The results in Column (3) show that the coefficient of specialization is positive and statistically significant ($\beta = 1.405$, $P < 0.05$). This suggests that specialization promotes regional innovation performance. *H2* is supported. The results in Column (4) show that the coefficient of the interaction item is positive and statistically significant ($\beta = 0.332$, $P < 0.05$), indicating that the positive effects of diversification and specialization on regional innovation can be mutually strengthened. *H3* is supported.

Results of moderating of development stage

Test based on innovation stages

Table 4 shows the results of the relationship between industrial agglomeration and regional innovation in different innovation stages.

The results in Table 4 show that in the leading region, diversification has no significant impact on regional innovation ($\beta = -0.033$, $p > 0.1$). Industrial specialization has a significant positive impact on regional innovation ($\beta = 1.980$, $p < 0.05$). In the catching-up region, diversification has no significant effect on regional innovation ($\beta = 0.020$, $p > 0.1$). Specialization has no significant effect on regional innovation ($\beta = -0.548$, $p > 0.1$). In backward regions, diversification has a significant positive impact on regional innovation ($\beta = 0.273$, $p < 0.05$). Specialization has a significant positive impact on regional innovation ($\beta = 2.310$, $P < 0.05$).

When the innovation capability is relatively backward, the regional innovation factors can meet the innovation demand. The scope economy and scale economy formed by diversification and specialization will promote regional innovation performance. With the continuous improvement of innovation capability, the demand for innovation factors in the region increases the industrial agglomeration shows a competitive effect. The scale of industrial agglomeration is gradually expanding, which leads to serious homogenization competition. With the further enhancement of innovation capability, some industries lacking

	Leading region		Catching-up region		Backward region	
	(1)	(2)	(3)	(4)	(5)	(6)
DIV	−0.033 (0.03)		0.020 (0.03)		0.273** (0.11)	
SPEC		1.980*** (0.52)		−0.548 (0.47)		2.310** (0.93)
RD	1.929*** (0.27)	1.982*** (0.22)	1.703*** (0.24)	1.610*** (0.24)	1.691* (0.86)	2.068** (0.84)
FDI	0.296*** (0.08)	0.290*** (0.08)	0.124*** (0.04)	0.118*** (0.04)	−0.053 (0.08)	0.003 (0.07)
TRADE	0.396 (0.32)	0.661** (0.31)	0.138 (0.67)	0.073 (0.66)	−3.511** (1.74)	−3.339* (1.75)
EMP	−0.004 (0.01)	−0.014 (0.01)	−0.002 (0.01)	0.001 (0.01)	−0.023 (0.02)	−0.015 (0.02)
FAI	0.073 (0.46)	1.066** (0.49)	2.909*** (0.34)	3.027*** (0.34)	2.304*** (0.51)	2.242*** (0.51)
CTR	0.495*** (0.07)	0.436*** (0.06)	0.398*** (0.03)	0.405*** (0.03)	0.178*** (0.05)	0.146*** (0.05)
INFR	0.271*** (0.07)	0.174** (0.07)	−0.051 (0.06)	−0.041 (0.06)	0.481*** (0.11)	0.392*** (0.12)
Cons.	−4.259*** (0.96)	−5.972*** (1.03)	0.376 (0.49)	1.124 (0.70)	0.330 (1.03)	−0.792 (1.32)
N	144	144	294	294	72	72
R^2	0.924	0.932	0.909	0.910	0.867	0.867

Notes: *$p < 0.1$; **$p < 0.05$; ***$p < 0.001$

Table 4.
Results for different innovation stages

competitiveness are eliminated. Some specific industries form technical barriers through technological innovation new specialization appears in the region.

Test based on economic development

Table 5 shows the relationship between industrial agglomeration and regional innovation in different economic development regions.

