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Industrial Agglomeration and Enterprise Innovation Sustainability: Empirical Evidence from the Chinese A-Share Market

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Abstract: The data from 285 prefecture-level cities in China are selected as research samples from 2005 to 2021, using the panel data of listed companies. The empirical study examines the impact of regional industrial agglomeration levels on enterprise innovation sustainability and its heterogeneity effects. The findings reveal that industrial agglomeration in the manufacturing sector significantly hampers enterprise innovation sustainability, while agglomeration in the producer services sector promotes it. Mechanism analysis demonstrates that industrial agglomeration affects enterprise innovation sustainability through the micro-conductive mechanism of financial constraints. Heterogeneity analysis shows that the impact of manufacturing agglomeration on enterprise innovation sustainability is more pronounced in technology-intensive and high-end technology industries, whereas the impact of producer services agglomeration varies significantly in knowledge-intensive and resource-intensive industries. Furthermore, heterogeneity analysis suggests that the influence of industrial agglomeration on enterprise innovation sustainability varies according to different firm characteristics. These research findings contribute to a deeper understanding of the microeconomic effects of industrial agglomeration and expand the research perspective on the internal mechanisms and external factors driving sustainable corporate innovation.

Keywords: industrial agglomeration; enterprise innovation sustainability; manufacturing; producer services; innovation quality; innovation efficiency

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1. Introduction

Against counter-globalization and global value chain restructuring, the industrial structure is gradually shifting to emerging economies. The global outbreak of COVID-19 and geopolitical games worldwide have intensified the trend of industrial return and value chain "domestication" in various regions. As the advantages of low-cost labor and resource environment gradually disappear and global protectionism and unilateralism rise, the past model of promoting economic growth by relying on low-cost advantages and technology imports through methods such as introduction and imitation is unsustainable. Therefore, enhanced capacity for independent innovation is the fundamental driver of sustained economic growth through technological progress.

For microeconomic entities, such as enterprises, the high investment, high risk, and long cycle characteristics of innovation activities will encourage companies to undertake strategic innovation projects that can accelerate capital inflows, avoiding implementing and promoting substantial innovation projects with extensive research and development (R&D) investment and high uncertainty. Furthermore, the inherent information asymmetry in innovation activities has led to adverse selection and moral hazard, exacerbating external financing friction, and severely restricting the enhancement of corporate innovation capabilities. Any interruption or continuation of innovation will lead to irreparable losses for enterprises [1]. Therefore, against the backdrop of rapid deindustrialization and urbanization, exploring the economic consequences and mechanisms of industrial clustering's impact on enterprise innovation sustainability has significant theoretical value and practical significance in maintaining the sustainability of corporate innovation activities, ensuring enterprises can sustain investment in innovation, and promoting global economic globalization and sustainable development.

Industrial agglomeration refers to the high concentration and interaction of industries of the same type in a specific geographical area and the continuous clustering of production factors within a spatial area. Previous research has mainly classified and discussed the economic consequences that industrial agglomeration can trigger from the perspective of macro-regional economic development. Some studies in the literature suggest that industrial agglomeration exists in a positive feedback loop with regional economic growth and self-growth due to its spatial spillover and industrial association effects. Marshall (1890) defined industrial agglomeration as the economies of scale achieved by related firms specializing in different stages of production. This can create a virtuous circle of regional economic growth and self-growth with differentiated products [2–6]. Porter (1998) approached it from the perspective of competitive advantage and defined industrial agglomeration as a spatial organizational form that optimizes scale efficiency, benefits, and flexibility to create competitive advantage. This form achieves dual growth in the "quality" and "quantity" of the regional economy through spatial spillovers, economies of scale, improved factor utilization efficiency, optimized and upgraded industrial structure, and promotion of employment and wage levels [7–10]. In particular, the homogenization, low-end, and extensive development mode of industrial agglomeration will destroy the coordinated development mechanism of industrial agglomeration and regional economic growth. This may cause heterogeneous effects or even the failure of positive externalities of industrial agglomeration, resulting in a stagnation of regional economic growth [11–14].

The so-called sustainability of innovation refers to the continuity of investment in innovative activities by a company. Enterprise innovation sustainability involves intentionally changing the firm's products, services, or processes that address the triple bottom line of people, planet, and profit [15]. Enterprise innovation sustainability can enhance the firm's competitiveness, reputation, and resilience in the face of global challenges such as climate change, resource scarcity, and social inequality. Enterprise innovation sustainability can also create value for various stakeholders, such as customers, employees, suppliers, investors, regulators, and communities. Currently, two key factors affect a company's ability to maintain the sustainability of its R&D innovation. The first is information asymmetry. Compared to fixed asset investments, R&D investments face higher levels of information asymmetry, greater investment risks, and more severe financing constraints [16–18]. As a result, R&D innovation activities are highly susceptible to disruptions in funding, which can lead to stagnation. The second factor is adjustment costs. The costs associated with hiring, training, and the negative externalities resulting from proprietary innovation knowledge spillovers generated during the interruption and continuation of the R&D innovation process can lead to significant adjustment costs [19–24]. Against this backdrop, it is essential to maintain the sustainability of a company's R&D innovation through internal smoothing mechanisms. The existing literature indicates that bank loans, working capital, cash holdings, organizational redundancy, foreign investment, corporate savings, and government subsidies play a smoothing role in investment fluctuations. Although existing research has provided a comprehensive discussion of the internal and external factors that affect innovation sustainability, there is a lack of in-depth exploration of the specific mechanisms involved [25–29]. Empirical research on the agglomeration spillover effects in the industry has primarily been explored at the macro- and meso-levels. However, there needs to be a more necessary exploration of the dynamic mechanisms and heterogeneous effects of such effects on the sustainability of R&D innovation at the micro-level of companies.

Firms in China face a unique environment with the state's strong role, complex regulations, and environmental and social challenges. Some factors affecting them are the SOEs that control many sectors and receive preferential treatment. The industrial policies and plans that set economic goals and direction include innovation, digitalization, and green development. Firms have to follow them. The market reforms improve the efficiency and competitiveness of the economy, such as opening up more sectors, reducing barriers, and improving the legal system. Taking enterprise innovation sustainability as the entry point and under the strategic background of "continuously advancing China's national innovation strategy" we discuss the impact of industrial agglomeration on enterprise innovation sustainability, mechanisms of action, and heterogeneity effects. The possible marginal contributions follow. First, by introducing the perspective of enterprise innovation sustainability, we attempt to expand the research scope of the relationship between industrial agglomeration—an endogenous macro-variable in economic transition—and enterprise innovation sustainability, incorporating rules of enterprise development into the analysis framework and depicting a linear relationship between industrial agglomeration and enterprise innovation sustainability, providing essential supplements to the studies of microeconomic consequences of industrial agglomeration. Second, we clarify the differentiated impact effects of manufacturing agglomeration and producer services agglomeration on enterprise innovation sustainability and their different mechanisms of action, proposing the theoretical logic of how industrial agglomeration affects enterprise innovation sustainability, making necessary supplements to the micro-mechanisms between the two in existing research. Third, we explore and further reveal the differentiated impact effects of industrial agglomeration on enterprise innovation sustainability under different industry and enterprise characteristics from macro- and micro-perspectives, providing empirical evidence for enterprises in different areas.

The remainder of this paper is structured as follows: Section 2, "Theoretical Analysis and Research Hypothesis", develops research hypotheses. Section 3, The "Methodology" section describes samples, data, measures, and statistical techniques. Section 4, "Results", outlines our empirical results. Section 5, "Heterogeneity test", describes the heterogeneity test of industries and enterprises, and Section 6, "Extensibility test", examines the manifestations of firm heterogeneity. Finally, this paper concludes with a discussion of the policy implications, limitations, and future research directions in the final section, " Discussions and conclusions."

2. Theoretical Analysis and Research Hypothesis

As one of the critical carriers of macroeconomic policy implementation, the externalities of industrial agglomeration can affect firms' micro-level innovation sustainability. Therefore, the degree of industrial agglomeration directly determines the enterprise innovation sustainability of the region in which it is located. We propose potential mechanisms and research hypotheses that affect enterprise innovation sustainability. We use manufacturing and producer services agglomeration as links to the spillover effects on enterprise innovation sustainability and heterogeneous economic consequences.

2.1. The Effect of Manufacturing Agglomeration on the Enterprise Innovation Sustainability

The main reasons why manufacturing agglomeration inhibits enterprise innovation sustainability are as follows: First, manufacturing agglomeration may lead to congestion effects and sunk costs, which increase the production costs and innovation risks of enterprises, reduce their profit margins, and create innovation barriers. Second, manufacturing agglomeration may intensify market competition and homogenization, which causes enterprises to fall into price wars and low-end competition, lacking differentiation and high-value-added products and services. Third, manufacturing agglomeration may lead to technology spillover effects and knowledge outflow, resulting in a lack of awareness and ability for technological and model innovation, making it difficult to adapt to technological and market changes [30].

