Original Research Article

Impact of Population Concentration in Urban Agglomeration on Corporate Green Innovation

Comment [TMY1]: Change the "term impact" to "influence" because before and after effect which is often associated with impact analysis is not included in the study.

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ABSTRACT

Green innovation is considered to be able to coordinate economic development with ecological environment improvement. Scholars are increasingly focusing on the factors influencing corporate green innovation capability. The analysis is based on the panel data econometric model with fixed effects to examine the relationship between population concentration in urban agglomeration and corporate green innovation. By analyzing company-level data of Chinese A-share listed companies from 2009 to 2019, I find that: (i) Population concentration in urban agglomerations has a significant positive impact on corporate green innovation in the domain. (ii) This relation is stronger for firms in central and western regions, low marketization regions and small cities. (iii) This relation is stronger for small and medium-sized and state-owned enterprises.

Comment [TMY2]: It was discovered.......

Comment [TMY3]: No recommendation?

Keywords: Urban agglomeration; green innovation; regional integration development; corporate sustainable growth.

1. INTRODUCTION

Green innovation is becoming the key to the new round of global industrial revolution and technological competition. As a kind of excellent instrument to balance economic development and environmental protection[1], green innovation is expected to provide inexhaustible driving force toward economic sustainable development and break the bottleneck of economic development constraints [2-4]. For enterprises, green innovation can help them achieve a win-win situation in terms of economic development and environmental protection by helping them to achieve energy saving and emission reduction as well as assisting them to produce green and differentiated products. As the country with the highest total carbon emissions, China is under tremendous pressure to reduce emissions. In order to promote the development of low-carbon transformation, China has proposed the strategic goal of achieving peak carbon by 2030 and carbon neutrality by 2060.Green innovation is the key to energy saving and emission reduction, and it is also an effective means to effectively solve environmental pollution such as carbon emissions [5], which can promote the low-carbon transformation of energy consumption and realize the transformation of economic development mode. Enterprises are the important subjects to implement the strategic goals of carbon peak and carbon neutral. By accelerating the development of quantity and quality of green technology innovation, enterprises can better realize the prevention and control of environmental pollution, promote the green and low-carbon transformation of enterprises and green development of economy and society, and then continuously reduce carbon emissions, which can provide important technical support to achieve the goal of carbon peaking and carbon neutrality.

However, in the context of China's ecological civilization practice and high-quality development, green innovation is still at a low level in China. The main reason for this phenomenon is the lack of green innovation exchange platform in China and the low level of inter-regional green innovation cooperation [6]. Another factor is the general situation of domestic regional segmentation in China [7].

New urbanization is an effective way to alleviate the situation of domestic regional segmentation. The 20th National Congress of the Communist Party of China pointed out that

China should build a coordinated development pattern of small, medium and large cities based on urban clusters and then promote a new type of people oriented urbanization. The concentration of industry and population in regions with economic advantage is an inexorable long-term trend of global economic development. In 2022, Chinese government issued a policy to support the integration of counties into the construction and development of neighboring large cities by pooling resources, promoting growth, stimulating innovation, optimizing the division of labor, and promoting competition through unified large market. Gao and Zhang [8] proposed that the core of industrial and population clustering is to enable neighboring regions to achieve regional comprehensive competitiveness. Modern economic theory suggests that population and industry clustering can lead to agglomeration effects and large-scale economy can promote economic growth and green innovation through the mechanism of sharing, matching and learning. Labor force is the most important and mobile resource element for regional economic and social development. My research explores the impact of population concentration in urban agglomeration on regional green innovation vitality by studying corporate green innovation activities.

Many empirical studies focusing on European and American countries have found that urban agglomerations play an important role in regional economic development [9, 10]. By comparing the urban systems of China, the United States, and European countries, Glaeser, Ponzetto [11] find that the urban system in the United States is mainly a few metropolitan areas dominated by large central cities, while the urban system in Europe is the network of cities formed by small and medium-sized cities. Relatively speaking, China is more suitable for the urban network model because of its huge population size. The increase in population concentration in urban agglomeration can promote urban economic development by optimizing industrial structure and promoting regional integration. In terms of the internal structure of urban agglomeration, the development of the central cities and their radiation capacity play an important role in the overall development of urban agglomeration, and the interconnectedness of non-central cities also contributes to the realization of this externality. Alonso [12] proposed that, by taking advantage of the surrounding areas, a city can get more development opportunities and perform better in terms of economic than the city of the same size. And this idea has been further refined and tested by related scholars[9, 13]. From the perspective of coordinated development, the development of urban agglomeration can help to reduce the financial development gap between regions. As the division of functions within the urban agglomeration continues to advance, the regional economic gap will also gradually decrease. From the perspective of spatial externality, agglomeration can reduce the cost of flow of factors, goods and information, which means that economic agents can enjoy larger labor and demand market and have access to more technology and information. [14, 15]. Externalities arising from upstream and downstream industry linkages and technological knowledge spillovers can improve economic performance, which is empirically reflected in productivity gains and labor wage premiums [16, 17]. All the characteristics of population concentration of urban agglomeration mentioned above are conducive to the corporate level of green innovation.

