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Sustainable development with city, industry, economic and environment: The role of city-industry integration on green economic growth

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ABSTRACT

In order to avoid the real economy development lags behind and the deterioration of ecological problems in the process of traditional urbanization, China has been promoting city-industry deep integration, but the connection between city-industry integration and green economic growth, especially the spatial effect, has not been systematically explained. Based on the panel data from 2007 to 2018, this paper constructs an evaluation index system and uses the SEEA method to measure city-industry integration (CII) level and green economy growth (GEG) level. Then, by employing spatial Durbin model and intermediary effect model, it further systematically investigates the spatial impact of CII on GEG and the potential mechanism. The study found that: (1) On the whole, CII shows "slow-steady integration" trend, but regional heterogeneity was obvious and accompanied by "slow gap expansion". GEG experienced "sharp increase" with "polarization" characteristic. (2) CII can directly promote regional GEG (with a marginal effect of 0.689), more effectively than traditional urbanization, and CII has obvious spatial spillover effects on GEG in both "local effect" and "neighboring effect". (3) Interestingly, technological innovation and consumption structure upgrading are significant mediating mechanisms. (4) The direct positive effect of CII shows the regional imbalance characteristic. Finally, the corresponding policy implications are put forward.

KEYWORDS

City-industry integration; Green economic growth; Spatial Durbin model; Spatial spillover effect; Intermediary effects

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1. Introduction

Urbanization is the process of population and industry gathering in cities and towns, and it is the reflection of social changes in the process of industrialization and modernization of various countries (Yu et al., 2014; Hao et al.,2022). Since the founding of the People's Republic of China, China's urbanization has gone through three stages: starting, accelerating development and basically maturing, and urbanization has made great leaps while stimulating the momentum of economic growth and promoting the sustainable growth of the national economy (Zhou et al., 2019; Ren et al.,2022). According to the data of the 7th National Census, while the urbanization rate of China's resident population has increased from 49.68 percent in 2010 to 63.89 percent (obtained from the National Bureau of statistics of the People's Republic of China) in 2020, there is still an obvious gap compared with over 80 percent of the high urbanization rate in developed countries.

China's rapid economic development since the reform and opening-up, China's GDP in 2020 exceeded 100 trillion U.S. dollars, ranking as the world's second largest economy (He, 2019). But as China's economy enters the new normal and investment and export-driven growth patterns become increasingly weak, the economic development model urgently needs to shift to innovation and domestic demand-driven (Fan et al., 2018; Qiao, 2020).The new urbanization is considered to be the greatest potential to expand domestic demand (Liu, 2020), but in the past extensive and rapid urbanization has brought about unbalanced basic public services, unreasonable industrial structure, serious consumption of resources, environmental pressure and other social and economic problems that are not conducive to sustainable development 0(Li et al., 2009; Chikaraishi et al, 2015; Zhao et al,2018). Besides, the emergence of excessive urbanization or lagging urbanization are caused by "empty city " and other deformed urban forms (Wang, 2010;Chai et al.,2021). Fundamentally, the phenomenon is due to the lack of corresponding matching between urbanization and industrialization (Henderson et al., 2009). Therefore, how to realize the integration and coordinated development of city construction and industrial development under the background of new people-oriented urbanization is the key to promote sustainable economic growth, especially to green economic growth.

This brief review of the existing studies on city-industry integration, evaluation system, internal mechanism and other qualitative research has highlighted following deficiencies. First, a connotation definition and measurement index system of CII based on people-oriented new urbanization are lacked. Second, although a lot of studies have done in-depth research on the effect of CII on economic growth, the spatial spillover effect of CII on GEG lacks due attention. Specifically, previous studies ignore that regional green economic growth has strong spatial dependence and its spatial agglomeration characteristic directly affects the regional coordinated development. Third, despite some studies paying attention to intermediary mechanism of CII affecting GEG, no existing studies, to the best of our knowledge, have examined and quantified the intermediary mechanism.

The main contribution of this paper is the following. Firstly, employ evaluation index system to quantify the level of CII and GEG, and Moran's Index to test the spatial dependence of regional GEG. Secondly, via the spatial Durbin model and intermediary effect model, systematically investigate the spatial spillover effect of CII on GEG in the process of China accelerating "New Urbanization Construction" and explore the potential intermediary mechanisms from two dimensions - technological innovation and consumption upgrading. Thirdly, analyze its regional heterogenous effect, including the imbalance characteristic of direct positive effect of CII and an opposite "marginal contribution decrease" characteristic of the spatial spillover effect. The empirical evidence provides a reference for the urbanization construction and green transformation.

The remainder of this study is organized as follows. Section 2 is literature review and research hypotheses. Section 3 research design, including basic model construction, description of variables and data source. Section 4 provides a detailed description and analysis of the spatial dependence of regional green economic growth, the spatial spillover effect of CII on green economic growth. Section 5 is robustness test. Section 6 presents further

discussion about the potential intermediary mechanism and the regional heterogeneity. The last section concludes and discusses policy implications. The research framework is shown in Fig. 1.

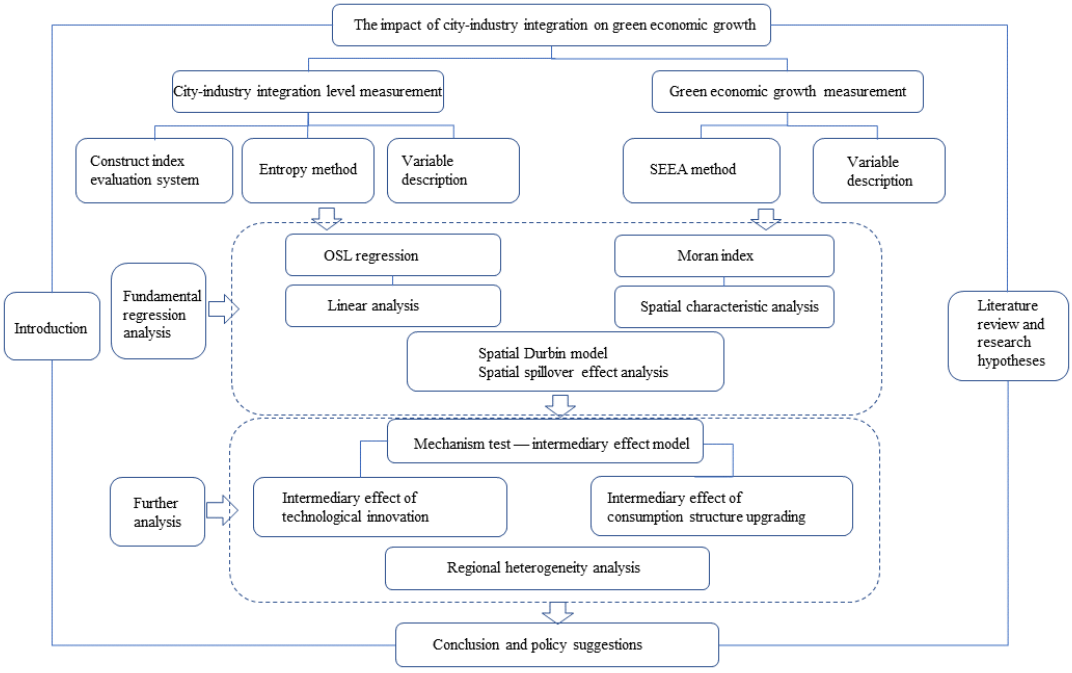


Figure 1. Research framework diagram.