Firstly, there are congestion effects and sunk costs. When manufacturing enterprises are excessively concentrated in a particular region, their production scale and market share will gradually saturate, their marginal benefits will show a decreasing trend, and the scale effect of agglomeration will be offset or even surpassed by the crowding effect. The market expansion boundaries of enterprises will contact and penetrate each other [31]. The competition among industries will become more fierce, which will lead to insufficient or rising prices of factors such as infrastructure, public services, land resources, etc., in the region, thus forming a "congestion effect" which will be detrimental to the product competitiveness and quality of manufacturing, causing the operational pressure and resource waste of enterprises to increase, increasing their production costs and innovation risks. At the same time, since manufacturing agglomeration often requires a large amount of fixed investment and specific assets, these investments are difficult to transfer or recover when the industrial structure changes or the market demand fluctuates, forming sunk costs, which in turn affect the flexibility and innovativeness of manufacturing exports, because it will increase the exit barriers and transformation costs of enterprises as well as reduce their investment returns and innovation motivation [32].

Secondly, there is excessive competition and homogenization. Manufacturing agglomeration will lead to an oversupply of similar or related products, resulting in problems such as product price decline, profit margin shrinkage, market share dispersion, etc. There is often a high degree of product substitutability and market overlap among enterprises, resulting in a lack of differentiation and characteristics in innovation, making it challenging to form core competitiveness. Manufacturing enterprises, in order to survive in the industry competition, will spontaneously or passively participate in the market competition, while excessive competition will lead to enterprises falling into price wars, vicious competition, and other quagmires, thus affecting enterprise innovation sustainability. In addition, excessive competition will lead to the overexploitation and utilization of resources, increasing energy consumption and pollution emissions, thereby reducing environmental quality and sustainability [33]. At the same time, due to the homogenization of industry and technology caused by manufacturing agglomeration, enterprises tend to develop similar or close products or services, which lack differentiation in function, quality, design, and other aspects. Enterprises are limited to their industries or fields, lacking communication and cooperation with other industries or fields, resulting in market saturation, consumer aesthetic fatigue, insufficient innovation demand, and other problems, hindering cross-border integration and open innovation of enterprises, reducing their profit margins and market opportunities, and lowering their innovation breadth and depth [34].

Finally, there are technology spillover effects and knowledge outflow. Manufacturing agglomeration may cause inertia and dependence on enterprises, inhibiting their technological change and innovation motivation. In manufacturing agglomeration, enterprises can obtain faster market feedback and benefits by learning from or imitating other enterprises' technologies or products, thereby reducing their input and risk of independent research, development, and innovation [35]. At the same time, manufacturing agglomeration leads to industrial lock-in and technological inertia, inhibiting enterprises' exploration and trial of new technologies. Enterprises may find it challenging to cross the existing industrial boundaries and technological paradigms, lacking the motivation to improve and enhance themselves, thus limiting the breadth and depth of innovation activities [36]. Although manufacturing enterprise agglomeration will strengthen inter-enterprise technological cooperation and talent mobility, thus promoting knowledge sharing and dissemination, it also involves technological leakage, knowledge outflow, talent loss, and other risks, leading to enterprises' core technologies or patents being imitated or stolen by competitors. This not only reduces the difficulty of technology protection and intellectual property rights, weakens enterprises' technological barriers and innovation advantages, and exposes them to more risks of technology leakage and knowledge theft but also makes them too conservative or closed, unwilling to share or exchange technologies or knowledge with external partners, making it challenging to achieve cross-border integration and open innovation [37,38].

Based on the above analysis, the following hypothesis is proposed:

Hypothesis 1. *Manufacturing agglomeration has negative impacts on enterprise innovation sustainability.*

2.2. The Effect of Producer Services Agglomeration on the Enterprise Innovation Sustainability

The producer services refer to the sector that provides services directly or indirectly to support industrial production, intending to promote technological progress, efficiency improvement, and industrial upgrading. It covers various stages of agriculture, industry, and service sectors and is characterized by solid professionalism, a high degree of industrial integration, and a significant driving force.

Compared to manufacturing, producer services have distinct characteristics. The manufacturing is primarily driven by economies of scale and cost advantages, often lacking effective mechanisms for knowledge spillover and technology diffusion, and struggling to form innovative synergies. In contrast, the producer services are primarily driven by knowledge intensity and technological upgrading, which can promote technological innovation through industry-related effects, R&D factor agglomeration, knowledge spillover, and synergies. The former is prone to overcapacity, homogeneous competition, technological lock-in, and path dependence. At the same time, the latter can generate positive effects such as industrial integration, differentiated competition, technological breakthroughs, and path exploration [39].

Firstly, the agglomeration of producer services helps to promote the generation, flow, and diffusion of knowledge, creating spillover and learning effects that enhance the efficiency and quality of enterprises' research and development [40]. The agglomeration of producer services can provide enterprises with specialized, high-value-added, high-knowledge-intensive services such as R&D design, technology transfer, and scientific consultation, which facilitate enterprises to tackle key core technologies, accelerate the transformation of scientific achievements, consolidate the foundation of industry–university–research collaborative innovation, and thus advance the precise alignment and deep integration of industrial chains and innovation chains [41]. Meanwhile, agglomeration can attract R&D institutions, universities, government departments, and other innovation actors to participate actively, forming combined effects such as innovation networks and ecosystems that enable them to share or bear the risks and outcomes of innovation activities, thereby offering enterprises more diversified, high-quality and low-cost innovation services [42]. These services can stimulate innovation motivation and awareness, generate economies of scale and synergy for knowledge resources and technical support, and ultimately improve enterprises' sustainable innovation capability and level [43].

Secondly, the agglomeration of producer services can provide personalized products and services, meeting the diverse needs of enterprises and enhancing their market competitiveness and added value. Producer services can provide customized, differentiated, and comprehensive products and services based on the different needs of enterprises, such as intelligent logistics, supply chain finance, and talent cultivation, which can help enterprises optimize production processes, reduce operating costs, expand market channels, and provide technical support for sustainable innovation. Additionally, agglomeration can further increase the variety and quality of products and services, creating economies of scale and cooperation for personalized, efficient, and high-value services that help improve the precision of enterprise R&D activities. These services can effectively enhance the quality of enterprise products and services, meet the diverse and personalized needs of consumers, enhance the market competitiveness and value-added of enterprises, promote the transformation of innovative enterprise behavior from quantity expansion to quality improvement, from low-end to high-end, adapt to the constantly changing market demands and technological changes, mitigate the risks of innovation activities, and ensure uninterrupted innovation activities [44].

Finally, the producer services agglomeration can provide enterprises with a collaborative innovation platform, achieving deep integration of products and services, reducing production costs, manufacturing, and social transactions, and improving resource utilization efficiency and environmental friendliness [45]. Producer services can provide services for agricultural and industrial production activities, such as general aviation, productive leasing, wholesale and trade agent brokerage, R&D design, and more. These services can facilitate labor matching and spatial selection effects, promote the survival of the fittest among enterprises in the agglomeration area, enhance production efficiency, optimize production processes, and innovate production modes, ultimately creating more profit and investment space for enterprises and supporting more extraordinary innovation activities. Moreover, producer services can establish mutually beneficial, complementary relationships with manufacturing, generating economies of scale and cooperation through shared resources, platform construction, value creation, and more. This can provide manufacturing with more collaborative, intelligent, and flexible production modes, improving resource utilization efficiency and environmental friendliness and improving and upgrading enterprise R&D technology [46].