The results in Table 5 show that in the eastern region, diversification has a significant positive impact on regional innovation ($\beta = 0.071$, $p < 0.05$). Specialization has a significant positive impact on regional innovation ($\beta = 0.835$, $p < 0.05$). In the middle region, diversification has a significant negative impact on regional innovation ($\beta = -0.075$, $p < 0.1$). Specialization has a negative positive impact on regional innovation ($\beta = -1.251$, $p < 0.05$). In the government intervention region, diversification has a significant positive impact on regional innovation ($\beta = 0.201$, $p < 0.05$). Specialization has a significant positive impact on regional innovation ($\beta = 2.099$, $p < 0.05$).

The promoting effect of industrial agglomeration on regional innovation will not increase with economic development but presents a U-shaped relationship; that is, in the relatively backward and developed regions, diversification and specialization will promote regional innovation capability. But in the regions of economic development, diversification and specialization will have a negative impact on regional innovation, which verifies the "middle-income trap". After a period of rapid economic growth in the region the per capita income reached the middle-income level. Due to the imperfect legal system, the government and vested interest groups monopolized national resources through rent-seeking behavior, resulting in vicious competition in the region, weak industrial upgrading, stagnant growth, no guarantee of enterprise innovation further reduction of incentives for innovation behavior.

Test based on institutional environment

Table 6 shows the results of the relationship between industrial agglomeration and regional innovation in different marketization level regions.

The results in Table 6 show that in a market-oriented region, diversification has a significant positive impact on regional innovation ($\beta = 0.232$, $p < 0.05$). Specialization has

	Eastern region		Central region		Western region	
	(1)	(2)	(3)	(4)	(5)	(6)
DIV	0.071*** (0.02)		−0.065* (0.03)		0.201*** (0.07)	
SPEC		0.835* (0.44)		−1.251** (0.55)		2.099*** (0.58)
RD	2.631*** (0.23)	2.332*** (0.22)	1.961*** (0.33)	1.714*** (0.36)	1.417*** (0.34)	1.261*** (0.33)
FDI	0.153** (0.07)	0.151** (0.07)	0.405*** (0.07)	0.436*** (0.07)	0.049 (0.04)	0.096*** (0.04)
TRADE	−0.298 (0.30)	−0.344 (0.30)	−0.404 (1.05)	−0.498 (1.05)	3.344*** (0.73)	2.887*** (0.67)
EMP	0.010 (0.01)	0.008 (0.01)	0.003 (0.01)	0.005 (0.01)	−0.025** (0.01)	−0.021* (0.01)
FAI	0.512 (0.31)	0.899*** (0.34)	0.618 (0.46)	0.702 (0.46)	4.189*** (0.38)	4.204*** (0.37)
CTR	0.333*** (0.05)	0.355*** (0.05)	0.426*** (0.05)	0.442*** (0.05)	0.276*** (0.03)	0.258*** (0.03)
INFR	0.211*** (0.07)	0.210*** (0.07)	−0.147* (0.08)	−0.137* (0.08)	0.118* (0.07)	0.070 (0.07)
Cons.	−0.722 (0.79)	−1.600* (0.86)	−1.370* (0.76)	−0.770 (0.85)	−0.504 (0.53)	−1.760** (0.74)
N	187	187	136	136	187	187
R^2	0.917	0.914	0.946	0.946	0.922	0.924