2. Literature review and research hypotheses

At present, scholars have carried out a lot of research on the effect of the city-industry integration on regional economic growth, mainly focusing on the following four aspects:

2.1. The connotation and measurement of the city-industry integration

There is no clear definition, mainly because in the process of urbanization, traffic congestion, environmental pollution problems have been arising constantly (Palme et al.,2008; Holden, 2006). Ebenezer Howard's "Garden City Theory" proposed the concept of urban planning to achieve the best proportion of industrial, agricultural and residential areas, not only to achieve the integration of "industry" and "residential", reduce the frequency of the use of transport for ecological development, but also reduce commuting costs, improve worker satisfaction, promote productivity and innovation activities, which is the prototype of city-industry integration (Ebenezer, 1898). Previs Center - Peripheral Theory, Perroux's "Polarization" Theory (Perroux, 1955) and Boudreauville's "Lyon Tiff Multiplier Effect" are also involved in the idea of city-industry integration (Boudeville, 1967).

Chinese scholar first put forward the concept of city-industry integration in 2011, suggesting that only industry and city deep integration, can stimulate demand and activate industrial development (Zhang, D.G.,2011). Other more representative views are that city-industry integration is the mutual promotion of the new city and the old city (Liu & Wang, 2013), the positive interaction between the new city and high-tech (Su et al., 2013), the integration of industry and urban functions and structure matching (Li & Chen, 2012). Furthermore, it is premised on improving human utility to achieve the common prosperity of cities and industries (Li & Zhang, 2021).

With regard to measurement methods, some scholars choose infrastructure, industry, environment, transportation and other sustainable development indicators (Yigitcanlar & Dur, 2010). Combine the relationship between industrialization and urbanization process to establish a coupling coordination model to analyze the

degree of coordination of city and industry (Cong et al., 2017). Some scholars employ fuzzy comprehensive evaluation, factor analysis, entropy and other methods to measure (Su et al., 2013; Gan et al., 2020; Su & Jia, 2017).

2.2. Urbanization and green economic growth

Some scholars believe that urbanization has a positive effect on economic growth through a variety of channels. From China's development experience, urbanization plays a vital role in the early economic growth process (Gu et al., 2017), Some scholars have found that every 1% increase in urbanization rate can achieve 7.1% economic growth (Zhu et al.,2011). Scholars point out that urbanization will bring about external economies of scale, while reducing the cost of production by reducing the transaction costs of the economic system (Krugman, 1991; Kumar & Kober, 2012). In addition, the population agglomeration and industry agglomeration facilitate accessibility to finance, promote the dissemination of business ideas (Glaeser et al., 2010), and make cities more capable of innovation, thereby promoting industrial upgrading (Nguyen & Nguyen, 2018).

However, few scholars suggested urbanization as a means of promoting economic growth does not necessarily apply to all countries (Bloom et al., 2008). There is an uncertain relationship between urbanization and economic growth (Vernon, 2003). The development of urbanization and economic development, ecological environment, the impact on economic growth will change with the degree of coordination of CII (Zang & Su, 2019; Salesses et al., 2013).

2.3. City-industry integration and green economic growth

At present, many scholars mainly focus on industrialization or the coordinated coupling effect of industrialization and urbanization. Xu and other scholars found that good synergy between industry and cities has a significant effect on high-quality economic growth (Xu et al., 2019). City-industry integration will promote the convergence of new industries, which is conducive to the development of intensive, innovative and high value-added industries, and thus increase labor productivity (Sun & Zhou, 2016), and indirectly improving economic green development. In addition, city-industry integration can effectively reduce resource consumption and carbon emissions, improve ecological efficiency, so as to achieve a qualitative improvement in economic growth (Lu et al., 2020; Bian et al., 2020).

From the perspective of spatial difference, based on the quantitative measurement of city-industry integration in 2000-2015, Zou and Cong (2019) summarized the remarkable characteristics of city-industry integration, pointing out that China's GDP growth slowed down in 2003-2015, but city-industry integration showed a reverse growth trend. The realization of population agglomeration, cities, industries, ecology and other overall coordination are the urgent demand of China's sustainable development (Lin and Jing,2017; Gan et al.,2020). Accordingly, the following research hypothesis is proposed.

H1: Compared with urbanization, the realization of "city integration" can better promote regional green economic growth.

2.4. Regional green economic growth mechanism of city-industry integration has two strands

The first strand mainly suggests city-industry integration can solve the problem of separation of jobs and residences, so it can attract talents and create a good atmosphere of innovation to promote regional economic growth (Panne, 2004; Engel & Del-Palacio, 2011). In the Solo model, technological progress is the source of economic growth, and technological progress comes from a steady stream of innovation activities. At present, the relationship between industry, city and innovation is mainly discussed from two perspectives: (1)from industrial agglomeration and technological innovation, industrial agglomeration can promote the flow of innovation elements,

knowledge dissemination and the establishment of a better institutional environment (Filip & Beveren, 2012; Ning, 2016; Mohanty & Sethi, 2019), and Jacobs (1969) considers that diversification is conducive to heterogeneous knowledge spillovers and industrial innovation; (2) from urban development and technological innovation, some scholars have found that the innovation output of the United States is concentrated in large cities, and the larger the size of cities, the more advantage they have in the field of scientific and technological innovation (Swanson & Pred, 1969; Feldman et al., 2007. Duranton & Puga (2001). Qiu (2013) further discussed that cities can take advantage of the external and scale advantages of human capital to promote economic development.

The second strand mainly discusses city-industry integration can not only promote the support of public infrastructure, but also has important power support for releasing the potential of domestic demand and promoting consumption upgrading. Existing research is based on urbanization, we are now trying to analyze from the perspective of city-industry integration. On the one hand, city-industry integration can allocate resources more efficiently and rationally, deepen the division of labor, increase production efficiency and labor income (Maddison, 1987), and accelerate the process of civilization of migrant workers, which is conducive to expanding the demand for life-oriented services, releasing consumption potential, and promoting the transformation and upgrading of consumption structure (Miren & Giordano, 2007). On the other hand, city-industry integration will facilitate the transportation of residents and a more sound social security system to improve their welfare level, disposable income increase, along with the improvement of the consumption environment and consumption of "demonstration" and "comparison " effect (Duesenberry, 1949; Feldstein, 1974; Li & Li, 2016). According to Maslow's demand level theory and with Clark's law, residents pursue enjoyable, development-oriented high-level consumption, stimulate domestic demand (Muellbauer, 1988; Tang & Ma, 2016), which will further promote regional green economic growth (Fig. 2).

Accordingly, the following research hypotheses are proposed.

H2: City-industry integration can promote technological innovation and have a significant positive impact on regional green economic growth.

H3: City-industry integration can promote regional green economic growth through the upgrading of consumption.