Based on the above analysis, the following hypothesis is proposed:

Hypothesis 2. *Producer services agglomeration has positive impacts on enterprise innovation sustainability.*

3. Methodology

3.1. Data and Sample

Considering the completeness of time series data, the timeliness of industrial agglomeration, and the differences in research dimensions, this study collected and organized data from both macro- and micro-levels. At the macro-level, panel data of cities at or above the prefecture level in China, excluding Hong Kong, Macao, Taiwan, and the Tibet Autonomous Region, from 2005 to 2021 were selected as research samples. The specific selection process included the initial sample of 291 cities, excluding samples with significant administrative regional adjustments during the study period, and finally resulting in 285 cities at or above the prefecture level as our research samples. The macro-level data sources included the *China City Statistical Yearbook, China Statistical Yearbook, China Financial Statistical Yearbook, China Industrial Statistical Yearbook, China Industrial Economic Statistical Yearbook*, statistical yearbooks, and statistical bulletins of provinces, autonomous regions, and municipalities directly under the central government, and CNRDS. The research data were manually compiled and checked, verified, and supplemented with the Economy Prediction System (EPS) database one by one to ensure data accuracy, and missing values were supplemented by linear interpolation. The micro-level data were derived from the financial data of A-share listed companies from 2000 to 2021. The micro-level financial data of listed companies were obtained from the Chinese Research Data Services Platform (CNRDS), the CSMAR database, the WIND database, and the DACHIN information network. They were checked, verified, and supplemented one by one with the companies' annual reports to ensure the data's accuracy. The initial sample was screened as follows: samples with unclear or missing disclosure of critical financial data, debt-to-equity ratio (LEV > 1), abnormal listing status such as ST/*ST/PT during the study period, companies with less than 30 employees, companies with a survival time of less than or equal to 3 years, IPOs, cross-listed A/H/N/B shares, and obvious errors such as total assets less than net fixed assets or current assets. The data from the two levels were matched according to the company's registered address to the prefecture-level city. All continuous variables were subjected to Winsorize processing in the [1%, 99%] range to eliminate the influence of extreme outliers.

3.2. Operationalization of Key Variables

3.2.1. Dependent Variable: Industrial Agglomeration

The agglomeration of industries mainly reflects the spatial concentration of enterprises and the supply chain of the industrial chain. Existing research has explored the measurement methods of industrial agglomeration from different perspectives. The mainstream measurement methods include economic density, location quotient, spatial Gini coefficient, Herfindahl index, EG index, and DO index [47–49]. To a certain extent, the location quotient can eliminate the potential concern of the regional-scale heterogeneity effect and can reflect the current spatial distribution of industrial elements in the region relatively accurately; thus, academia widely favors it. Therefore, we choose the location quotient index to measure the level of regional industrial agglomeration, and the calculation formula is as follows:

$$AGG_{j,t} = Ln\left[\frac{(E_{m,j,t} - E_{i,j,t})/\sum E_{j,t}}{\sum E_{m,t}/\sum E_t} + 1\right]$$

where $AGG_{j,t}$ represents the location entropy index of urban industrial agglomeration, and we select the manufacturing agglomeration ($Zagg_{j,t}$) and producer services agglomeration ($Sagg_{j,t}$) for representation in this study. $E_{m,j,t}$ represents the total employment of the manufacturing (producer services) in city j in year t, $E_{i,j,t}$ represents the total employment of the manufacturing enterprise (producer services enterprise) in city j and industry i in year t, and $\sum E_{j,t}$ represents the total employment in city j in year t. $\sum E_{m,t}$ represents the total employment of the manufacturing (producer services) in the country in year t, and $\sum E_t$ represents the total employment in the country.

According to existing research, the definition and scope of manufacturing in this article are based on the *National Economic Industry Classification*. The definition and scope of the producer services are based on the *Statistical Classification of Producer Services (2019)*, which includes explicitly the financial industry; transportation, warehousing, and postal services; information transmission, computer services, and software industry; leasing and commercial services industry; wholesale and retail industry; environmental governance and public facility management industry and scientific research and technical services industry.

3.2.2. Independent Variable: Enterprise Innovation Sustainability

To explore and effectively measure enterprise innovation sustainability based on a whole-process perspective, as well as inhibit more information on enterprise innovation inputs and comprehensively reflect the results of enterprise innovation activities, we adopt the incremental perspective based on innovation output to measure enterprise innovation sustainability, which is divided into two dimensions: innovation quality and innovation efficiency.

In the dimension of innovation quality (*QUA*), according to economic development theory, only when technological inventions are applied to economic activities can they truly become "innovations ". A patent citation reflects the borrowing and inheritance of new patent technology from existing patent technology, which means that whether a patent is cited and the level of citation rate are essential criteria for judging innovation quality [50,51]. Therefore, we adopt the natural logarithm of the number of times listed companies cite a patent as a proxy variable for measuring enterprise innovation quality based on the method of Hsu et al. (2014) [52].

In innovation efficiency (*EFF*), one of the landmark achievements of enterprise innovation R&D is the number of patent applications, which is also a direct indicator of measuring innovation output. The reality is that Chin's patent application and authorization quantity are already ranked first globally. However, the problem of weak original innovation capability and low innovation efficiency still exists. Based on the research method of Hirshleifer et al. (2013) [53], we make adjustments and use the natural logarithm of the number of patent applications plus one divided by the natural logarithm of R&D investment plus one to represent it [54].

3.2.3. Definition of Main Variables

To eliminate the possible interference of omitted variables on the research results and control for other factors that affect enterprise innovation sustainability, we select enterprise size (*Size*), financial leverage (*Lev*), cash flow (*Cfo*), growth potential (*Grow*), asset structure

(*Tag*), board independence (*Dir*), ownership structure (*Share*), enterprise age (*Age*), cash holdings (*Cash*), and regional economic level (*Eco*) as control variables, following existing research. The definitions of each variable are shown in Table 1.

Table 1. Definition of main variables.

Variable	Symbol	Definition
Industrial agglomeration	*Zagg*	Manufacturing location quotient index
	Sagg	Producer services location quotient index
Enterprise innovation Sustainability	*Qua*	ln (excluding the cumulative number of citations in each year from the citation + 1)
	Eff	ln(1 + patent applications)/ln(1 + R&D investment level)
Enterprise size	*Size*	ln (total operating income + 1)
Financial leverage	*Lev*	Total liabilities/total assets at the beginning of the period
Cash flow	*Cfo*	Net cash flow from operating activities/total assets at the end of the period
Growability	*Grow*	The market value of the company/replacement cost of the company = (market value of equity + book value of liabilities at year-end)/book value of total assets at year-end
Asset structure	*Tag*	Net fixed assets/total assets
Board independence	*Dir*	Percentage of independent directors to the total number of board of directors
Equity structure	*Share*	Number of shares held by the company's largest shareholder/total number of shares
Company age	*Age*	Current year minus the logarithm of the year the business was founded plus 1
Cash holding	*Cash*	(Monetary funds + trading financial assets)/[Total assets − (Monetary funds + trading financial assets)
Regional economic level	*Eco*	Natural logarithm of regional GDP per capita

3.2.4. Empirical Specification

In order to explore the impact of industrial agglomeration on enterprise innovation sustainability from a macro-perspective, this study sets the following benchmark regression model:

$$QUA_{i,t}(EFF_{i,t}) = \alpha_0 + \alpha_1 Zagg_{j,t} + \gamma Control_{i,t} + \sum \eta_j + \sum \mu_t + \varepsilon_{i,t} \quad (1)$$

$$QUA_{i,t}(EFF_{i,t}) = \beta_0 + \beta_1 Sagg_{j,t} + \gamma Control_{i,t} + \sum \eta_j + \sum \mu_t + \varepsilon_{i,t} \quad (2)$$

α_0 and β_0 represent the intercept term of the model; Control$_{i,t}$ represents the control variable. The Hausman test result p-value is less than 0.1, rejecting the random effect hypothesis, which indicates that the fixed effect has better estimation. Considering the better goodness of fit, we therefore use the fixed effects model. $\eta_{j,t}$ and $\mu_{j,t}$ are controlling for year and industry fixed effects separately; $\varepsilon_{j,t}$ represents the random disturbance term.

We tested the variables included in the model for multicollinearity, and the Pearson correlation coefficients between the variables showed no significant multicollinearity. The statistical regressions in this study use a fixed effects model, with standard errors adjusted for clustering and robust adjustment at the firm level. In the "Results" section, we provide additional robustness for further tests.

4. Results

4.1. Summary Statistics

Table 2 presents the descriptive statistics of the main variables involved in this study. The mean value of *Zagg* is 0.723 with a minimum value of 0.155 and a maximum value of 1.321. The mean value of *Sagg* is 0.753 with a minimum value of 0.262 and a maximum value of 1.229. This indicates that the degree of industrial agglomeration in China's prefecture-level administrative units is relatively common, and there is a slight tendency for producer services agglomeration to be higher than manufacturing. The mean value of *QUA* is 3.110, with a minimum value of 0.693, a maximum value of 7.875, and a standard deviation of 0.235. This shows a significant difference in the number of patent citations among sample enterprises, indicating significant differences in innovation quality among different enterprises. The mean value of *EFF* is 0.069, with a minimum value of 0, a maximum value of 0.321, and a standard deviation of 0.099. This suggests that the overall innovation efficiency of A-share listed companies is relatively low. The distribution of the remaining variables is generally consistent with previous research.

Table 2. Summary statistics.