Based on the theoretical framework of new economic geography, taking Chinese development history of urbanization into account, my study examines whether the population concentration in urban agglomeration is conducive to green innovation of firms. Using Chinese A-share listed companies from 2009-2019 as the sample, my study constructs indicator based on the geographical location characteristics of the companies to empirically test the relationship between the population concentration in urban agglomeration and corporate green innovation. The result shows that with the increase of population concentration in urban agglomeration, the level of corporate green innovation tends to increase significantly, which holds for both large and small cities. On average, when the level of population concentration in urban agglomeration rises by one standard deviation, the companies green innovation will on average increase by 0.06 percentage points. From the perspective of geographic location, compared with eastern cities, firms in central and western cities benefit more from the population concentration in urban agglomeration.

Compared with other existing studies, my study contributes to the literature in three ways. Firstly, enrich the literature on corporate green innovation. Although scholars have paid increasing attention to corporate green innovation, there is relatively little literature examining the impact of population concentration in urban agglomeration on corporate green innovation. Secondly, my study examines the economic impact of population concentration in urban agglomeration at the micro level. Most of the existing studies on urban agglomeration have focused on the city level, which pays more attention to the overall economic development of urban agglomeration. There are relatively few empirical studies on the population concentration in urban agglomeration and how it affects corporate behavior. Thirdly, my study can provide evidence to support the national decision of choosing population clustering in cross-regional urban agglomeration as a focus for future regional development.

The remainder of the paper proceeds as follows. In Section 2, I sort out the relevant literature. In Section 3, I present the sample selection and the construction method of variables. In Section 4, I give empirical results and explanations. Finally, Section 5 is the conclusion and discussion of this paper.

2. LITERATURE REVIEW

Recently, there are many studies paying attention to the extension and influencing factors of green innovation. Green innovation refers to the innovation of environment and ecology [18], which is defined as the hardware and software innovation related to green processes and products, including areas such as energy conservation, pollution prevention, waste recycling, green product design, enterprise environmental management and so on [19, 20].Betz [21] point out that technological breakthrough can bring great benefit to the development of enterprise and society.

The existing literature studies green innovation mainly at two levels: one is the meso- or macro-level, and the other is the firm level. Some scholars study the topic of green innovation from the perspective of government policy [22-24]. Xiang, Liu [25] and Xiang, Liu [25] point out that for state-owned enterprises, political connections have a significant positive impact on enterprises' green innovation by promoting investment in organizational capital and R&D. Additionally, compared to the debt and equity financing, government subsidies have an even greater impact on green innovation of firm. Chen and Zhu [26] examine the relationship between local debt and corporate green innovation and find that local government debt is significantly and negatively related to corporate green innovation. Zhang and Liang [27] study the relationship between environmental regulation and green innovation and suggest that environmental laws in China have an important influence on the process of green innovation. Pan and Cheng[28] study the relationship between environmental policy and green innovation in the sample of regions with high pollution level, drawing a conclusion that green innovation is not strongly influenced by environmental regulations in regions with high pollution level. Moreover , some studies show that the green innovation can be affected by many other meso an macro factors such as media coverage[29], capital market opening[30], the construction of innovative cities [31] and so on.

In addition, some scholars discuss the topic related to green innovation from the perspective of corporate behavior. Amore and Bennedsen [32] point out that corporate governance has significant implications for corporate green innovation performance. This is demonstrated by the fact that ineffective corporate governance has a negative impact on green innovation activities. Amore and Bennedsen [32] further find that personnel in the R&D department and the expenditure on R&D promote corporate green innovation. Qi and Zeng [33] indicate that foreign customers have a significant positive effect on the use of green product innovation strategies and processes by firms. Bin Yousaf and Ullah [34] study the relationship between board traits and innovation activities, drawing a conclusion that board capital has a significant positive impact on green innovation. Moreover, some studies show that the green innovation can be affected by many other corporate factors such as overseas experience of executives [35], academic experience of senior management[36], CEO arrogance [37], female board members[38], corporate resources[25], social responsibility of enterprises[39] and so on.

A few scholars have also discussed the impact of external shocks such as terrorism and natural disaster on green innovation. For example, using panel data of OECD countries from 1975 to 2018, Zheng and Feng [40] examine the impact of natural disaster on green innovation performance, concluding that the occurrence of natural disaster hinders green innovation activities. In addition, Zheng and Feng [41]point out that terrorism has a negative impact on the invention of renewable energy technologies in OECD countries.