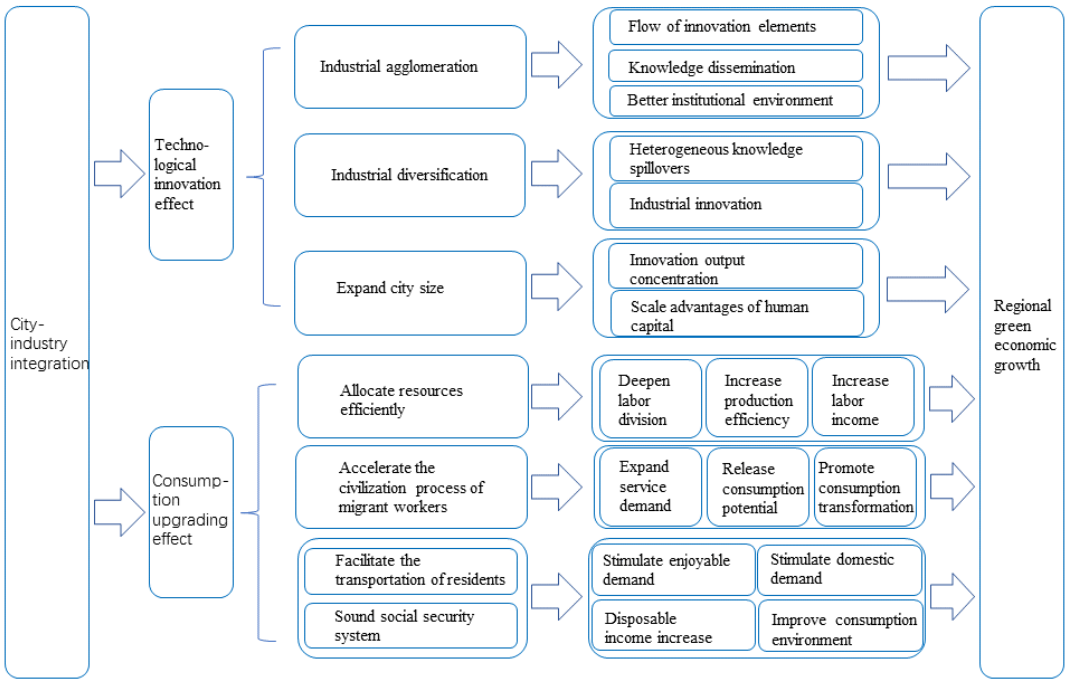


Figure 2. Mechanism analysis diagram.

3. Research design

3.1. model settings

3.1.1. Benchmark model

To test whether CII can improve green economic growth, the benchmark model is constructed as follows:

$$lnggdp_{it} = \alpha_0 + \alpha_1 CII_{it} + \alpha_2 X_{it} + \mu_i + \varepsilon_{it} \quad (1)$$

where $lnggdp_{it}$ represents green economic growth; that is, the logarithm of ggdp in province i at time t; CII_{it} is the CII of province i at time t; X_{it} is a set of control variables; μ_i and ε_{it} are the province fixed effect and the random disturbance term.

3.1.2. intermediary effects model

This research also examines whether industrial structure adjustment and consumption structure upgrading have indirect effects in the mechanisms. According to Baron and Kenny's (1986) research, this paper constructs intermediary effects model. Using the stepwise regression method, the following model is set to verify the possible mechanism:

$$Med_{it} = \beta_0 + \beta_1 CII_{it} + \beta_2 X_{it} + \mu_i + \varepsilon_{it} \quad (2)$$

$$lnggdp_{it} = \gamma_0 + \gamma_1 CII_{it} + \gamma_2 Med_{it} + \gamma_3 X_{it} + \mu_i + \varepsilon_{it} \quad (3)$$

There are two testing steps. Firstly, test whether α_1 is significant. If α_1 is significant, then do the follow-up tests. Secondly, β_1, γ_1, and γ_2 are tested. If β_1, γ_1, and γ_2 are all significant, but β_1 is significantly less than γ_1, a partial mediation effect can be considered.

3.1.3. Moran index - spatial characteristic

At the same time, in order to further examine whether green economic growth is spatially autocorrelated, Referring to Jiang et al.(2020), this study used the following formula to calculate the Moran index of green economic growth to find its spatial correlation:

$$I = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}(y_i - \bar{y})(y_j - \bar{y})}{S^2 \sum_{i=1}^{n} \sum_{i=1}^{n} w_{ij}} \quad (4)$$

where n is the number of spatial individuals; n = 30; S^2 is the overall variance of the sample; y_i denotes the lnggdp of region i; $\bar{y}$ is the mean value of lnggdp; and w_{ij} is the spatial weight element. This study constructed the spatial weight matrix using adjacent indicators. If region i is adjacent to region j, the space weight value $w_{ij} = 1$; otherwise $w_{ij} = 0$.

3.1.4. Spatial Durbin model

Spatial econometric models have been widely used in the economic growth (You et al.,2018;Li & Li,2020). Anselin (2010) pointed that ignoring spatial correlation can lead to estimation bias. Common models include spatial self-regression model (SAR), spatial error model (SEM) and spatial Durbin model (SDM), SAR model and SEM model focus on examining the spatial correlation between dependent variables and random perturbations, The spatial Durbin model contains the spatial lag terms of explanatory variables and explained variables, which can avoid the parameter estimation deviation of missing variables (Lee & Yu,2010). To further examine CII spatial spillover effects on green economic growth development, based on the study of Elhorst (2014), the following spatial Durbin model (SDM) is constructed in Equation (6).

$$lnggdp_{it} = \rho \sum_{j=1}^{30} \omega W_{ij} lnggdp_{jt} + \beta CII_{it} + \theta \sum_{j=1}^{30} W_{ij} CII_{jt} + \gamma X_{it} + \alpha + \mu_i + \varepsilon_{it} \quad (5)$$

Where, $lnggdp_{it}$ represents level of green economic growth in year t of the i-th province; CII_{it} indicates the integration degree of city and industry in year t of the i-th province; X_{it} as a series of control variables，includes labor input, the degree of government intervention and the level of opening up；ρ is spatial auto-correlation coefficient；W is the spatial weight matrix， $\sum_{j=1}^{30} \omega_{ij} CII_{jt}$ and $\sum_{j=1}^{30} \omega_{ij} lnpgdp_{jt}$ are spatial lag items of green economic growth level and the degree of city-industry integration.

3.2. Variables description

3.2.1. Dependent variable: green economic growth

The dependent variable green economic growth (GEG), represented by the logarithm of the per capita green GDP of each province, in order to ensure that the green economic growth variable maintains the same magnitude as other variables. The specific calculation process is the following:

①Construct the accounting system of Green GDP in SEEA-2012 Frame proposed by the United Nations according to the following formula (6)

$$GGDP = TGDP - CRD - CEDL \quad (6)$$

Where, GGDP is green GDP, TGDP is traditional GDP, CRD is cost of resource depletion, and CEDL is cost of environmental degradation loss. Index system of CRD and CEDL are shown in Table 1.

Table 1. Index system of CRD and CEDL.

Comprehensive index	Sub-indexes	
Cost of resource depletion (CRD) CRD=X1+X2+X3	X1:Cost of water resources consumption=Water resources consumption× average water price	
	X2:Cost of energy resource consumption =Energy resource consumption × average energy price	
	X3:Cost of arable land resource depletion = reduced area of cultivated land× agricultural output value per unit of cultivated land =reduction of arable land area × (total agricultural output value / agricultural arable land area)	
Cost of environmental degradation loss (CEDL) CEDL=X4+X5	X4: Total expenditure on environmental pollution control	
	X5:Environmental disaster cost	X5.1 Direct loss of natural disasters
		X5.2 Direct loss of geological hazards
		X5.3 Direct loss of earthquake disaster
		X5.4 Discounts on forest fire losses

②Calculate per capita green GDP of each province according to the following formula (7)

Per capita green

$$GDP = \frac{GGDP}{NP} \quad (7)$$

Where, GGDP is green GDP of each province, and NP is the number of the population of each province.

3.2.2. Independent variable: city-industry integration (CII)

The independent variable is city-industry integration(CII). The surface meaning of city-industry integration refers to the realization of industrial prosperity and urban construction to promote mutual integration, the essential

pursuit of which is to meet the multi-faceted needs of people, uphold the principle of people-oriented, and ultimately achieve the harmonious and sustainable development of industry, city, ecology and people. Because there are no direct statistical indicators for the city-industry integration, for objectivity and rationality, based on the scientific, comprehensive and operable principles, as shown in Table 2, this paper constructs the following evaluation index system from the five perspectives-industrial development, municipal construction, urban service, residents' life and environmental integration, and weight is assigned by entropy value method.

(1) Construction of evaluation index system of CII (shown in Table 2)

Table 2. Evaluation index system of CII.