Variable	N	Mean	Median	STD.DEV.	Min	Max
Zagg	31,344	0.723	0.703	0.235	0.155	1.321
Sagg	31,344	0.753	0.750	0.235	0.262	1.229
QUA	9158	3.110	2.944	1.656	0.693	7.875
EFF	19,728	0.069	0	0.099	0	0.321
Size	30,711	21.27	21.17	1.428	16.84	25.59
Lev	28,574	0.543	0.512	0.304	0.058	2.627
Cfo	28,954	0.046	0.046	0.068	−0.197	0.252
Grow	30,064	−0.058	−0.092	0.304	−0.794	2.248
Tag	30,707	0.220	0.188	0.166	0.002	0.728
Dir	30,927	0.371	0.333	0.057	0.250	0.571
Share	30,761	0.354	0.333	0.147	0.086	0.750
Age	31,077	3.253	3.258	0.201	2.639	3.689
Cash	30,121	0.276	0.178	0.286	0.013	1.790
Eco	30,687	1.955	2.051	0.623	−0.037	2.996

4.2. Baseline Results

Table 3 reports the benchmark test results of the relationship between industrial agglomeration and enterprise innovation sustainability. Columns 1 to 4 show the regression results without fixed effects, while columns 5 to 8 report the regression results with fixed time and individual effects. The results show that whether or not fixed effects are controlled for, the estimation parameters of the agglomeration of manufacturing and producer services are significant for enterprise innovation sustainability overall. In column 5, the estimated parameter of manufacturing agglomeration is negative and reaches a level of 10%, indicating that a 1% increase in manufacturing agglomeration will lead to a 0.290% decrease in enterprise innovation quality. In column 7, the estimated inhibitor of manufacturing agglomeration is negative and reaches a level of 1%, indicating that a 1% increase in manufacturing agglomeration will lead to a 0.021% decrease in enterprise innovation efficiency. These results indicate that manufacturing agglomeration reduces enterprise innovation quality and efficiency, thus proving the existence of a decreasing linear relationship between manufacturing agglomeration and enterprise innovation sustainability and supporting hypothesis H1. In column 6, the estimated parameter of production-oriented services agglomeration is positive and reaches a level of 1%, indicating that a 1% increase in producer services agglomeration will lead to a 0.323% inhibition in enterprise innovation quality. In column 8, the estimated parameter of producer services agglomeration is positive and reaches a level of 1%, indicating that a 1% increase in producer services agglomeration will lead to a 0.033% increase in enterprise innovation efficiency. These results indicate that producer services agglomeration enhances enterprise innovation quality and efficiency, thus proving the existence of an increasing linear relationship between producer services agglomeration and enterprise innovation sustainability and supporting hypothesis H2.

Table 3. Baseline effects test.

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	QUA	***QUA***	***EFF***	***EFF***	***QUA***	***QUA***	***EFF***	***EFF***
Zagg	−0.577 *** (−3.690)		−0.029 *** (−3.761)		−0.290 * (−1.746)		−0.021 *** (−2.627)	
Sagg		−0.083 (−0.527)		0.020 ** (2.365)		0.323 * (1.956)		0.033 *** (3.865)
Size	0.473 *** (13.530)	0.489 *** (14.069)	0.006 *** (3.713)	0.007 *** (4.174)	0.490 *** (13.695)	0.492 *** (13.761)	0.007 *** (3.728)	0.007 *** (3.862)
Lev	−0.727 *** (−5.640)	−0.766 *** (−5.943)	−0.002 (−0.273)	−0.003 (−0.529)	−0.437 *** (−3.453)	−0.431 *** (−3.425)	0.009 (1.582)	0.009 (1.563)
Cfo	−0.273 (−0.605)	−0.450 (−0.992)	−0.012 (−0.612)	−0.011 (−0.546)	−0.412 (−0.923)	−0.379 (−0.853)	−0.027 (−1.337)	−0.022 (−1.131)
Grow	0.003 (0.041)	0.024 (0.351)	−0.009 *** (−2.843)	−0.009 ** (−2.569)	0.028 (0.421)	0.030 (0.453)	−0.010 *** (−3.063)	−0.010 *** (−3.094)
Tag	−0.818 *** (−2.771)	−0.928 *** (−3.169)	−0.048 *** (−3.689)	−0.049 *** (−3.712)	−0.761 ** (−2.487)	−0.739 ** (−2.430)	−0.065 *** (−4.674)	−0.061 *** (−4.406)
Dir	0.723 (1.360)	0.699 (1.309)	0.018 (0.724)	0.016 (0.670)	0.487 (0.938)	0.449 (0.872)	0.015 (0.611)	0.013 (0.555)
Share	−1.310 *** (−4.778)	−1.309 *** (−4.797)	0.006 (0.466)	0.005 (0.341)	−0.794 *** (−2.874)	−0.802 *** (−2.906)	0.020 (1.454)	0.018 (1.341)
Age	0.265 (1.289)	0.234 (1.134)	−0.002 (−0.253)	−0.004 (−0.436)	0.698 *** (3.403)	0.693 *** (3.387)	0.011 (1.121)	0.010 (1.000)
Cash	−0.413 *** (−3.791)	−0.407 *** (−3.672)	−0.009 (−1.580)	−0.010 * (−1.800)	−0.307 *** (−2.825)	−0.316 *** (−2.905)	−0.001 (−0.257)	−0.002 (−0.383)
Eco	0.537 *** (8.017)	0.495 *** (7.296)	0.025 *** (7.643)	0.018 *** (5.389)	0.197 ** (2.181)	0.082 (0.923)	0.017 *** (3.970)	0.007 * (1.735)
μ	NO	NO	NO	NO	YES	YES	YES	YES
η	NO	NO	NO	NO	YES	YES	YES	YES
_cons	−7.682 *** (−7.919)	−8.125 *** (−8.402)	−0.079 * (−1.674)	−0.107 ** (−2.284)	−9.200 *** (−9.329)	−9.423 *** (−9.592)	−0.124 ** (−2.530)	−0.143 *** (−2.938)
adj. R^2	0.179	0.173	0.035	0.032	0.262	0.262	0.080	0.083
N	7469	7469	15,441	15,441	7469	7469	15,441	15,441

Note: ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively, with Z-values in parentheses.

4.3. Robustness Checks

To ensure the robustness of the study, we further conducted the following tests:

(1) Dependent variable replacement. Referring to the existing literature, we chose the natural logarithm of the cumulative number of citations for listed companies' patents in each year +1 as a proxy variable for enterprise innovation quality (*QUA1*) and re-measured it [55]; we used the ratio of the number of patents (innovative output) and the absolute amount of natural logarithm of R&D input (innovative input) to measure the enterprise's innovation efficiency (*EFF1*). We then Winsorized the new proxy variables and incorporated them into the quantitative model for regression testing. The regression results are shown in Table 4, Panel A.

Table 4. Robustness tests.

Panel A	Dependent Variable Replacement			
	QUA1	*QUA1*	*EFF1*	*EFF1*
Zagg	−0.289 * (−1.745)		−0.378 ** (−2.298)	
Sagg		0.322 * (1.949)		0.522 *** (2.893)
Control	YES	YES	YES	YES
η/μ	YES	YES	YES	YES
_cons	−9.190 *** (−9.320)	−9.413 *** (−9.584)	−8.483 *** (−6.939)	−8.806 *** (−7.131)
adj. R^2	0.262	0.262	0.087	0.088
N	7469	7469	12,649	12,649
Panel B	**Lagged Dependent Variable**			
	QUA	*QUA*	*EFF*	*EFF*
Zagg	−0.330 * (−1.766)		−0.025 *** (−3.192)	
Sagg		0.422 ** (2.302)		0.033 *** (3.961)
Control	YES	YES	YES	YES
η/μ	YES	YES	YES	YES
_cons	−9.366 *** (−7.957)	−9.585 *** (−8.234)	−0.259 *** (−5.091)	−0.278 *** (−5.507)
adj. R^2	0.251	0.252	0.081	0.083
N	4536	4536	10,123	10,123
Panel C	**Adjusted Sample Scope**			
	QUA	*QUA*	*EFF*	*EFF*
Zagg	−0.290 * (−1.746)		−0.021 *** (−2.627)	
Sagg		0.323 * (1.956)		0.033 *** (3.865)
Control	YES	YES	YES	YES
η/μ	YES	YES	YES	YES
_cons	−9.200 *** (−9.329)	−9.423 *** (−9.591)	−0.124 ** (−2.530)	−0.143 *** (−2.938)
adj. R^2	0.261	0.262	0.080	0.083
N	7468	7468	15,441	15,441
Panel D	**Eliminate Sample Random Error**			
	QUA	*QUA*	*EFF*	*EFF*
Zagg	−0.292 * (−1.755)		−0.021 *** (−2.621)	
Sagg		0.326 ** (1.967)		0.033 *** (3.896)
Control	YES	YES	YES	YES
η/μ	YES	YES	YES	YES
_cons	−0.012 (−0.868)	−9.424 *** (−9.590)	0.007 (0.519)	−0.143 *** (−2.934)
adj. R^2	0.262	0.262	0.080	0.083
N	7468	7465	15,440	15,438

Note: ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively, with Z-values in parentheses.