Although various perspectives have been adopted in the literature to explore the factors influencing green innovation, the relationship between the population concentration in urban agglomeration and green innovation has not been fully studied in the previous literature so far. Economic globalization requires the enhancement of urban agglomeration, which has become a very important model of economic development in modern countries. The development of urban agglomeration and its impacts have become a focus of scholarly attention [42-44].As an important way to drive China's economic development and accelerate urbanization, the construction of urban agglomeration is transcending regional boundaries and becoming "nodes" connecting different regions and even the global economy, which facilitates the achievement of the 14th Five-Year Plan and the 2035 Long-Range Goals. Therefore, we need to pay more attention to the potential impact of population concentration in urban agglomeration on green innovation, which will not only help China's urbanization level steadily increase, but also help us promote sustainable economic development from the perspective of green innovation.

3. MATERIAL AND METHODS

My study examines the relationship between population concentration in urban agglomeration and green innovation by using A-share listed companies' data from 2009-2019. I collected financial and ownership data of sample companies from the CSMAR database, excluding financial listed companies, companies with unusual listing status during the sample period and companies with abnormal financial indicators. Finally, there are 19953 annual company observations in the sample. The source of the corporate innovative data is the CNRDS database. The city-level data involved are obtained from the China City Statistical Yearbook and the China Urban Construction Statistical Yearbook, and some missing data are supplemented according to the statistical yearbooks and statistical bulletins of each province.

3.1 Empirical methods

Fixed effects models are widely used in the study of panel data, such as the fixed effects models constructed by scholars to study the effect of Academic workstations on corporate green innovation[45] and robot adoption on green innovation[46]. Inspired by previous studies, this study constructs a panel fixed effects model with industry fixed effect and time fixed effect to examine the relationship between population concentration in urban agglomeration and corporate green innovation in the domain. The inclusion of fixed effects in the model can well solve the problem caused by missing variables which would change with time and industry. Therefore, this model can objectively reflect the relationship between population concentration in urban agglomeration and corporate green innovation in the domain.

Comment [TMY4]: How is your own model differ from othe empirical models?

$$Y_{ijt} = \beta_0 + \beta_1 Concentration_{jt} + \beta_2 Scale_{jt} + Controls_{ijt} + Year + Ind + \varepsilon_{ijt} \quad (1)$$

Where Y_{ijt} is the proxy variable for the corporate green innovation level of firm i in period t, which includes LnTotal, LnInva and LnUma. $Concentration_{jt}$ refers to the population concentration level in urban agglomeration in period t. The control variables selected for this paper include two levels: firm-level and city-level. Firm-level control variables include Cashflow, Lev, ROA, PPE, Top1, Seperation and Age. City-level control variables include Scale, Fiscal_e, Loan, Road, Sec_ind_ratio and Fdi. This study mainly focuses on the coefficient β_1. If β_1 is significantly less than 0, it means that population concentration in urban agglomeration is negatively related to corporate green innovation, while the opposite is true if it is significantly greater than 0.

3.2. Variables

3.2.1 Population concentration in urban agglomeration

The explanatory variable of this study is the population concentration in urban agglomeration, which can be interpreted as the summation of urban population sizes within urban agglomeration. Considering that interactions vary with distance, this summation is weighted by the inverse of the inter-urban distance, and the variable is constructed as follows:

$$Concentration_{jt} = \sum_{k\in D, k\neq j} \frac{pop_{kt}}{d_{kj}} \quad (2)$$

Where j represents the city, t represents the time, D is the collection of cities within a certain geographical distance around city j, and pop is the population size of city k during the t period. Urban population size data comes from the China Urban Statistical Yearbook. d is the geographical distance between city k and city j. Our study calculates the distance between cities using the longitude and latitude coordinates of the city government location on Baidu map. Moreover, the preliminary calculation results show that the average distance between a certain city in China and its nearest five cities is 151 kilometers, so our study set the geographical range of city cluster D to 150 kilometers.

3.2.2 Greem innovation

Green innovation is a form of innovation that is guided by sustainable development and combines the innovation of products and production processes with features such as environmental protection and resource conservation [47, 48] . Summarizing the existing studies, we can see that the number of corporate patents is a common indicator for measuring innovation performance[49]. Referring to previous studies [50, 51] , this study measures the level of green innovation by the number of green patent applications. The green innovation activities of enterprises can be divided into substantive innovation and strategic innovation. Invention patent is a kind of substantive innovation achievement which reflects the enterprises' pursuit of green innovation "quality". In contrast, the utility model patent is a kind of less difficult strategic innovation, reflecting the pursuit of "quantity" of green innovation. Specifically, in this study, the total amount of green innovation is the sum of the number of green invention patent applications and the number of green utility model patent applications. At the same time, the number of green invention patent applications can be used to measure the quality of green innovation, and the number of green utility model patent applications can be used to measure the quantity of green innovation. In order to eliminate the right-skewed distribution problem of green patent application data, this study takes the natural logarithm of the number of green patent applications after adding 1 to get the green innovation indicators LnTotal, LnInva and LnUma.