Target level	Standard level	Index level	Index attribute	weight
City-industry integration(CII)	Industrial development	The proportion of the output value of the secondary industry to GDP (%)	+	0.0195
		The proportion of employed persons in the tertiary industry (%)	+	0.0051
		The actual utilization of foreign capital in the current year (ten thousand dollars)	+	0.2007
		Energy consumption of per GDP(Ten thousand tons of standard coal/billion yuan)	-	0.0745
	Municipal construction	Urban gas coverage rate (%)	+	0.0143
		The proportion of the area of the urban built-up area (%)	+	0.0605
		road area per citizen (m2)	+	0.0381
	Urban service	Number of doctors per 10,000 people	+	0.0321
		Total postal and telecommunications business per capita (yuan)	+	0.1422
		Number of university students per 10,000	+	0.0587
	Residents' life	Disposable income per urban resident (yuan)	+	0.0827
		registered unemployment rate in cities and towns (%)	-	0.0176
		Urbanization rate of the resident population (%)	+	0.0446
		Average wage of staff and workers employed (yuan)	+	0.0767
		Population density	+	0.0507
	Environmental integration	Green coverage of built-up areas (%)	+	0.0181
		Life-friendly waste disposal rate (%)	+	0.0206
		Per capita green area	+	0.0433

(2) Indicator processing method

The specific indicator processing by entropy value method is as follows:

① Standardized treatment. Considering the large differences in the magnitude and dimension of each index, the original data is quantitatively analyzed by the extremum method in this paper, and the specific standardized formula is as follows:

If the evaluation index is positive, then:

$$X_{ij}{}' = \frac{X_{ij} - minX_{ij}}{maxX_{ij} - minX_{ij}} \tag{8}$$

If the evaluation index is negative, then:

$$X_{ij}{}' = \frac{maxX_{ij} - X_{ij}}{maxX_{ij} - minX_{ij}} \tag{9}$$

where, $X_{ij}{}'$ indicates the standardized value of the index j in the region i, $maxX_{ij}$ indicates the maximum value of the indicator j, $minX_{ij}$ represents the minimum value of the indicator j, X_{ij} represents the raw data the indicator j in the region i.

② Weight distribution. The specific process is as follows:

Firstly, for the indicator j, calculate the weight P_{ij} of the region i of the indicator j :

$$P_{ij} = \frac{X_{ij}{}'}{\sum_{i=1}^{n} X_{ij}{}'} \tag{10}$$

Then, calculate the entropy value e_j and the coefficient of difference g_j of the indicator j :

$$e_j = -\frac{1}{ln\, n}\sum_{i=1}^{n} p_{ij}\, ln\, p_{ij} \tag{11}$$

$$g_j = 1 - e_j \tag{12}$$

At last, calculate the weight w_j of the indicator j :

$$w_j = \frac{g_j}{\sum_{j=1}^{m} g_j} \tag{13}$$

3.2.3. Description of core variables

Descriptions of city-industry integration level and per capita green GDP in 2007-2018 of whole country and different regions are shown in Fig. 3.

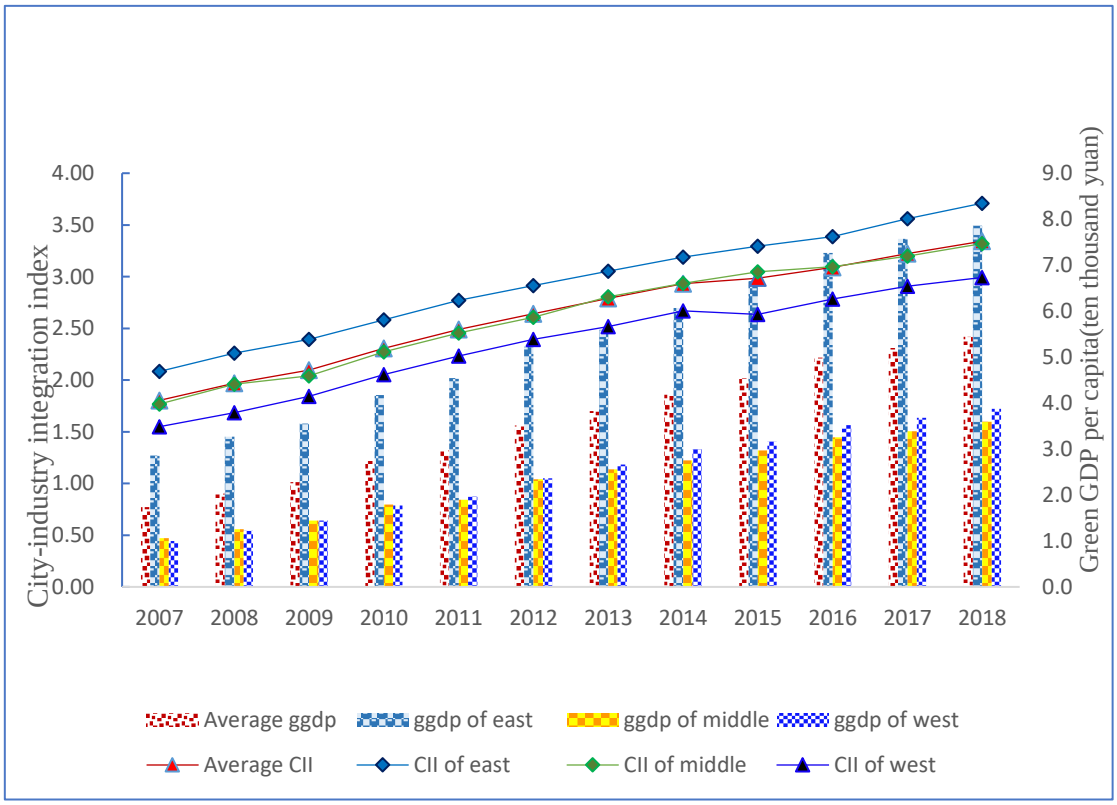


Figure 3. City-industry integration level and per capita green GDP in 2007-2018.

From Fig. 3, the following characteristics can be seen. (1) China's city-industry integration level shows "slow-steady integration". On the whole, it increased from 1.804 in 2007 to 3.343 in 2018, with an average annual growth rate of 7.8%. (2) The regional heterogeneity was obvious and accompanied by "slow gap expansion" -the central region was basically the same as the national average, the eastern region was always highest and the western region lagged significantly behind. (3) China's green economic growth level experienced "sharp increase" with per capita green GDP increased from 17.4 thousand yuan in 2007 to 54.4 thousand yuan in 2018, but regions' green economic growth shows "polarization" characteristic -the eastern region leads the country, more than twice as much as the western region.

3.2.4. Other variables

(1) Labour input (*lab*). It is represented by taking the logarithm of the number of urban employees (10,000) in the provinces at the end of the year. Labor input increase push the agglomeration of labor and talent, especially in the third or emerging industry, thereby higher income and environmental awareness motivate the growth of green economy. Therefore, labor input (lab) is taken as a control variable.

(2) The degree of government intervention (*gov*). It is measured by the proportion of local government public budget expenditure to regional GDP (Lan, et al., 2021). When fiscal expenditure is properly used for administrative management, it may be conducive to the optimal allocation of resources and the improvement of green economic growth. Therefore, government intervention level (gov) is taken as a control variable.

(3) The level of opening up (*open*). It is denoted by the proportion of the total import and export in regional GDP (Usman et al., 2021). Opening-up will help the region absorb advanced technology and knowledge, make use of high-quality resources from other countries, and achieve regional green economic growth. Therefore, opening level (open) is taken as a control variable.

(4) Technological innovation (*inno*). According to mechanism analysis, it is taken as a mediating variable in the process of CII affecting GEG. Referring to related researches, it is represented by the number of invention patents granted at each provincial level (Baden-Fuller & Haefliger, 2013).