(2) Lagged dependent variable. Considering that macro-industrial agglomeration effects may lag behind micro-enterprise innovation sustainability, to avoid the problem of endogeneity within the same period, we separately re-regressed the benchmark mode's

dependent variables (*QUA*, *EFF*) lagged three periods. The regression results are shown in Table 4, Panel B.

(3) Adjusted sample scope. Enterprises with a survival time of less than or equal to 3 years may have relatively weak competitiveness due to low levels of fund holdings and insufficient technological innovation capabilities, and they also lack a reference value, so enterprises with a survival time of less than or equal to 3 years were excluded in the robustness test. The regression results are shown in Table 4, Panel C.

(4) Eliminate random sample error. Industrial agglomeration level differences may affect regional economic development levels, affecting enterprise innovative activities and efficiency and leading to biased test results. In the robustness test, we found that the proportion of enterprise innovation sustainability included in the top 5 ranking sample cities in terms of industrial agglomeration level exceeded the mean level, and then, we separately excluded the five cities with relatively high levels of manufacturing agglomeration and producer services agglomeration in the sample. The regression results are shown in Table 4, Panel D.

We run the regression using the alternative measures with the same control inhibitions. The above steps were repeated for the empirical regression analysis of the original model, and the specific results are presented in Table 4. As seen from Table 4, our results have not changed significantly, and the research conclusion remains unchanged, thus confirming the robustness of the study.

4.4. Endogeneity Problem

Since industrial agglomeration belongs to the macro-level economic structural changes, it is difficult for micro-level enterprise innovation decision making and efficiency to reverse the impact of industrial structure. Therefore, industrial agglomeration and enterprise innovation sustainability can be approximated as having no reverse causal relationship. Furthermore, the empirical method of lagging in the robustness test can effectively avoid the possible reverse causal relationship. However, considering the potential existence of reverse causality and other omitted variables, this study adopts an instrumental variable approach to alleviate concerns about endogeneity problems.

The results of the endogeneity test are shown in Table 5. Referring to the existing research, we selected the average industrial agglomeration of other provincial cities as instrumental variables (*IVZagg*, *IVSagg*). The IV-GMM estimation results show that after using instrumental variables to alleviate endogeneity concerns in the second stage, the research conclusion remains essentially unchanged and is consistent with the main test effect.

4.5. Influence Channel Analysis

To comprehensively grasp the theoretical logic between industrial agglomeration and enterprise innovation sustainability, exploring the internal transmission mechanism is necessary. For manufacturing, agglomeration primarily exacerbates enterprise financing constraints, thereby suppressing enterprise innovation sustainability. When manufacturing enterprises form economies of scale in the same region, they attract more resources, such as policy support, capital investment, and talent inflows, which improve their development conditions and advantages. However, it also causes an uneven distribution of resources among regions, clusters, and enterprises, resulting in the "scale effect" "technology effect" and "information effect" among enterprises. Industries, enterprises, or individuals with more extensive scale, newer technology, and more information are more likely to reduce transaction costs, improve credit ratings, and increase financing opportunities for resource elements.

Table 5. Endogeneity tests.

Panel A	*Zagg*	*Sagg*	*QUA*	*QUA*
IVZagg	1.002 *** (354.79)			
IVSagg		0.971 *** (379.99)		
Zagg			−0.285 * (−1.66)	
Sagg				0.318 * (1.86)
Control	YES	YES	YES	YES
η/μ	YES	YES	YES	YES
_cons	0.064 *** (4.41)	−0.043 *** (−3.28)	−9.884 *** (−9.73)	−9.993 *** (−9.87)
N	7345	7221	7345	7221
Panel D	*Zagg*	*Sagg*	*EFF*	*EFF*
IVZagg	1.000 *** (490.96)			
IVSagg		0.969 *** (474.86)		
Zagg			−0.020 ** (−2.48)	
Sagg				0.034 *** (3.80)
Control	YES	YES	YES	YES
η/μ	YES	YES	YES	YES
_cons	0.034 *** (3.17)	−0.038 *** (−4.04)	−0.145 *** (−2.88)	−0.162 *** (−3.21)
N	15,402	15,154	15,402	15,154

Note: ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively, with Z-values in parentheses.

For producer services agglomeration, it mainly alleviates enterprise financing constraints, thereby enhancing enterprise innovation sustainability. On the one hand, producer services agglomeration can provide various services to enterprises, including market research, product design, and technical consulting. These services help enterprises reduce their information asymmetry and moral hazard in the financial market, improving their financing likelihood and conditions. On the other hand, producer services agglomeration can also provide financial services, trade brokerage, leasing services, and other financial services to enterprises. These services help enterprises reduce their dependence on a single financial institution or market, reduce their bargaining disadvantage and financing costs in the financial market, and ultimately provide possibilities for enterprise innovation sustainability [56].

To further explore the possible transmission path of the degree of industrial agglomeration on enterprise innovation sustainability and test the logical channels constructed earlier, this paper builds a mechanism analysis model as follows [57]:

$$M_{i,t} = \alpha_0 + \delta_1 Zagg_{j,t}(Sagg_{j,t}) + \gamma Control_{i,t} + \sum \eta_j + \sum \mu_t + \varepsilon_{i,t} \tag{3}$$

$$QUA(EFF)_{i,t} = \zeta_0 + \beta_1 M_{i,t} + \gamma Control_{i,t} + \sum \eta_j + \sum \mu_t + \varepsilon_{i,t} \tag{4}$$

Here, $M_{i,t}$ represents the possible mechanism variables, more precisely, enterprise financing constraint (*FC*), with the definitions of other variables remaining the same as in the previous formula. In order to avoid endogenous interference and consider factors at the enterprise level, such as asset size and financial leverage, the FC index further optimizes the above indicators. Therefore, this study refers to the existing research and constructs the FC index to measure the degree of financing constraints of enterprises.

The results of the mechanism analysis are presented in Table 6. *Zagg* and *FC* are positively correlated at a significance level of 1%, indicating that manufacturing agglomeration exacerbates enterprise financing constraints. *Sagg* and *FC* are positively correlated at a significance level of 10%, indicating that producer services agglomeration alleviates enterprise financing constraints. After incorporating the intermediate variable *FC* into the main effect test model, *FC* is negatively correlated with *QUA* at a significance level of 1%, and *FC* is negatively correlated with *EFF* at a significance level of 10%, indicating that as the degree of enterprise financing constraints increases, enterprise cash flow gradually tightens, thus suppressing the development of enterprise innovation activities at the financial level, which in turn hinders enterprise innovation sustainability activities. The above results demonstrate that financing constraints are the transmission path through which industrial agglomeration affects enterprise innovation sustainability.

Table 6. Mechanism test.

Variable	*FC*	*QUA*	*FC*	*EFF*
Zagg	0.056 *** (5.983)			
Sagg			−0.043 *** (−4.486)	
FC		−1.398 *** (−6.731)		−0.016 * (−1.787)
Control	YES	YES	YES	YES
η/μ	YES	YES	YES	YES
_cons	3.554 *** (70.211)	−3.765 *** (−2.917)	3.598 *** (71.510)	−0.064 (−1.043)
adj. R^2	0.639	0.274	0.171	0.079
N	22,477	7128	22,477	14,669

Note: ***, and * represent significance at the 1%, and 10% levels, respectively, with Z-values in parentheses.

5. Heterogeneity Test: Exploring the Classification for Macro- and Micro-Perspectives

The preceding analysis provides a benchmark and correlation testing for the relationship between industrial agglomeration and enterprise innovation sustainability and their mechanism of action. Furthermore, what effects do manufacturing and producer services agglomeration have on enterprise innovation sustainability under different industry types? Are there heterogeneous effects for industrial agglomeration under different micro-level enterprise characteristics? To identify and thoroughly investigate the interference of various dimensional differences on this study, the following section will comprehensively explore the classification based on industry differences from a macro-perspective and enterprise differences from a micro-perspective.