Notes: *$p < 0.1$; **$p < 0.05$; ***$p < 0.001$

Table 5.
Results for different economic development

Table 6.
Results for different marketization level

	Market-oriented		Market transformation		Government intervention	
	(1)	(2)	(3)	(4)	(5)	(6)
DIV	0.232*** (0.07)		0.050** (0.02)		0.033 (0.05)	
SPEC		2.227*** (0.65)		0.669 (0.43)		0.992 (0.64)
RD	−0.449 (0.41)	−0.334 (0.41)	2.749*** (0.24)	2.676*** (0.24)	1.572*** (0.40)	1.394*** (0.37)
FDI	0.041 (0.04)	0.071* (0.04)	0.223*** (0.05)	0.212*** (0.05)	0.442*** (0.14)	0.449*** (0.14)
TRADE	−1.792* (1.01)	−1.212 (0.99)	1.949*** (0.42)	1.780*** (0.42)	−0.532 (0.47)	−0.352 (0.48)
EMP	−0.006 (0.01)	−0.003 (0.01)	−0.007 (0.01)	−0.005 (0.01)	0.014 (0.02)	−0.003 (0.02)
FAI	3.829*** (0.44)	4.042*** (0.40)	1.401*** (0.33)	1.494*** (0.32)	2.544*** (0.72)	2.963*** (0.77)
CTR	0.233*** (0.04)	0.184*** (0.04)	0.391*** (0.03)	0.386*** (0.03)	0.245** (0.10)	0.272*** (0.09)
INFR	0.197*** (0.07)	0.132* (0.07)	−0.012 (0.06)	−0.007 (0.06)	0.375*** (0.11)	0.339*** (0.11)
Cons.	0.770 (0.61)	−0.163 (0.77)	−1.491*** (0.51)	−1.871*** (0.65)	−3.887** (1.91)	−5.189** (2.03)
N	144	144	274	274	92	92
R^2	0.910	0.911	0.912	0.911	0.922	0.924

Notes: *$p < 0.1$; **$p < 0.05$; ***$p < 0.001$

a significant positive impact on regional innovation ($\beta = 2.227$, $p < 0.05$). In the market transformation, diversification has a significant positive impact on regional innovation ($\beta = 0.050$, $p < 0.05$). But specialization has no significant effect on regional innovation ($\beta = 0.669$, $p > 0.1$). In the government intervention region, diversification has no significant impact on regional innovation ($\beta = 0.033$, $p > 0.1$). Specialization has no significant effect on regional innovation ($\beta = 0.992$, $p > 0.1$).

The above results show that the better the regional institutional environment, the better the promotion effect of industrial agglomeration on regional innovation performance. In a region with a good institutional environment, the market plays a central role in the allocation of innovation factors that will improve innovation efficiency. For diversification, the free flow of innovation factors promotes the complementarity and coordination between regional diversification. For specialization, a good institutional environment can guarantee the innovation achievements of enterprises and encourage technological innovation of enterprises.

In summary, the relationship between industrial agglomeration and regional innovation various in different development stages, supporting *H4*.

Conclusions and implications

Conclusions

There has been a paradox in the impact of diversification and specialization on innovation. Using the data of 30 provinces in China from 2002 to 2017, this paper explores the implications of diversification and specialization on regional innovation in the context of China. Besides, based on the uneven regional development in China, this paper analyzes the effect of industrial agglomeration on regional innovation in different development stages, namely, regional innovation capability, economic development and institutional environment. The conclusions are as follows:

First, in the context of China, diversification and specialization have a significant and positive impact on regional innovation. The interaction of diversification and specialization also significantly and positively impacts regional innovation. The conclusion of this paper supports both MAR externalities and Jacobs externalities. Diversification and specialization may co-exist and be conducive to regional innovation in China. Diversification provides

complementary assets for developing enterprises in the region, while specialization improves innovation efficiency by sharing infrastructure and human capital.

Second, the effect of industrial agglomeration is also heterogeneous under different institutional development stages. In the market-oriented region, diversification and specialization significantly and positively impact regional innovation. In the market transformation region, diversification has a significant and positive impact on regional innovation and specialization has no significant effect on regional innovation. In the government intervention region, diversification and specialization significantly and positively impact regional innovation. The better the regional institutional environment, the better the promotion effect of industrial agglomeration on regional innovation performance. In a region with a good institutional environment, the market plays a main role in allocating innovation factors that will improve innovation efficiency. The free flow of innovation factors for diversification promotes the complementarity and coordination between regional diversification. For specialization, a sound institutional environment can guarantee the innovation achievements of enterprises and encourage technological innovation of enterprises.