(5) Consumption structure upgrading (constr). According to mechanism analysis, it is taken as a mediating variable in the process of CII affecting GEG. It is represented by the proportion of non-food consumption expenditure of urban residents to total expenditure, equal to subtracting the Engel coefficient of urban residents from 1 (Yu et al., 2021).

3.3. Data sources

The data used in this paper are mainly from the China Statistical Yearbook, the China Labor Statistics Yearbook, the China Urban Statistics Yearbook, the websites of provincial and municipal statistical bureaus, EPS databases and Wind databases, and the sample selection period is 2007-2018, taking into account the availability of data, Hong Kong, Macao, Taiwan and Tibet were not included in the sample analysis, and 30 provinces and cities were selected as the study subjects.

4. Analysis of empirical results

4.1. The spatial characteristics of green economic growth

4.1.1. Spatial correlation test of green economic growth

A Moran test is conducted to determine whether green economic growth has spatial correlation and dependence. Table 3 shows the test results of the Moran test.

Table 3. Moran's I and Statistical Test of green economic growth from 2007 to 2018.

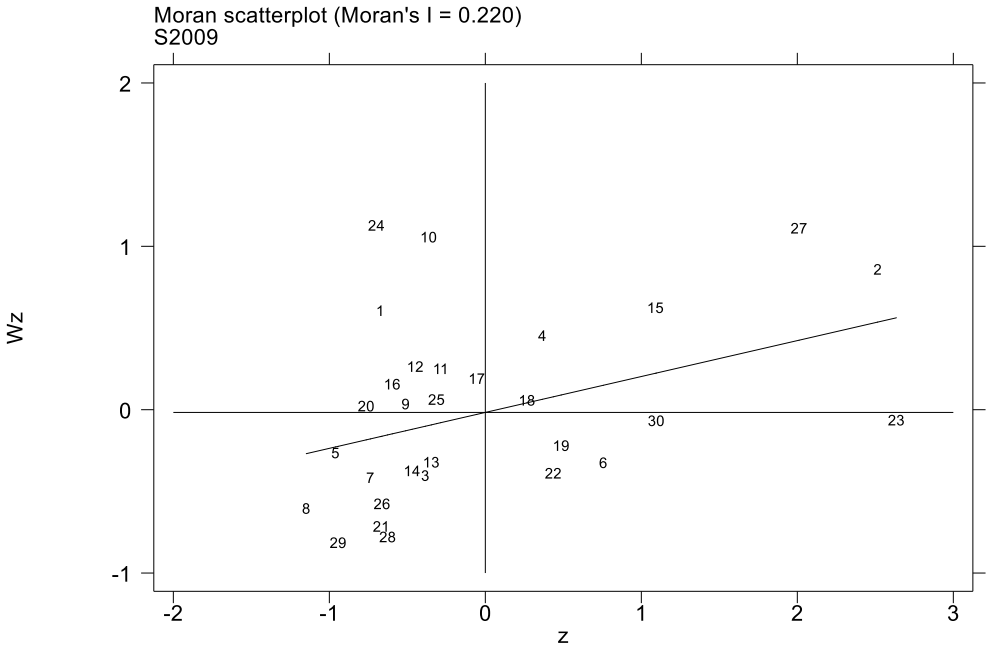
Year	Moran's I	Z	p
2007	0.209**	2.111	0.017
2008	0.232**	2.275	0.011
2009	0.227**	2.217	0.013
2010	0.235**	2.258	0.012
2011	0.257***	2.450	0.007
2012	0.245**	2.328	0.010
2013	0.217**	2.086	0.018
2014	0.193**	1.891	0.029
2015	0.198**	1.947	0.027
2016	0.199**	2.188	0.026
2017	0.208**	2.016	0.022
2018	0.209**	2.015	0.022

*Note: Two-tailed test statistical results; ** and *** indicate the significance level at 5% and 1% respectively.*

As can be seen from Table 3, the Moran's I index of regional green economic growth in 2007-2018 is positive, and has passed the 5% level of significance test. Spatial self-correlation test proves that China's regional green economic growth shows strong spatial dependence, which is similar to the conclusion of the study on the ecological efficiency. The main reasons may be that some provinces have similar economic conditions, factor endowments, coupled with geographical proximity and developed transportation system. Therefore, factor flow and commodity circulation are more convenient, and the government in the process promoting the construction of new urbanization with a “demonstration” and “imitation” effect, this similarity in space shows relevance.

4.1.2. Spatial heterogeneity of green economic growth

Through above analysis, we can see that green economic growth has spatial correlation and dependence. Therefore, it is necessary to thoroughly explore its spatial heterogeneity, this paper uses data from 2009, 2015 and 2018 to map local Moran's I scatter points. As can be seen from Fig. 4, the vast majority of provinces are in the one-three quadrant, showing the “high-high” or “low-low” spatial agglomeration characteristics, most areas of green economic growth have a positive dependence, showing regional non-homogeneity. Therefore, in the study of green economic growth, in order to reduce the bias of the estimated results, it is necessary to consider spatial dependence.


Moran scatterplot (Moran's I = 0.220)
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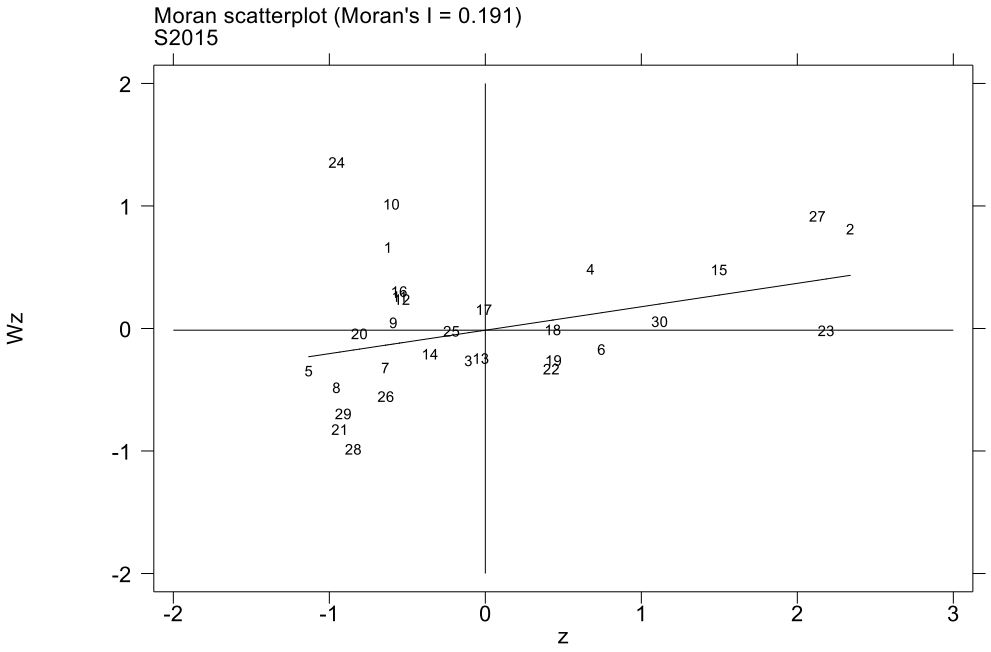
Moran scatterplot (Moran's I = 0.191)
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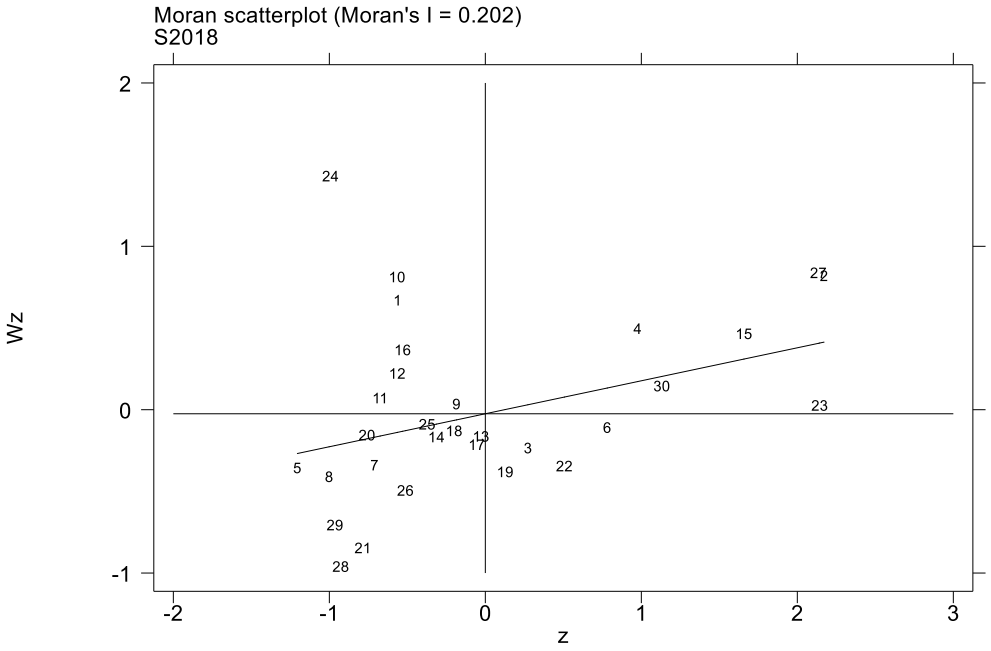