5.1. Industry Heterogeneity Test

5.1.1. Manufacturing Heterogeneity Test

According to the theoretical analysis presented earlier, manufacturing agglomeration emphasizes the improvement of innovative technological levels and industry factor productivity, leading to a continuous upgrade process from low-end to mid-end and eventually high-end. Existing research has often measured the manufacturing structure by the proportion of various industries and subsequently divided the manufacturing into different types. This paper focuses on analyzing the structural adjustment process in manufacturing in different regions. Based on the classification standards of the WIOD, this study divides the manufacturing into “high-end technology” “mid-end technology” and “low-end technology” based on technological levels. The high-end technology industry includes general equipment, transportation, specialized equipment, electrical machinery and equipment, communication electronics, instrumentation and cultural office machinery, and chemical and pharmaceutical industries. The middle-end technology industry includes petroleum processing, coking and nuclear fuel processing, rubber, plastics, non-metallic minerals, black metal smelting and refining, non-ferrous metal smelting and refining, and metal products. The low-end technology industry encompasses food processing and manufacturing, beverages, tobacco, textiles, clothing, leather, wood, furniture, papermaking, printing and stationery, and other manufacturing industries.

Furthermore, industry development levels and resource endowments limit enterprise innovation sustainability activities to a certain extent, resulting in an uneven distribution of R&D activities among different industrial types and stages under different resource endowment backgrounds. Therefore, this paper classifies manufacturing into "labor-intensive" "capital-intensive" and "technology-intensive" based on factor intensity and conducts heterogeneity tests according to different types of manufacturing. Labor-intensive industries mainly include food processing, textile industry, leather, fur, feather (down) and its products industry, wood processing, and wood, bamboo, rattan, straw, furniture manufacturing, printing industry, recording medium replication, cultural and educational sports goods manufacturing, rubber products industry, plastic products industry, non-metallic mineral products industry, and metal products industry. Capital-intensive industries mainly consist of beverage manufacturing, tobacco products, papermaking and paper products, petroleum processing and coking, chemical raw materials and chemical products manufacturing, chemical fiber manufacturing, black metal smelting, and rolling processing industry, non-ferrous metal smelting and rolling processing industry, and general equipment manufacturing. Technology-intensive industries mainly include pharmaceutical manufacturing, specialized equipment manufacturing, transportation equipment manufacturing, electrical machinery and equipment manufacturing, communication equipment, computer, and other electronic manufacturing, and instrumentation and cultural office machinery manufacturing. The following section examines the impact of manufacturing agglomeration on enterprise innovation sustainability under different types of manufacturing. The following section examines the impact of manufacturing agglomeration on enterprise innovation sustainability under different types of manufacturing [58].

Table 7 presents the results of a grouping test based on different types of manufacturing industries. In grouping technological levels, the estimated coefficients of *Zagg* on *QUA* and *EFF* are insignificant in the low-end and middle-end technology groups. However, in the high-end technology group, *Zagg* is negatively correlated with *QUA* at a significance level of 10% and with *EFF* at 1%, which is consistent with the main test effect. In the grouping of factor intensity, *Zagg*'s estimated coefficient on *QUA* is not significant in labor-intensive, capital-intensive, and technology-intensive manufacturing groups. *Zagg*'s estimated coefficient on *EFF* is insignificant in the labor-intensive manufacturing group. However, it is significant and shows an increasing trend in the capital-intensive and technology-intensive manufacturing groups. The impact of manufacturing agglomeration on enterprise innovation sustainability shows an overall trend of high-end technology industries > middle-end technology industries and low-end technology industries, and technology-intensive industries > capital-intensive industries > labor-intensive industries in terms of development. As production efficiency and technological level improve, the impact of manufacturing agglomeration on enterprise innovation sustainability gradually increases.

5.1.2. Producer Services Heterogeneity Test

Due to differences in production scale, knowledge, and technological content, there are significant differences between industries within the productive service sector, and their methods of conducting innovative activities also differ. Since different manufacturing industries can have heterogeneous impacts on enterprise innovation sustainability, is there also variation in the impact of different types of producer services agglomeration on enterprise innovation sustainability? Therefore, the following sections decompose the productive service sector into types and production methods to examine the effect of different types of producer services sector agglomerations on innovation sustainability. Specifically, this study will investigate the impact of the financial industry (*Flagg*), scientific research and technical services industry (*SRTSagg*), information transmission, computer services and software industry (*INSRTagg*), leasing and business services industry (*LBSagg*), wholesale and retail trade industry (*WRTagg*), transportation, warehousing, and postal industry (*TSRagg*), and environmental governance and public facilities management industry (*MWCEPFagg*) on enterprise innovation sustainability.

Table 7. Manufacturing heterogeneity test.

Panel A	Low-Tech		Mid-Tech		High-Tech	
	QUA	***EFF***	***QUA***	***EFF***	***QUA***	***EFF***
Zagg	−0.325	0.017	−0.351	−0.012	−0.354 *	−0.035 ***
	(−0.540)	(0.887)	(−0.680)	(−0.543)	(−1.654)	(−2.894)
Control	YES	YES	YES	YES	YES	YES
η/μ	YES	YES	YES	YES	YES	YES
_cons	−6.403 *	−0.410 **	−12.017 ***	−0.177	−9.870 ***	−0.051
	(−1.824)	(−2.450)	(−3.530)	(−1.328)	(−7.780)	(−0.740)
adj. R^2	0.265	0.080	0.310	0.055	0.278	0.067
N	683	1576	754	1766	4314	8429
Panel B	**Labor-Intensive**		**Capital-Intensive**		**Technology-Intensive**	
	QUA	***EFF***	***QUA***	***EFF***	***QUA***	***EFF***
Zagg	−0.345	0.016	−0.390	−0.029 *	−0.301	−0.035 **
	(−0.717)	(0.903)	(−1.055)	(−1.797)	(−1.255)	(−2.467)
Control	YES	YES	YES	YES	YES	YES
η/μ	YES	YES	YES	YES	YES	YES
_cons	−9.385 ***	−0.173	−8.334 ***	−0.313 ***	−10.783 ***	0.036
	(−2.831)	(−1.206)	(−3.802)	(−3.377)	(−8.015)	(0.447)
adj. R^2	0.239	0.050	0.277	0.103	0.299	0.054
N	837	2206	1524	3213	3345	6233

Note: ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively, with Z-values in parentheses.

After inspecting the subdivided industries of different types of producer services, the results are shown in Table 8. The overall impact of agglomerations of different producer services on enterprise innovation sustainability is consistent with the main test effect. Among them, the estimated coefficients of *Sagg* for *QUA* present the following situation: scientific research and technical services industry > transportation, warehousing, and postal industry > information transmission, computer services, and software industry > leasing and business services industry. Meanwhile, the estimated coefficients of *Sagg* for *EFF* overall present the following situation: wholesale and retail industry > transportation, warehousing, and postal industry > scientific research and technical services industry > leasing and business services industry > information transmission, computer services, and software industry > environmental governance and public facility management industry. It is not difficult to find that the impact of agglomerations of producer services on the quality of enterprise innovation is more significant in knowledge-intensive producer services such as scientific research and technical services industry, information transmission, computer services, and software industry. On the other hand, the impact of agglomerations of producer services on the efficiency of enterprise innovation is more significant in resource-intensive producer services such as wholesale and retail industries, transportation, warehousing, and the postal industry.

Table 8. Producer services heterogeneity test.

Variable	*QUA*	*EFF*	*QUA*	*EFF*	*QUA*	*EFF*	*QUA*	*EFF*	*QUA*	*EFF*	*QUA*	*EFF*	*QUA*	*EFF*
Flagg	0.115	0.009												
	(0.961)	(1.347)												
SRTSagg			0.252 ***	0.015 ***										
			(3.536)	(3.958)										
INSRTagg					0.155 **	0.006 *								
					(2.393)	(1.702)								
LBSagg							0.139 *	0.008 *						
							(1.931)	(1.834)						
WRTagg									0.178	0.019 ***				
									(1.562)	(3.273)				
TSPagg											0.236 **	0.017 ***		
											(2.320)	(2.872)		
MWCEPFagg													0.018	0.003 ***
													(1.475)	(4.790)
Control	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
η/μ	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
_cons	−9.529 ***	−0.154 ***	−9.501 ***	−0.151 ***	−9.490 ***	−0.142 ***	−9.351 ***	−0.140 ***	−9.481 ***	−0.148 ***	−9.452 ***	−0.144 ***	−9.242 ***	−0.117 **
	(−9.391)	(−3.070)	(−9.528)	(−3.034)	(−9.374)	(−2.822)	(−9.362)	(−2.835)	(−9.514)	(−3.028)	(−9.501)	(−2.939)	(−9.478)	(−2.441)
adj. R^2	0.260	0.080	0.262	0.083	0.258	0.079	0.260	0.079	0.261	0.082	0.260	0.081	0.261	0.086
N	7446	15,403	7351	15,231	7285	15,122	7362	15,255	7450	15,406	7445	15,401	7469	15,441

Note: ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively, with Z-values in parentheses.