Theoretical contributions

This paper may have some contributions in the following aspects. First, we introduce diversification and specialization into the research framework at the same time to analyze their impact on innovation performance, deepening the research of industrial agglomeration and regional innovation. Most diversification and specialization may co-exist and synergy (Duranton and Puga, 2000; Abdel-Rahman and Fujita, 1993). Unlike existing studies using a single indicator to analyze diversification and specialization (Li, 2015), we explore the impact of specialization and diversification and their interaction on regional innovation performance. The results show that both diversification and specialization affect regional innovation and their interaction also plays a vital role in regional innovation.

Second, we explore the relationship between industrial agglomeration and regional innovation in the context of China. We interpret the reasons for the uneven regional development in China from the perspective of industrial agglomeration, which enriches the relevant research contents of emerging economies. Scholars have realized the uneven development of innovation, economy and institutional environment in China (Liu and White, 2001; Fu, 2008; Fan *et al.*, 2019) made a series of analysis on it. From the perspective of the differences in the externalities of industrial agglomeration, this paper analyzes the different stages of regional development, and the impact of industrial agglomeration on regional innovation capability, which provides a new perspective for the innovation capability promotion of emerging economies.

Third, from the dynamic perspective of the regional development stages, we reveal the relationship between industrial agglomeration and regional innovation. There has been a paradox in the relationship between industrial a and innovation (Beaudry and Schiffauerova, 2009; Li, 2015). Due to the differences in institution setting and economic development between different countries and regions, the industrial agglomeration has a heterogeneous impact. From the regional development stage perspective, based on the uneven development in China's transition period, this paper analyzes the effect of regional industrial agglomeration in different development stages and reveals the contradictions of industrial agglomeration to some extent.

Practical implications

This paper verifies the positive role of diversification and specialization and their interaction in promoting regional innovation. This paper provides a theoretical basis for developing industrial agglomeration in emerging economies. The impact of industrial agglomeration on innovation is dynamic and changes with the regional development process. Emerging economies should make appropriate industrial agglomeration strategies according to their development stages. This paper analyzes the relationship between industrial agglomeration and regional innovation performance in different stages of innovation development, economic development and institutional environment, which provides a theoretical basis for emerging economies to improve innovation performance relying on industrial agglomeration.

Limitations

This paper systematically examines the influence of diversification and specialization agglomeration on regional innovation performance, which has certain theoretical and practical significance. At the same time, this article also has some limitations, providing a direction for our future research. First, this article explores the impact of industrial agglomeration on the overall regional innovation performance, without further subdividing the types of innovation. However, the effect of industrial agglomeration on different types of innovation may also be different. In future research, we will explore the impact of industrial agglomeration on different types of innovation, such as breakthrough, exploratory and incremental innovation.

Second, this article takes each province as the basic unit of analysis, ignoring the heterogeneity between different cities in the province. Many provinces in China have a large region, and the innovation between other cities in the same province is also heterogeneous. So, research based on the city level may lead to more precise conclusions. Future research will further explore the relationship between industrial agglomeration and innovation performance at the city level and strengthen the theoretical research on industrial agglomeration in the Chinese context.

Third, this paper does not consider the spatial effects of industrial agglomeration.

Regional industrial agglomeration affects the local innovation performance and impacts the innovation of surrounding regions through spillover effects. Future research will expand the spatial effects of diversification and specialization.

Notes

1. According to the division of innovation groups by Liu and Hu (2002), this paper takes 30 and 20 as the basic criteria for the division of different groups, that is, the first group is the province with more than 30, the second group is the province with more than 20 and less than 30, and the third group is the province with less than 20. At the same time, considering the balance between the groups and the score gap between the criteria, we made appropriate adjustments to the group division of the provinces near the critical points.
2. The eastern region includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan. The central region includes Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan and eight other provinces. The western region includes 11 provinces, including Sichuan, Chongqing, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang, Guangxi, Inner Mongolia, etc.

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