Figure 4. Local Moran Index Scatter Chart in 2009, 2015 and 2018.

4.2. The spatial effect of CII on green economic growth

4.2.1. Comparative analysis of empirical results of OLS and SDM

In order to thoroughly investigate the spatial effect of CII on green economic growth, it is necessary to make comparative analysis between CII and urbanization(UR) under the SDM model and OLS regression model, which consider and do not consider the spatial spillover effect. The regression results of CII and UR under the SDM model and OLS model are shown in Table 4.

Table 4. Regression results of SDM model and OLS model.

	Model(1)	Model(2)	Model(3)	Model(4)
	OLS	*SDM*	*OLS*	*SDM*
CII	0.689***	0.325***		
	(0.022)	(0.033)		
UR			0.071***	0.042***
			(0.002)	(0.003)
lnlab	0.545***	0.469***	0.868***	0.632***
	(0.157)	(0.047)	(0.134)	(0.099)
gov	1.152***	0.476**	0.888***	0.329*
	(0.263)	(0.228)	(0.234)	(0.200)
open	0.460***	0.317 ***	-0.310***	-0.041
	(0.107)	(0.082)	(0.093)	(0.075)
$W * CII$		0.058		
		(0.053)		
$W * UR$				-0.007
				(0.005)
$W * lnlab$		-0.201		0.565***
		(0.053)		(0.190)
$W * gov$		-0.021		-0.135
		(0.361)		(0.318)
$W * open$		0.253*		0.268**
		(0.140)		(0.122)

$W * lnggdp$		0.512***		0.491 ***
		(0.052)		(0.051)
$Obs.$	360	360	360	360
$R-squared$	0.888	0.9147	0.9122	0.9353
$Log-likelihood$		295.360		342.457
$Province\ FE$	YES	YES	YES	YES

*Note: SEM in parentheses; *, ** and *** indicate the significance level at 10%,5% and 1% respectively.*

Observing the regression results, whether considering the spatial effect or not, CII(OLS, 0.689; SDM, 0.325)and UR(OLS, 0.071; SDM, 0.042) coefficients are positive, and pass the significance test at the 1% level, which means both CII and UR promote regional green economic growth. Compare CII with UR, when considering the spatial effect in Model(2) and Model(4), CII(0.325)>UR(0.042); when not considering the spatial effect in Model(1) and Model(3) , CII (0.689)>UR(0.071), which means that city-industry integration is more conducive than population urbanization to the improvement of regional green economic development.

Besides, for the control variables, in Model(1), Model(2) and Model(3), the direct contribution of government intervention (gov) to the regional green economic growth is the largest, followed by labor input. The main reason is that local government public budget expenditure can provide fundamental support for green economic growth.

Finally, for spatial interactions, the estimation coefficient does not directly reflect the effect of independent variables on the dependent variables, but it shows effect characteristic. In Model(4), the regression coefficient of spatial weighting of population urbanization(W * UR) is -0.007, but it did not pass the 1% significance test. The main reason is that labor force concentration in the early stage of population urbanization has positive scale effect, but the mass accumulation of population will be accompanied by traffic congestion, resource consumption, environmental pollution and other negative congestion effects inhibiting the regional green economic development (Zha et al., 2010). In Model(2), although the spatial spillover effect of the city-industry integration (W * CII) is positive, it does not pass the significance test, mainly because that the city-industry integration within the province is still in the continuous development, and has not yet formed a strong radiation effect on the surrounding province.

4.2.2. Marginal spatial effect analysis of CII

Lesage and Pace (2014) point out that, based solely on the point estimation results of the spatial Durbin model itself, the analyzing of spatial spillover effects may lead to biased conclusions. Therefore, it is necessary to analyze spatial spillover effect of CII and UR on green economic growth from three perspectives-the direct, indirect and total effects-based on the fixed effect SDM model. The regression results are shown in Table 5.

Table 5. Decomposition results of spatial effects.

	Model(1)	Model(2)	Model(3)	Model(4)	Model(5)	Model(6)
	Urbanization			City-Industry Integration		
	direct effect	indirect effect	total effect	direct effect	Indirect effect	total effect
UR	0.044***	0.024***	0.068***			
	(0.003)	(0.004)	(0.004)			
CII				0.361***	0.408***	0.770***
				(0.031)	(0.052)	(0.053)
$lnlab$	0.756***	1.550***	2.306***	0.472***	0.089	0.561
	(0.103)	(0.322)	(0.378)	(0.128)	(0.471)	(0.552)
gov	0.352***	0.029	0.381	0.533**	0.386	0.919
	(0.188)	(0.511)	(0.553)	(0.215)	(0.599)	(0.645)
$open$	-0.006	0.432**	0.426*	0.381***	0.757***	1.138***
	(0.076)	(0.204)	(0.228)	(0.081)	(0.253)	(0.280)

*Note: SEM in parentheses; *, ** and *** indicate the significance level at 10%,5% and 1% respectively.*

(1)The direct effect in Model(1) and Model(4) represents marginal effect of independent variables on dependent variables in local regions, considering spatial correlation. Under the adjacent weight matrix, the

estimated coefficients of core independent variables UR and CII were 0.044 and 0.361respectively, passing the 1% significance test, consistent with the regression coefficient direction of point estimation results in the spatial Durbin model. When the urbanization rate of the population increased by 1%, the level of green economic growth in the region increased by 0.044% on average; 1% increase in the degree of city-industry integration will lead to the average growth of the local green economy increasing by 0.361%. Combined with Table 4, the OLS regression coefficient of spatial overflow is 0.071 and 0.689 respectively, indicating that the impact of CEI and UR on green economic growth is overestimated without considering spatial correlation.

(2)The indirect effect in Model(2) and Model(5) represents marginal spatial spillover effect of independent variables on dependent variables in neighbor regions. The coefficient of UR and CII is significantly positive. Compared with population urbanization(0.024), the spatial spillover effect of city-industry integration is stronger: every 1% increase in city-industry integration will cause the average growth of green economy in neighboring provinces increasing by 0.408 percent.