Regarding these results, a possible explanation is that knowledge-intensive producer services have higher demands for technology and capital at a higher level and higher requirements for industrial agglomeration and the coupling effect it generates. Thus, they stimulate the positive effects of industrial agglomeration on the quality of enterprise innovation through pathways such as economies of scale and research and development innovation. On the other hand, resource-intensive producer services can enhance the efficiency of enterprise innovation by leveraging their resource endowment advantages. However, innovation quality is a specific deficiency due to the lack of knowledge and high-quality technology. The above results indicate that differences in technological development levels and factor intensity have heterogeneous impacts on enterprise innovation sustainability. The impact of producer services agglomerations on enterprise innovation sustainability has stage-specific characteristics as the industry evolves, following the production laws of industrial development and conforming to expected cognition.

5.2. Enterprise Heterogeneity Test

Existing research indicates that factors like financial conditions, financing capabilities, ownership nature, and technological levels cause industrial agglomeration to affect different enterprises' innovative sustainability, necessitating further classification and discussion. This section will divide the factors based on enterprise attributes and analyze and discuss the economic consequences of industrial agglomeration's impact on different enterprise attributes, providing further elucidation.

Regarding financial conditions, industrial agglomeration promotes competition and cooperation between enterprises. Enterprises with higher financial risks face more pressure from funds and finances with relatively less money available for R&D activities. Thus, the inhibition effect of manufacturing agglomeration and the promotional effect of business services agglomeration impact such enterprises relatively weakly. We employ the adjusted Altman Z-score to measure enterprise financial risk and divide the sample into groups based on the mean and median, classifying enterprises in the top 50% of financial risk in their industries as the high financial risk group and those in the bottom 50% as the low financial risk group.

Regarding financing constraints, enterprises with higher constraints devote more attention to investor demands and investment behavior; consequently, they must rely more on technological superiority to garner capital market funding support. Enterprises facing more significant financing constraints possess a stronger motivation to leverage the scale of industrial agglomeration economies to achieve this goal and external access financing. We select the median FC index of the same industry in the same year as the target level of financing constraint by dividing companies within the top 50% of the FC index in their industries into the highly constrained group and those within the bottom 50% into the low constrained group.

Regarding property rights, competition between industries in industrial agglomeration areas will compel companies to adopt more aggressive research and development measures to maintain sustainable competitiveness. State-owned enterprises can obtain external financing through government–enterprise cooperation, credit support, or policy tilt channels. In contrast, private enterprises face limited external financing opportunities and financial institution financing discrimination. As a result, they are more motivated to actively engage in research and innovation activities [59].

Regarding the technological level, high-tech enterprises are more easily influenced by local industrial structures because their industrial chains are more complex, precise, and fragile. Industrial agglomeration plays a role in the joint advantage of high-tech enterprises, making competition and cooperation closer. This will encourage enterprises to pay more attention to the performance of research and development innovation activities to gain market recognition and trust from cooperation partners. Referring to existing studies, we divide industries according to the high-tech industry standard in "*Statistics Law of the*

People's Republic of China" "*National Economic Industry Classification (GB/T 4754-2017)*". We define six major industries as high-tech enterprises: aerospace equipment manufacturing; pharmaceutical manufacturing; electronic and communication equipment manufacturing; medical equipment manufacturing; information chemical manufacturing; computer and office equipment manufacturing.

The regression results for subgroups based on representative enterprise characteristics are shown in Table 9. The effect of industrial agglomeration intensity on innovative sustainability under different enterprise characteristic subgroups is generally consistent with the main test effect, indicating that the linear relationship between industrial agglomeration and enterprise innovation sustainability holds across different subsamples. As a further comparison of high and low subgroups finds, for the financial condition grouping, *Zagg*'s impact on enterprise innovation sustainability is more significant in the low financial risk group, while *Sagg*'s impact is more significant in the high financial risk group. For the financing constraint grouping, the impact of both *Zagg* and *Sagg* on enterprise innovation sustainability is more pronounced in the high financing constraint group. For the ownership property grouping, the impact of both *Zagg* and *Sagg* on enterprise innovation sustainability is more pronounced in the non-state-owned enterprise group. For the technology level grouping, the impact of both *Zagg* and *Sagg* on enterprise innovation sustainability is more pronounced in the high-tech group. The above results are broadly consistent with existing research findings.

Table 9. Enterprise heterogeneity test.

Group	High Financial Risk				High Financing Constraint				State-Owned				High Technology Level			
	QUA	***EFF***	***QUA***	***EFF***	***QUA***	***EFF***	***QUA***	***EFF***	***QUA***	***EFF***	***QUA***	***EFF***	***QUA***	***EFF***	***QUA***	***EFF***
Zagg	−0.300	−0.019 *			−0.279	−0.019 **			0.186	0.005			−0.066	−0.034 **		
	(−1.298)	(−1.744)			(−1.495)	(−2.111)			(0.613)	(0.276)			(−0.232)	(−2.309)		
Sagg			0.303	0.036 ***			0.333 *	0.030 ***			−0.244	0.015			0.230	0.041 ***
			(1.303)	(3.058)			(1.753)	(3.180)			(−0.900)	(0.903)			(0.790)	(2.653)
Control	YES	YES	YES		YES	YES	YES		YES	YES	YES		YES	YES	YES	
η/μ	YES	YES	YES		YES	YES	YES		YES	YES	YES		YES	YES	YES	
_cons	−8.976 ***	−0.177 ***	−9.237 ***	−0.196 ***	−7.397 ***	0.193 ***	−7.628 ***	0.170 ***	−5.691 ***	−0.155 *	−5.622 ***	−0.158 *	−10.515 ***	−0.095	−10.798 ***	−0.116
	(−6.673)	(−2.627)	(−6.858)	(−2.943)	(−5.561)	(3.023)	(−5.655)	(2.638)	(−3.155)	(−1.667)	(−3.126)	(−1.706)	(−6.081)	(−1.059)	(−6.356)	(−1.310)
adj. R^2	0.282	0.080	0.283	0.083	0.174	0.114	0.174	0.116	0.344	0.107	0.345	0.108	0.261	0.063	0.269	0.066
N	3701	7616	3701	7616	3469	7515	3469	7515	3173	5432	3173	5432	2460	4654	2484	4693
Group	**Low Financial Risk**				**Low Financing Constraint**				**Non-State Owned**				**Low Technology Level**			
	QUA	***EFF***	***QUA***	***EFF***	***QUA***	***EFF***	***QUA***	***EFF***	***QUA***	***EFF***	***QUA***	***EFF***	***QUA***	***EFF***	***QUA***	***EFF***
Zagg	−0.283	−0.022 **			−0.161	−0.014			−0.359 *	−0.023 **			−0.283	−0.015		
	(−1.398)	(−2.314)			(−0.631)	(−1.125)			(−1.750)	(−2.522)			(−1.368)	(−1.536)		
Sagg			0.335 *	0.030 ***			0.261	0.029 **			0.582 ***	0.031 ***			0.191	0.027 ***
			(1.668)	(2.994)			(1.064)	(2.247)			(2.798)	(3.126)			(0.968)	(2.701)
Control	YES	YES	YES		YES	YES	YES		YES	YES	YES		YES	YES	YES	
η/μ	YES	YES	YES		YES	YES	YES		YES	YES	YES		YES	YES	YES	
_cons	−9.697 ***	−0.057	−9.890 ***	−0.076	−6.325 ***	−0.297 ***	−6.391 ***	−0.308 ***	−9.349 ***	−0.013	−9.894 ***	−0.043	−9.039 ***	−0.146 **	−9.228 ***	−0.160 ***
	(−7.330)	(−0.955)	(−7.513)	(−1.265)	(−3.874)	(−3.771)	(−3.960)	(−3.957)	(−7.054)	(−0.215)	(−7.367)	(−0.675)	(−7.497)	(−2.564)	(−7.653)	(−2.826)
adj. R^2	0.239	0.082	0.240	0.084	0.283	0.074	0.284	0.076	0.223	0.084	0.227	0.086	0.272	0.091	0.271	0.093
N	3767	7825	3767	7825	3659	7154	3659	7154	4203	9803	4203	9803	5048	10,849	5048	10,849

Note: ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively, with Z-values in parentheses.

6. Extensibility Analysis: Industrial Co-Agglomeration

Previous research has demonstrated industrial agglomeration's inhibitory and facilitative effects on enterprise innovation sustainability and the differences between these effects under macro- and micro-perspectives. However, an important issue that cannot be overlooked is that most regions do not have a single industrial agglomeration pattern of manufacturing or producer services. Existing studies mainly examine the impact of manufacturing or producer services agglomeration on enterprise R&D innovation from a single perspective, while studies exploring the impact of industrial agglomeration on enterprise innovation sustainability from an industry synergy perspective are relatively scarce. Although this study has made some improvements on this issue, some questions still provoke our deep thinking: Does manufacturing agglomeration inhibit enterprise innovation sustainability? In contrast, if producer services agglomeration promotes enterprise innovation sustainability, then what kind of impact does the synergy agglomeration of manufacturing and producer services have on enterprise innovation sustainability? To answer this question, this section will delve into the impact of industry synergy agglomeration on enterprise innovation sustainability based on the synergy agglomeration effect generated by manufacturing and producer services.