Table1 The description of variables

	Variable Abbreviation	Meaning of Variables
Independent variable	Concentration	Degree of population concentration in urban agglomeration
Dependent variable	LnTotal	Total green innovation: ln(1+ the number of green patent applications)
	LnInva	Green innovation quality: ln(1+ the number of green invention patent applications)
	LnUma	Number of green innovations: ln(1+ the number of green utility model patent applications)
Enterprise-level control variables	Cashflow	Company operating cash flow/total assets
	Lev	Asset liability ratio
	ROA	Net profit/total assets
	PPE	Cash paid for fixed assets, intangible assets and other long-term assets/total assets
	Top1	Shareholding ratio of the largest shareholder
	Seperation	Seperation of two rights
	Age	Year of establishment
	Soe	state-owned enterprises assigned a value of 1
City-level control variables	Fiscal_e	Local fiscal general public budget expenditure/regional GDP
	Loan	Loan balance of depository financial institutions/regional GDP
	Road	road person ratio
	Fdi	Actual utilized foreign capital × average exchange rate / regional GDP
	Scale	Population size of central cities

4. RESULTS

4.1.Data and descriptive statistics

Table 2 shows the results of descriptive statistics for the sample, including the number of observations, minimum, mean, standard deviation, and maximum. From the result of the descriptive statistics we can see that the standard deviation of Chinese population concentration in urban agglomeration is 0.64 and the mean value is 3.29, which indicates that there are some differences in the degree of population concentration in different urban agglomeration. For the control variables, the mean value of gearing ratio is 41.00%, the mean value of return on assets is about 4% and the percentage of state-owned enterprises is 38%, which are generally consistent with the descriptive statistics in the existing literature.

Table 2 Summary statistics

variable	observations	mean	min	max	sd
LnTotal	19953.00	0.41	0.00	3.85	0.78
LnInva	19953.00	0.27	0.00	3.53	0.61
LnUma	19953.00	0.25	0.00	3.09	0.57
Concentration	19953.00	3.29	1.18	4.33	0.64
Scale	19953.00	6.45	4.71	8.11	0.65
Cashflow	19953.00	0.05	-2.61	8.85	0.07
Lev	19953.00	0.41	0.05	0.93	0.20
ROA	19953.00	0.04	-0.28	0.20	0.05
PPE	19953.00	0.05	0.00	0.55	0.05
Top1	19953.00	0.35	0.02	0.89	0.15
Seperation	19953.00	4.39	0.00	28.32	7.10
Age	19953.00	16.58	4.00	31.00	5.40
Soe	19953.00	0.38	0.00	1.00	0.49
Fiscal_e	19953.00	0.15	0.07	0.28	0.05
Loan	19953.00	1.52	0.40	3.15	0.63
Road	19953.00	14.95	4.04	33.26	7.30
Sec_ind_ratio	19953.00	0.42	0.16	0.65	0.11
Fdi	19953.00	0.03	0.00	0.12	0.02

4.2. The impact of population concentration in urban agglomeration on corporate green innovation

This study investigates the correlation between population concentration and corporate green innovation in urban agglomeration, and the results are shown in Table3. The dependent variable in columns (1) (2) is the total number of green patent applications (LnTotal). The dependent variable in columns (3) (4) is the quality of corporate green invention (LnInva). The dependent variable in columns (5) (6) is the quantity of corporate green innovation (LnUma). Region-level and firm-level control variables are added in columns (2)(4)(6). Additionally, time and industry fixed effects are controlled in all columns. From the result in columns (1)(2), we can see that the regression coefficients of population concentration in urban agglomeration and corporate green innovation are significantly positive at the 1% level, indicating that the increase of population concentration in urban agglomeration can promote corporate green innovation activities and increase the number of corporate green patent applications. Specifically, if the population concentration level of urban agglomeration increases by one unit, the green innovation of enterprises in the domain will increase by 0.06 units. Moreover, from the result in columns (3)-(6), we can see that the regression coefficients are also significantly positive at the 1% level, indicating that the increase of population concentration in urban agglomeration can promote corporate green innovation quality and quantity.