There are two main reasons. On the one hand, CII provides an attractively livable environment for high-quality personnel and attracts advantaged resources. Regional introduction of high-tech application, innovation ability's improving, intensive and efficient use of resources, will change extensive economic development mode and promote local green economic development, meanwhile, because of the spillover of technology and knowledge, the green economic development level in surrounding area will be raised as well. On the other hand, CII optimizes the layout of industrial space, improves the construction of urban infrastructure and public services, strengthens factor mobility. Transportation and transaction costs are reduced. Industrial structure is constantly upgraded to the tertiary industry with strong labor adsorption capacity. The integration of production, life and ecological coordinated development will continue to create new environmental protection industries, and form a demonstration role for the surrounding provinces.

(3) The direct and indirect effects of control variables.

From the perspective of population urbanization, labor input and government fiscal expenditure have significant positive influence on local green economic growth according to Model(1); labor input and opening up have positive spatial spillover effects on green economic growth in surrounding areas according to Model(2). The main reason is that knowledge spillover and forward-to-back correlation effect caused by opening up and labor flow can significantly improve the green economic growth in the surrounding area.

From the perspective of city-industry integration, increasing labor input(0.472***) and government fiscal expenditure(0.533**) only can significantly promote local green economic growth according to Model(4), but not to the near neighbors to form a radiation effect(lnlab,0.089; gov, 0.386) according to Model(5). The main reason is that the higher CII in the region means higher efficiency in the use of financial expenditure funds, residents' stronger awareness of environmental protection, higher sense of government responsibility. Therefore, the region has a "siphon effect " to attract the surrounding high-quality labor force and high-quality manufacturers to enter, further leads to unfavorable impact on green economic development of the surrounding area.

Notably, opening up not only exerts a good promoting effect on local green economic development, but also has a significant positive spatial spillover effect. specifically, for each 1% increase in the level of opening up, its direct and indirect effects on green economic growth increased by 0.381 and 0.757. This is mainly because opening up brings more technology exchange, more efficient allocation of innovative elements, and ultimately it will make win-win cooperation of the local region and neighboring areas.

(4)To sum up, compared with urbanization, city-industry integration has a strong "push and pull" effect on the green economic development of the region and its surrounding areas, if the integration of provinces and cities has reached a higher level, the regional green economic development will show the effect of "1+1>2 ", thereby verifying Hypothesis 1.

5. Robustness test

In order to test the reliability of the above conclusions, the robustness test is based on the spatial weight matrix, where the inverse of distance between provinces is used as the spatial weight matrix.

$$w_{ij} = \begin{cases} \frac{1}{d_{ij}} & i \neq j \\ 0 & i = j \end{cases} \tag{14}$$

Where, d_{ij} is the spherical distance from the capital city of the province i to the capital city of province j. The geographic distance matrix is a supplement to the adjacent matrix, which can consider the economic conduction effect between provinces that are close but not adjacent.

Based on the geographical distance weight matrix, this paper estimates the SDM model to test the robustness of the conclusion, and the results are shown in Table 6, Model 1 and Model 2. Empirical analysis shows that the direct effect, indirect effect and total effect of UR and CII on green economic growth are significantly positive, and CII has stronger positive influence on the green economic development of local and surrounding provinces. It shows that the empirical results of this paper are robust.

Table 6. Robustness test results.

	Model1	Model2
UR	0.021***	
	(0.003)	
CII		0.136***
		(0.026)
$W * lngdp$	0.777***	0.823***
	(0.057)	(0.047)
control	YES	YES
Province FE	YES	YES
Direct effect	0.024***	0.181***
	(0.003)	(0.029)
Indirect effect	0.085***	1.404***
	(0.024)	(0.394)
Total effect	0.108***	1.585***
	(0.024)	(0.407)
Obs.	360	360

*Note: SEM in parentheses; *, ** and *** indicate the significance level at 10%,5% and 1% respectively.*

6. Further analysis

6.1. Moran's I and Statistical Test of green economic growth from 2007 to 2018

The above theoretical analysis shows that city-industry integration may promote regional green economic growth through technological innovation and consumption structure upgrading. In order to further verify these two mechanisms, according to Baron and Kenny's (1986) research, this paper constructs intermediary effects model. The specific mediation mechanism test results are shown in Table 7.

Table 7. Mediation mechanism test.

	lnpgdp	Model 1		Model 2	
		lninno	*lnpgdp*	*constr*	*lnpgdp*
CII	0.689***	1.366***	0.304***	0.056***	0.560***
	(0.022)	(0.050)	(0.030)	(0.004)	(0.025)
lninno			0.281***		
			(0.018)		
constr					2.284***
					(0.270)

Control	YES	YES	YES	YES	YES
Province	YES	YES	YES	YES	YES
Obs.	360	360	360	360	360
Sobel Test	Z= 13.39, P-value=0.000			Z= 7.239, P-value=4.505e-13	
Proportion of total effect that is mediated:	0.385			0.129	
Bootstrap--95%CI	[-0.324, -0.445-]			[-0.096-, -0.161-]	

*Note: SEM in parentheses; *, ** and *** indicate the significance level at 10%,5% and 1% respectively.*

(1) When Sobel test is carried out with technological innovation as an intermediate variable, the intermediary effect 0.264(=1.366x0.281) accounts for 38.5% of the total effect. Given that the Sobel test may have the first type of error, the retest using the Bootstrap method for the mediation test shows that Bootstrap's 95% confidence interval does not contain 0, indicating that technological innovation has a significant intermediary effect in the process of CII affecting green economic growth.

CII promotes green economic growth by optimizing the layout of urban space, considering people's multi-faceted needs and concerns, scientific and rational planning of industrial layout, industrial efficiency linkage, urban production and living facilities service support, convenient communication, harmonious and beautiful livable environment. Ultimately, a good urban industrial ecological system is built, which effectively solves the past problems-the high commuting costs, unbalanced living infrastructure services- caused by "industry-oriented " guidance and "job-life separation". On the one hand, the livable environment can attract talents to gather, build a talent ecosystem, improve the efficiency of regional technological innovation and the implementation of scientific and technological achievements transformation. The government urges energy-intensive industries to apply energy-saving and emission-reduction technologies to fulfill the social and environmental responsibilities of enterprises. On the other hand, technological innovation makes the resources and energy in the region use efficiently and comprehensively, and the industry develops in a coordinated and aggregate manner, which ultimately promotes the transformation of industrial structure into high-level, high-value-added strategic emerging industries, continuously improves the quality of the environment, and achieves sustainable growth of the regional green economy，thereby verifying Hypothesis 2.

(2) When Sobel test is carried out with consumption upgrade as an intermediate variable, the intermediary effect 0.128 (=0.056x2.284) accounts for 12.9% of the total effect. The intermediary variable passed the Sobel and Bootstrap test. "People" have the dual characteristics-production and consumption, who are not only one of the important input elements of industrial development, but also the ultimate service object of urban construction.

The essence of the CII is people-oriented. Therefore, its goal includes creating a good employment and entrepreneurial environment, the steady development of regional pillar industries. When the industry continues to upgrade to the tertiary industry, which is conducive to increasing the employment population and improving the income level of workers. With the continuous improvement of people's living, their desire for ecological environment is improving too. Green consumption concept deepened, and they pay more attention to the enjoyment, development and other needs. Therefore, the upgrading of the consumption structure and diversified demand guide new supply, the industrial structure is constantly optimized to provide more energy-saving and environmental protection products. Supply creates new demand, and enhances consumption's effect on green economic growth, thereby verifying Hypothesis 3.

6.2. Regional heterogeneity analysis

Due to the obvious differences in natural endowment and economic structure between different provinces in China, in order to further consider the spatial distribution of the spillover effects of CII on green economic growth, according to the regional division guidelines of the National Development and Reform Commission of China, the selected 30 provinces are divided into the eastern, central and western regions, respectively. The regional spatial

heterogeneity results are shown in Table 8.