Industrial co-agglomeration refers to industries with horizontal or upstream and downstream linkages clustering together in a geographic space. On the one hand, through industrial co-agglomeration, technology service industries can provide diversified and refined services to manufacturing industries, thus promoting the optimization of a division of labor between industries and improving the production efficiency and technological innovation level of industries. On the other hand, the spatial proximity and synergistic positioning relationship between producer services and manufacturing industries can promote interactive learning and knowledge dissemination, increasing the opportunity for face-to-face communication required for resource or tacit knowledge exchange, thereby enhancing the technological innovation level of industries. In addition, as the technological innovation level of each link in the manufacturing chain increases, the demand for more complex and higher invisibility knowledge technology will increase, thereby driving industries to carry out deeper collaboration and cooperation, further enhancing the sustainable technological innovation of enterprise [60]. In terms of variable selection, unlike single-form industrial agglomeration, industrial co-agglomeration emphasizes the associated agglomeration of heterogeneous industries with input–output relationships in a certain space, which has both industry attributes and spatial attributes. Existing research primarily measures the degree of industrial co-agglomeration from the perspective of spatial attributes. This study mainly focuses on its industry attributes, studying the development of industrial co-agglomeration between manufacturing and producer services by studying the industrial interdependence relationship between the two. The specific calculation method is as follows:

$$Coagg_{j,t} = \left[1 - \frac{|Zagg_{j,t} - Sagg_{j,t}|}{Zagg_{j,t} + Sagg_{j,t}} + |Zagg_{j,t} + Sagg_{j,t}|\right]$$

The co-agglomeration index reflects the degree of co-agglomeration between manufacturing and producer services. The higher the value, the higher the degree of agglomeration.

Table 10 shows the regression results of the impact of industrial co-agglomeration on enterprise innovation sustainability. *Coagg* is positively correlated with *QUA* at the 10% significance level, indicating that an increase in the degree of industrial agglomeration by 1% will lead to a 0.206% improvement in the quality of enterprise innovation. *Coagg* is positively correlated with *EFF* at the 1% significance level, indicating that an increase in the degree of Industrial agglomeration by 1% will lead to a 0.019% improvement in the quality of enterprise innovation. These results indicate that although the industrial agglomeration of a single industry may have different positive or negative impacts on enterprise innovation sustainability, the overall external effect of industrial co-agglomeration promotes enterprise innovation sustainability.

Table 10. Further analysis: industrial co-agglomeration.

Variable	*QUA*	*EFF*
Coagg	0.206 *	0.019 ***
	(1.814)	(3.353)
Control	YES	YES
η/μ	YES	YES
_cons	−9.676 ***	−0.164 ***
	(−9.502)	(−3.269)
adj. R^2	0.261	0.082
N	7424	15,347

Note: ***, and * represent significance at the 1%, and 10% levels, respectively, with Z-values in parentheses.

7. Discussions and Conclusions

7.1. Conclusions and Policy Implications

In the era of rapid industrialization and urbanization, promoting industrial agglomeration is a critical way to implement the innovation-driven development strategy, and studying the impact of industrial agglomeration on enterprise innovation sustainability has profound implications for policymaking and sustainable economic development. Based on this, this study uses the financial data of prefecture-level cities and listed companies from 2005 to 2021 as the research sample and reveals the external heterogeneity characteristics and causes as well as the internal micro-transmission mechanism and dynamic laws of the relationship between industrial agglomeration and enterprise innovation sustainability based on the examination and demonstration of their impact.

We find the following. (1) Manufacturing agglomeration significantly inhibits enterprise innovation sustainability. (2) Producer services agglomeration significantly promotes enterprise innovation sustainability. (3) The analysis of the impact mechanism shows that the financing constraints is an important way for manufacturing agglomeration and producer services agglomeration to affect the innovation sustainability of Chinese A-share listed enterprises. (4) The effect of manufacturing agglomeration on the enterprise innovation sustainability is significant in technology-intensive industries and high-end technology industries. (5) Producer services agglomeration has a more significant impact on enterprise innovation quality in knowledge-intensive productive service industries, while producer services agglomeration has a more significant impact on enterprise innovation efficiency in resource-intensive productive service industries. (6) The degree of industrial agglomeration has a more significant impact on enterprise innovation sustainability in groups with low financial risk, high financing constraints, non-state-owned enterprises and high technology levels. (7) A synergistic agglomeration of manufacturing and producer services significantly promotes enterprise innovation sustainability.

The above findings indicate that industrial agglomeration generally positively affects firms' production and operations, which is largely consistent with existing research [61,62]. The research conclusions of this study also have policy implications:

(1) It is important to strengthen the synergistic development of the manufacturing and producer services to promote effective coordination and innovative collaboration across the industrial chain. On the one hand, local governments should increase investment and construct infrastructure, such as transportation, communication, and energy, to reduce logistics costs and time between manufacturing and producer services. They should also build a logistics network and platform connecting the two sectors. On the other hand, by providing preferential policies in finance, taxation, and talent cultivation, local governments can encourage technological cooperation and innovative activities between manufacturing and producer services.

(2) Second, it is important to strengthen internal innovation management within enterprises to enhance innovative quality and efficiency. Local governments should guide enterprises to foster an innovative mindset and spirit, arouse innovation motivation and enthusiasm, and protect and enforce intellectual property rights to safeguard enterprise

innovation outcomes and interests. Simultaneously, by establishing standards, providing technical support, and building evaluation systems, assistance should be rendered to enterprises in perfecting innovative mechanisms and enhancing innovative capabilities. Finally, local governments should break down departmental barriers and regional isolation by constructing diversified, open innovation resource-sharing platforms to elevate the efficiency of innovative resource utilization and output.

(3) Enterprises should actively cooperate and communicate within industrial cluster areas while closely examining new trends and opportunities in industrial development. To achieve this, companies should take full advantage of the public service platforms, technological innovation platforms, logistics service platforms, and intermediary service platforms provided by the cluster areas, effectively expanding their market channels, technology sources, talent reserves, and other elements while promoting resource sharing and collaborative innovation. Simultaneously, companies should increase their investment and innovation in high-tech and environmental protection based on the government's financial and tax support policies and social publicity mechanisms.

7.2. Limitations and Future Potentials

Despite the valuable insights derived from the results, some limitations remain. First, our study's focus on firms in China restricts the generalizability of our findings. Future research should therefore conduct cross-national analyses to examine the validity of our results in other economic contexts. Second, measuring manufacturing agglomeration and producer services agglomeration at the prefecture-level city may need revision and refinement, as it may not capture all aspects of the economic correlation between industries. Future empirical research can explore this issue further by adopting field research and case studies. Third, the regression analysis and mediation effect test may not provide sufficient parameter estimation for China's large population and numerous enterprises. Therefore, it is necessary to increase the sample size in future studies. Lastly, although we have controlled for firm size and industry, these variables may not account for all possible contextual differences that may influence the relationships studied in our conceptual models. Hence, future studies should consider other potentially significant control variables. In addition, the FE model may be unable to control for endogeneity issues and eliminate potential reverse causality. Follow-up studies could be conducted with more advanced statistical tools.

Despite these limitations, our study suggests some possible directions for future research. For instance, R&D investment and the ratio of profit to cost can be used as mediators to investigate further the outside–in mechanism of promoting enterprise innovation sustainability. Moreover, scholars can verify this study's findings from other perspectives by examining the relationship between industrial agglomeration and enterprise innovation sustainability using data from the Chinese industrial enterprise database.

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Data Availability Statement: The industrial data sourced in this study are partially available in the public statistical yearbooks of various cities on the China National Knowledge Infrastructure (CNKI) website, which can be accessed at https://data.cnki.net/yearBook/single?id=N2022040095, accessed on 3 June 2023, and the enterprise data sources in this study are partially available in the CSMAR website, which can be accessed at https://cn.gtadata.com/, accessed on 3 June 2023. As for the data we constructed for research purposes, we would like to share our dataset and econometric models with others who wish to replicate our results. However, the data we constructed for research purposes cannot be fully disclosed due to privacy concerns and other limitations. Interested researchers can contact the corresponding author to request access to the data. The authors will evaluate the request and decide whether to share the data, considering any ethical or legal restrictions.

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