Table 3 The relationship between Concentration and corporate green innovation

Variables	(1) LnTotal	(2) LnTotal	(3) LnInva	(4) LnInva	(5) LnUma	(6) LnUma
Concentration	0.0522***	0.0623***	0.0346***	0.0418***	0.0419***	0.0512***
	(0.0161)	(0.0174)	(0.0122)	(0.0134)	(0.0113)	(0.0121)
Scale		0.0137		0.0145		0.00417
		(0.0200)		(0.0156)		(0.0140)
Cashflow		0.0754		0.0801		-0.00949
		(0.0834)		(0.0649)		(0.0613)
Lev		0.524***		0.374***		0.350***
		(0.0584)		(0.0459)		(0.0413)
ROA		1.254***		0.999***		0.682***
		(0.162)		(0.129)		(0.114)
PPE		0.326**		0.215*		0.210*
		(0.156)		(0.123)		(0.110)
Top1		-0.0321		-0.0566		0.0326
		(0.0733)		(0.0578)		(0.0516)
Seperation		0.00387**		0.00282**		0.00224**
		(0.00154)		(0.00119)		(0.00110)
Age		-0.00814***		0.00481***		0.00555***
		(0.00224)		(0.00169)		(0.00159)
Soe		0.0999***		0.0968***		0.0352*
		(0.0279)		(0.0224)		(0.0188)
Fiscal_e		0.0804		0.0277		0.177
		(0.272)		(0.218)		(0.185)
Loan		-0.0281		-0.0202		-0.00830
		(0.0213)		(0.0164)		(0.0149)
Road		0.000323		0.000842		-0.000531
		(0.00187)		(0.00145)		(0.00132)
Sec_ind_ratio		-0.180		-0.218*		0.0493
		(0.149)		(0.119)		(0.102)
Fdi		-0.211		0.159		-0.621*
		(0.475)		(0.377)		(0.327)
Constant	0.243***	0.0305	0.159***	-0.0167	0.109***	-0.0849
	(0.0533)	(0.198)	(0.0401)	(0.153)	(0.0372)	(0.143)

Variables	(1) LnTotal	(2) LnTotal	(3) LnInva	(4) LnInva	(5) LnUma	(6) LnUma
Observations	19,953	19,953	19,953	19,953	19,953	19,953
R-squared	0.146	0.168	0.113	0.135	0.137	0.153

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.3. Further Analysis.

This study initially explores the positive impact of population concentration in urban agglomeration on corporate green innovation in the domain. However, it is worth noting that there are significant differences between intra-provincial agglomeration and cross-provincial agglomeration. On the one hand, cross-provincial urban agglomeration needs to face the problem from higher-level governments in different provinces, which will increase the difficulty of cross-provincial urban agglomeration development and reduce the positive spillover effect of cross-provincial urban agglomeration development. At the same time, the existence of competitive relationship among provincial governments may also hinder the process of building and developing cross-provincial urban agglomeration. On the contrary, cities within the same province have close geographic location, common customs and convenient conditions for integrated development, which can lay a good development foundation for promoting the construction of urban agglomeration. On the other hand, cross-provincial urban agglomeration can make cities form closely linked socio-economic networks, break the restrictions of administrative divisions, and build a "win-win" and "integrated" development pattern with complementary advantages, resource sharing and coordination.

Table 4 The difference between cross-provincial and intra-provincial concentration

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	LnTotal	LnInva	LnUma	LnTotal	LnInva	LnUma
	Intra-provincial urban agglomeration			Cross-provincial urban agglomeration		
Concentration	0.0619***	0.0390**	0.0522***	0.0939***	0.0746***	0.0569**
	(0.0228)	(0.0178)	(0.0156)	(0.0319)	(0.0228)	(0.0240)
Scale	0.00282	0.00758	0.00131	0.0703**	0.0478*	0.0404
	(0.0254)	(0.0202)	(0.0176)	(0.0338)	(0.0250)	(0.0251)
Cashflow	0.140	0.124	0.00780	-0.0175	0.00885	-0.0465
	(0.128)	(0.0978)	(0.0964)	(0.106)	(0.0835)	(0.0768)
Lev	0.511***	0.338***	0.377***	0.539***	0.418***	0.313***
	(0.0867)	(0.0673)	(0.0629)	(0.0800)	(0.0641)	(0.0542)
ROA	1.143***	0.881***	0.660***	1.469***	1.188***	0.796***
	(0.221)	(0.172)	(0.159)	(0.238)	(0.193)	(0.165)
PPE	0.506**	0.346**	0.339**	0.128	0.0792	0.0694
	(0.209)	(0.168)	(0.146)	(0.227)	(0.177)	(0.162)
Top1	-0.158	-0.154*	-0.0632	0.0194	-0.0132	0.0670
	(0.107)	(0.0843)	(0.0751)	(0.101)	(0.0800)	(0.0715)
Seperation	0.00361*	0.00277*	0.00225	0.00524**	0.00351**	0.00320**
	(0.00213)	(0.00163)	(0.00154)	(0.00212)	(0.00167)	(0.00149)
Age	0.00943***	0.00587**	0.00605***	-0.00512	-0.00202	0.00451**
	(0.00312)	(0.00231)	(0.00229)	(0.00325)	(0.00256)	(0.00222)