Table 8 shows that for the eastern, central and western regions, the estimated coefficients of CII passed the 1% significance test under the two spatial associations. Model 1, Model 3 and Model 5 are based on the estimate of the adjacent matrix; Model 2, Model 4, and Model 6 are based on the inverse of the geographic distance matrix.

Table 8. Regional heterogeneity test results.

	East		Middle		West	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model6
CII	0.636***	0.237***	0.223***	0.189***	0.137***	0.184***
	(0.061)	(0.064)	(0.043)	(0.043)	(0.042)	(0.041)
$lnlab$	0.532***	0.209	0.132	-0.918***	-0.324	-0. 340**
	(0.158)	(0. 147)	(0.233)	(0.232)	(0.214)	(0.171)
gov	1.089**	0.678	0.412	0.568**	-0.610**	-1.126***
	(0.508)	(0.444)	(0.280)	(0.258)	(0.252)	(0.241)
$open$	0.231***	0.072*	0.221	0.955***	-0.375**	-0.290
	(0.106)	(0.037)	(0.341)	(0.299)	(0.255)	(0.228)
$W * CII$	-0.215**	0.174*	0.116**	0.262***	0.310***	0.687***
	(0.087)	(0.098)	(0.048)	(0.088)	(0.086)	(0.137)
$W * lnlab$	-0.399***	0.553	-1.125***	2.286***	0.124	-0.730
	(0.088)	(0.353)	(0.357)	(0.580)	(0.525)	(0.831)
$W * gov$	0.998	1.268	1.572***	0.905	0.568	0.952**
	(0.945)	(1.121)	(0.473)	(0.602)	(0.346)	(0.437)
$W * open$	-0.366***	-0.421***	-0.223	-2.346***	0.568	-1.091*
	(0.162)	(0.067)	(0.374)	(0.542)	(0.346)	(0.649)
Direct effect of CII	0.634***	0.240***	0.335***	0.205***	0.226***	0.206***
	(0.062)	(0.066)	(0.041)	(0.041)	(0.043)	(0.036)
Indirect effect of CII	0.162***	0.183***	0.456***	0.377***	0.794***	0.857***
	(0.058)	(0.071)	(0.055)	(0.064)	(0.122)	(0.123)
Total effect of CII	0.472***	0.422***	0.792***	0.582***	1.021***	1.063***
	(0.061)	(0.056)	(0.073)	(0.059)	(0.140)	0.126
Obs.	132	132	96	96	132	132
R-squared	0.9350	0.9539	0.9480	0.9789	0.949	0.965
Log-likelihood	131.565	154.342	125.926	135.304	127.967	138.240

*Note: SEM in parentheses; *, ** and *** indicate the significance level at 10%,5% and 1% respectively.*

First of all, in the eastern regions, the positive effect of CII on the green economic growth effect is the strongest. The main reason behind this is that the eastern region is the forerunner of reform and opening up and the market economy establishment. With the rapid development over forty years, there has been a transition to the "Lewis inflection point " trend. Into the late stage of industrialization, this region accumulates a large amount of capital and advanced technology at a high level of urbanization, so it stresses the spatial coordination and functional matching between the city and industry, and constantly achieve a high degree of CII. Besides, many universities and high-tech enterprises gathered here, some cities in the eastern part become the innovation radiation center, to promote the development of environmental protection and energy-saving technology, which form strong green economic growth momentum.

Secondly, in the middle regions, the effect of CII on the green economic growth effect is positive. The main reason is that the central regions in recent years are still in the stage of rapid urbanization and development, a large number of people gathered in urban areas, resulting in a large increase in regional investment and consumption demand. In addition, it may be affected by the "demonstration effect" of the eastern regions, and take the advantages of spatial geographical location to absorb technology spillover from the eastern regions.

Finally, in the western regions, CII has not played a sufficient role in promoting green economic growth. The location advantage of the western region is insufficient, the new urbanization starts late, and the industrial base is relatively weak. The lack of pillar industries and high-quality personnel make western regions undertake the transfer of high-energy-consuming polluting enterprises from the central and eastern regions. Until now, a good development mechanism of CII- to promote city prosperity by industry development and to upgrade industrial

structure by city development-has not formed. In Table 8, notably, under the two weighting matrices, the western region government expenditure on the regional green economic growth has a negative effect, which is brought by private investment "crowding out " and market efficiency "weakening effect".

Interestingly, the spatial spillover effect of CII presents the strongest in the west, the second in the middle and the weakest phenomenon in the west, which is closely related to the degree of CII. The spatial spillover effect of CII has "marginal contribution weakening" characteristic. Specifically, The high degree of CII in the eastern regions leads to the small marginal contribution to the green economic growth in the surrounding areas; on the contrary, such as the western regions, though the degree of CII is low, when a region has better economic and environmental benefits, it is easy for the surrounding regions to imitate and follow, so there is a greater marginal contribution on the green economic growth of surrounding areas.

7. Conclusions and policy implications

Based on the panel data of 30 provinces in China from 2007 to 2018, this paper constructs an evaluation index system and uses the SEEA method to measure China's city-industry integration and green economy growth level, this paper systematically investigates the mechanism and spatial impact of the city-industry integration on green economic growth in a unified framework. The study found that: (1) On the whole, CII shows "slow-steady integration" trend, but regional heterogeneity was obvious and accompanied by "slow gap expansion". GEG experienced "sharp increase" with "polarization" characteristic. (2) CII can directly promote regional GEG (with a marginal effect of 0.689), more effectively than traditional urbanization, and CII has obvious spatial spillover effects on GEG in both "local effect" and "neighboring effect". (3) Interestingly, technological innovation and consumption structure upgrading are significant mediating mechanisms and the comparation of intermediary effects' sizes is: technological innovation > consumption structure upgrading. (4) The direct positive effect of CII shows the regional imbalance characteristic: eastern>middle>western, but the spatial spillover effect is opposite with a "marginal contribution decrease" characteristic. On the basis of the above conclusions, this paper puts forward the following policy-making suggestions.

(1) Unswervingly promote development of CII, rationally plan the distribution of ecological space for production and living, avoid hollowing out and idle resources caused by traditional urbanization, and promote regional green economic growth. Firstly, strengthen the industrial base of existing urban space; attach importance to the supporting services. Secondly, it should set up high-quality demonstration zones for integrated development of industry and city. Based on regional location, resource endowment and comparative advantages, it should formulate industry introduction and upgrading strategies in line with the actual situation of the city, provide policy and institutional guarantees, and realize the coordinated development of ecological protection and economic growth.

(2) Regional heterogeneity should be fully taken into account, and the positive spatial spillover effect of CII on regional green economic growth and surrounding areas should be brought into play. First, it is necessary to increase capital introduction in the central and western regions, give full play to the government's role in connecting the middle and providing policies, and increase the intensity of investment in industrial construction in the central and western regions by economically developed eastern provinces and regions. Second, break the "beggar-thy-neighbor" administrative mode, vigorously promote the flow and sharing of factor information among cities, fully release the radiation driving effect of the integration of industry and city green economic growth, and form a situation of coordinated growth of green economy among regions.

(3) Enhance the level of scientific and technological innovation and consumption upgrading to enhance the important driving force of the green economic growth effect of the CII. First, we will increase spending on science, education, R&D, foster emerging industries, empower traditional manufacturing and service industries with

digitalization, promote the rapid growth of science and technology and energy saving enterprises, and cultivate and attract innovative talents in green technology. Second, it is necessary to foster sustainable development of local high-quality characteristic industries, promote the agglomeration of population and the gradual improvement of urban functions, improve people's disposable income, and then promote the awareness of green environmental protection and consumption upgrading, to achieve green economic growth.

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Conflict of interest

All the authors claim that the manuscript is completely original. The authors also declare no conflict of interest.

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