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	LnTotal	**LnInva**	**LnUma**	**LnTotal**	**LnInva**	**LnUma**
	Intra-provincial urban agglomeration			**Cross-provincial urban agglomeration**		
Soe	0.101**	0.114***	0.0160	0.0985**	0.0761**	0.0586**
	(0.0406)	(0.0328)	(0.0269)	(0.0382)	(0.0304)	(0.0263)
Fiscal_e	0.677	0.557	0.506*	-0.304	-0.339	-0.0149
	(0.418)	(0.340)	(0.283)	(0.396)	(0.311)	(0.275)
Loan	-0.0476	-0.0377*	-0.0168	-0.00448	-0.00339	0.00176
	(0.0296)	(0.0227)	(0.0207)	(0.0309)	(0.0240)	(0.0216)
Road	0.00118	0.00201	-0.00133	0.00204	0.000739	0.00229
	(0.00274)	(0.00219)	(0.00182)	(0.00285)	(0.00219)	(0.00201)
Sec_ind_ratio	-0.288	-0.310*	-0.0592	-0.303	-0.307*	-0.0474
	(0.223)	(0.174)	(0.158)	(0.224)	(0.178)	(0.152)
Fdi	-0.236	-0.0786	-0.427	-0.145	0.296	-0.598
	(0.733)	(0.582)	(0.503)	(0.616)	(0.479)	(0.441)
Constant	0.170	0.0866	0.00184	-0.505*	-0.370*	-0.376*
	(0.270)	(0.211)	(0.192)	(0.285)	(0.218)	(0.206)
Year FE	yes	yes	yes	yes	yes	yes
Industry FE	yes	yes	yes	yes	yes	yes
Observations	9,996	9,996	9,996	9,954	9,954	9,954
R-squared	0.188	0.154	0.167	0.181	0.146	0.170

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In order to better understand the difference between population concentration of intra-provincial urban agglomeration and population concentration of inter-provincial urban agglomeration, this study intends to use sub-sample regression to investigate their relationship with corporate green innovation. Specifically, based on the definition of population concentration in urban agglomeration, if the sample cities in the urban agglomeration all belong to the same province, the study will define these samples as intra-provincial population concentration in urban agglomeration, otherwise they are defined as cross-provincial population concentration in urban agglomeration. The specific regression results are shown in Table 4. The results in columns (1)-(6) show that the coefficients of population concentration in urban agglomeration are significantly positive at the 1% level, indicating that the population concentration in intra-provincial urban agglomeration and cross-provincial urban agglomeration can effectively promote corporate green innovation in the domain. Moreover, from the result of sub-sample regression, this study finds significant differences in the regression coefficients of key explanatory variables. The result shows that population concentration in cross-provincial urban agglomeration can significantly enhance corporate green innovation level in the domain compared with population concentration in intra-provincial urban agglomeration.

4.4. Heterogeneity analysis

4.4.1 Regional heterogeneity analysis

Firstly, in the early stage of Chinese reform and opening-up, the eastern region became the pioneer of reform by virtue of its geographical advantage, which made its economic development level and regional innovation vitality better than those of the central and western regions. In order to balance the development gap between regions, China has introduced regional development strategies such as "Western Development" and "Rise of Central China" for the central and western region. In this study, the sample is divided into the eastern region and the central and western region according to the geographical location for group regression. The regression results are shown in columns (1) and (2) of Table 5. In both the eastern and the central and western region, the increase of population concentration in urban agglomeration is beneficial to enterprise green innovation, and the effect is more obvious for the central and western region. Compared with the cities in the eastern region, the cities in the central and western regions are relatively less endowed with innovation resources, and they can promote green innovation development by "grouping" with neighboring cities by forming a synergy.

Secondly, in this study, the sample is divided into high marketization group and low marketization group according to the degree of regional marketization. The regression results are shown in columns (3) and (4) of Table 5. In both high marketization and low marketization regions, the increase of population concentration in urban agglomeration is beneficial to enterprise green innovation, and the effect is more obvious for the low marketization regions. Green innovation in low marketization areas is more constrained than in high marketization areas. Coordinated development with neighboring cities is conducive to the improvement of green innovation capacity in low marketization areas, as firms can benefit from the market externalities of the neighboring areas.

Thirdly, in this study, cities are classified into large cities and small and medium-sized cities according to the average of city population size during the sample period. The regression results are shown in columns (5) and (6) of Table 5.In both large cities and small and medium-sized cities, the increase of population concentration in urban agglomeration is beneficial to enterprise green innovation, and the effect is more obvious for the small and medium-sized cities. Enterprises located in small and medium-sized cities can enjoy the scale advantage of large markets and accumulate industry-related technical knowledge by interacting with large cities in urban agglomeration, which is beneficial to the development of corporate green innovation activities.

Table 5 Regional heterogeneity analysis

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	East	**Midwest**	**High marketization**	**Low marketization**	**Big city**	**Small city**
	LnTotal	**LnTotal**	**LnTotal**	**LnTotal**	**LnTotal**	**LnTotal**
Concentration	0.0227*	0.0937***	0.0549***	0.0895***	0.0345*	0.0832***
	(0.0135)	(0.0139)	(0.0121)	(0.0146)	(0.0193)	(0.0113)
Scale	0.0225	0.0512***	0.0453***	-0.00169	0.127***	0.0206
	(0.0175)	(0.0168)	(0.0138)	(0.0183)	(0.0364)	(0.0173)
control variable	control	control	Control	control	control	control
Constant	0.00274	-0.853***	-0.571***	-0.324	1.096***	-0.314*
	(0.247)	(0.164)	(0.159)	(0.228)	(0.276)	(0.175)
Year FE	yes	yes	Yes	yes	yes	yes
Industry FE	yes	yes	Yes	yes	yes	yes
Observation	10,186	9,563	10,546	9,203	9,424	10,325
R-squared	0.185	0.175	0.174	0.197	0.177	0.192

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.4.2 Firm heterogeneity analysis

Firstly, in this study, enterprises are classified into large enterprises and small and medium-sized enterprises according to the median of enterprise size during the sample period. The regression results are shown in columns (1) and (2) of Table 6. For both large enterprises and small and medium-sized enterprises, the increase of population concentration in urban agglomeration is beneficial to corporate green innovation, and the effect is more obvious for large enterprises. Enterprises with larger production scale have more significant scale effect and the ability to layout their businesses in neighboring cities, which allows them to better take advantage of the growth potential of neighboring markets. In columns (3) and (4) of Table 6, enterprises are classified into state-owned enterprises and non-state-owned enterprises according to the nature of the enterprises. The result shows that the effect of population concentration in urban agglomeration on corporate green innovation is more significant in the state-owned enterprises compared to non-state-owned enterprises.

Table 6 Firm heterogeneity analysis

Variable	(1) Large enterprises	(2) Small and medium-sized enterprises	(3) State-owned enterprise	(4) Non state-owned enterprises
	LnTotal	LnTotal	LnTotal	LnTotal
Concentration	0.0821***	0.0312***	0.0718***	0.0617***
	(0.0143)	(0.0115)	(0.0143)	(0.0122)
Scale	0.0542***	-0.0389***	0.0638***	-0.0125
	(0.0160)	(0.0125)	(0.0169)	(0.0130)
Control variable	control	Control	control	control
Year FE	yes	Yes	yes	yes
Industry FE	yes	Yes	yes	yes
Constant	-0.788***	0.470***	-0.612***	-0.137
	(0.182)	(0.171)	(0.184)	(0.177)
Observations	9,768	9,981	7,597	12,152
R-squared	0.231	0.156	0.218	0.176

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.5. Robustness tests

Based on the baseline regressions, a series of robustness tests are conducted in this study.

4.5.1 Substitution of explanatory variables

In terms of the independent variables, I replace the population size data in the process of calculating independent variables. On the one hand, municipal district is an important subdivision of the administrative system in China. It is the area with higher economic activity, which can better reflect the economic development potential of a city and the positive externalities of external radiation. Therefore, the population size of the city is replaced by the

population size of the municipal district, and the size of the city itself is adjusted accordingly. The population size of municipal districts is obtained from the China Urban Statistical Yearbook. The regression result in columns (1)-(3) of Table 7 finds that after changing the population size measurement method, the degree of population concentration in urban agglomeration still has a significant positive impact on green innovation of enterprises. On the other hand, given the existence of China's household registration system, many people' household registration and permanent residence locations are different. For example, the urbanization rate of China's household population in 2020 is 45.40%, while the urbanization rate of the resident population is 63.89%.Compared with the registered residence population, the permanent population can better reflect the urban economic vitality. However, due to the fact that China's population census is conducted every 10 years, this study cannot obtain accurate real-time data. Therefore, this study selects the permanent population disclosed in the statistical yearbooks or statistical bulletins of each province as a substitute. The regression result in columns (4)-(6) of Table 7 finds that after changing the population size measurement method, the degree of population concentration in urban agglomeration still has a significant positive impact on green innovation of enterprises.
In addition, considering the differences in the sample of municipalities, I exclude the sample firms within the municipalities for robustness testing. The regression result in columns (1)-(3) of Table 8 shows that the regression coefficients of the key explanatory variables are always significantly positive at the 1% level, which again indicates that the above baseline regression results are robust.

Table 7 Substitution of explanatory variables

Variable	**(1) LnTotal**	**(2) LnInva**	**(3) LnUma**	**(4) LnTotal**	**(5) LnInva**	**(6) LnUma**
Concentration1	0.0433***	0.0323***	0.0336***			
	(0.0134)	(0.0103)	(0.00956)			
Scale1	0.0207	0.0144	0.0132			
	(0.0163)	(0.0128)	(0.0114)			
Concentration2				0.0472***	0.0325***	0.0387***
				(0.0157)	(0.0123)	(0.0108)
Scale2				0.0418**	0.0316*	0.0267*
				(0.0210)	(0.0164)	(0.0145)
Control variable	control	Control	control	control	control	control
Constant	0.0719	0.0337	-0.0665	-0.171	-0.146	-0.240*
	(0.166)	(0.130)	(0.119)	(0.200)	(0.154)	(0.145)
Year FE	yes	Yes	yes	yes	yes	yes
Industry FE	yes	Yes	yes	yes	yes	yes
Observations	19,953	19,953	19,953	19,953	19,953	19,953
R-squared	0.168	0.135	0.153	0.169	0.135	0.154

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.5.2. Using the dependent variable from the previous period

The baseline regression results in this paper may face endogeneity problem. Although the independent variable is a city-level variable and the dependent variable is a firm-level variable, there is still the possibility of reverse causality. For example, as the green innovation capability of local enterprises grows, it may attract population to the local area and its surrounding regions, leading to the increase of p population concentration in urban agglomeration. In addition, the problem faced by baseline regression is that enterprises with strong green innovation capabilities may prefer to concentrate in areas with high population concentration. In order to alleviate potential endogeneity issue, considering the potential time lag of corporate green innovation, this study selects the dependent variable from the previous period for regression, which results in a temporal mismatch between the independent variable and the dependent variable. The regression result in columns (4)-(6) of Table 8 shows that the regression coefficients of the key explanatory variables are still significantly positive at the 1% level, which indicates that the above baseline regression results are robust.

Table 8 Using the dependent variable from the previous period

Variable	(1) LnTotal	(2) LnInva	(3) LnUma	(4) F.LnTotal	(5) F.LnInva	(6) F.LnUma
Concentration	0.0698***	0.0471***	0.0567***	0.0701***	0.0477***	0.0555***
	(0.0183)	(0.0141)	(0.0127)	(0.0189)	(0.0146)	(0.0132)
Control variable	yes	Yes	yes	yes	yes	yes
Constant	0.0109	-0.0452	-0.0437	-0.0367	-0.0659	-0.133
	(0.231)	(0.170)	(0.171)	(0.212)	(0.163)	(0.153)
Year FE	yes	Yes	yes	yes	yes	yes
Industry FE	yes	Yes	yes	yes	yes	yes
Observations	15,717	15,717	15,717	15,930	15,930	15,930
R-squared	0.171	0.139	0.153	0.176	0.142	0.160

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

5.DISCUSSION AND CONCLUSIONS

In this study, I investigate the relationship between population concentration in urban agglomeration and corporate green innovation. My analysis is based on a wide sample of A-share listed companies in china from 2009 to 2019. My empirical results show that (i) population concentration in urban agglomeration has a significant positive impact on corporate green innovation. (ii)The heterogeneous characteristics of a company and area will affect the corporate green innovation capacity. The contribution of population concentration in urban agglomeration to the corporate green innovation is more significant among the central and western regions, the low marketization regions, the small and medium-sized cities, the large enterprises and the state-owned enterprises.

However, there are some limitations in my study which can provide opportunity to further study in the future. The first is the limitation of data source. Compared with listed companies, small companies disclose little information, so the data in this study mainly comes from listed companies, which cannot fully reflect the situation of small companies. Therefore, the results of this study may not be applicable to small enterprises. Green innovation is characterized by the high demand for capital and the high possibility of failure, while small enterprises are characterized by the weak risk tolerance capacity, which will lead to uncertainty about the direction and extent of the impact of population concentration in urban agglomeration on green innovation of small enterprises. Secondly, although my study examines the relationship between population concentration in urban agglomeration and corporate green innovation, I do not further investigate the mechanism underlying this relationship. In future research, more detailed empirical models should be designed to analyze the relevant mechanisms and consequences of higher green innovation capacity.

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