SUPPLY CHAIN AND SUSTAINABILITY RESEARCH: SCSR
VOL.1, NO.4; JUL. – SEP.; 2023, ISSN 2822-0412 (Online)

Analysis of the Influencing Factors of Green Collaborative Development between Enterprises and Industrial Parks in Industrial Undertaking Regions: A Case Study of Guangdong Province from 2006 to 2019

Li Fang *

Received: September 20,2023 / Revised: September 26, 2023 / Accepted: September 28, 2023
Doi: xxxxxxxxxxxx

Abstract

Against the backdrop of global industrial transfer, industrial parks undertake environmentally polluting industries and promote rapid development of regional economies. With the mature development of industrial parks and the restriction of resources and energy, green transformation of industrial parks has become particularly important. This study uses panel data from Guangdong Province from 2006 to 2019 as a sample. It adopts a grey correlation analysis method to analyze the factors influencing green collaborative development between enterprises and industrial parks. The results show that (1) the coordinated development of industry and the ecological environment in industrial parks must rely on active participation from relevant governance entities, including enterprises and the park itself. (2) The factors that influence enterprises and parks to jointly promote green development include capital investment, technological progress, and industrial structure adjustment. However, capital investment has the most significant impact on green development. Based on these findings, we propose that the government should increase green capital investment on the one hand. On the other hand, positive and effective measures should be taken to promote enterprises' green technology innovation and industrial structure adjustment and upgrading to achieve a win-win situation for both environmental protection and economic development.

Keywords: Green Collaborative Development, Influencing Factors, Grey Correlation Analysis, Industrial Parks

Corresponding : Lecturer, School of Economics & Management, Nanchang University, Nanchang, China,
E-mail: stif321@hotmail.com

Introduction

Research background

Currently, the world has witnessed five international industrial transfers with clear demarcation lines. With the development of industrial transfers, the economies of numerous countries have experienced rapid growth, accompanied by the optimization and upgrading of their industrial structures. With its economic progress and rapid development of the global economy, China has become one of the largest transfer places. Since the 1990s, certain more developed regions in eastern China have made significant economic progress over the past two decades, serving as destinations and hosts for industrial relocation, thereby exerting considerable influence on a global scale. Economic prosperity in China's eastern regions owes much to international industrial relocation, while the central and western regions, although not matching the scale of the east, have achieved certain levels of growth through such relocation (Hong-guan,2014). Industrial parks, represented by development zones and high-tech zones, have become the main spatial carriers of the industrial undertaking, and play a significant role in promoting regional economic development. Industrial parks characterized by industrial clusters have become significant vehicles for China's participation in the global manufacturing value chain division of labor, as well as a powerful driving force for promoting the synergistic development of the regional economy.

However, an agglomeration economy with industrial parks as the spatial carrier will also generate a "crowding effect," which is a major source of carbon emissions as well as wastewater, waste gas, and waste residue emissions, resulting in environmental pollution and unsustainable development problems. Economically developed areas of industrial parks are often areas where the ecological environment is seriously damaged. Simultaneously, as the development of industrial zones matures and the availability of exploitable incremental spatial resources gradually tightens, the development trend of industrial parks has shifted away from the earlier concept of a single industrial enterprise cluster, but towards ecological industrial parks and science parks with a closer relationship between enterprises, such as Kalundborg Eco-Industrial Park in Denmark. Consequently, the green development transformation of industrial parks after the industrial undertaking is of great significance to the green and sustainable development of the whole industry, as well as for China's pursuit of ecological civilization.

The establishment of industrial parks in industrial undertaking areas differs from the conventional approach of constructing pre-existing industrial parks. Owing to the intricate interplay of interests among various corporate entities, the earlier "pollute first, mitigate later" pollution control model, primarily driven by governmental intervention, no longer meets the needs of green transformation in industrial parks. Ideally, a park's green development should achieve a symbiotic relationship between the economic advancement of diverse industries within it and the park's own ecological progress. However, in practice, disparities emerge between the collective interests of the park and the individual interests of enterprises as well as between short-term gains and long-term benefits, resulting in strategic maneuvering and choices. Industrial parks often seek to enhance overall competitiveness by driving industrial upgrades and phasing out "backward capacity."

However, they remain path-dependent on existing pillar industries that are incongruent with future developmental demands. However, enterprises, particularly those operating profitably, tend to assume the risks associated with green transformation and upgrading. In the case of poor financial performance, effective transformation and upgrading are even more challenging. These constraints contribute to a lack of clarity in the roles and responsibilities of enterprises and industrial parks in the context of green development coupled with inadequate governance mechanisms. Consequently, a dichotomy emerges between industrial development and environmental protection within the park, leading to situations where, if higher departments of environmental protection inspection are encountered, the park lets enterprises with environmental problems suspend production, and once the “storm” passes, the enterprise returns to the “same old” circle. The phenomenon of enterprises and parks perfunctorily inspecting each other is serious. Taking Guangdong Province as an example, although advancements have been made in green development in recent years, some obstacles and problems still exist, particularly reflected in the uncoordinated development between parks and enterprises. In some places, during the remediation process, industrial parks often have a single remediation goal, without considering local economic development and other factors, which can easily lead to a "cliff-like" decline in the local economy and unstable employment. Some industrial parks often simply demand that enterprises with pollution problems shut down directly, rather than adopting market-oriented means, such as increasing pollution control, which damages the interests of enterprises. Some industrial parks continuously raise emission standards in the short term, leaving enterprises at a loss(Kostka & Mol, 2017). Therefore, it is of great significance to study the influencing factors of the green collaborative development of enterprises and parks in industrial undertaking areas and evaluate their effects to propose corresponding countermeasures and suggestions that will promote the green and sustainable development of industrial undertaking parks.

Using Guangdong Province as the research subject, this study aims to analyze the factors influencing green collaborative development in Guangdong Province and assess the degree of correlation between these factors and green collaborative development. Beyond these, this study also aims to offer specific policy recommendations to foster green development in Guangdong Province.

Literature review

The factors influencing green collaborative development between enterprises and industrial parks in industrial undertaking areas have been extensively studied in terms of industrial agglomeration and environmental governance. Scholars have proposed three main perspectives on this matter.

The first, industrial agglomeration promotes environmental governance. Firstly, industrial agglomeration promotes spillover of environmental protection and energy-saving knowledge among enterprises, leading to improved eco-friendly technologies and innovation. This reduces individual firms' pollution control costs, optimizing the regional ecological development environment (Hosoe & Naito, 2006; Wu et al., 2022). Secondly, industrial agglomeration generates economies of scale in environmental resource consumption, resulting in reduced resource use and lower pollution emissions per unit of industrial output (Brownstone &

Golob, 2009; Holden & Norland, 2005; Shen & Peng, 2021). Thirdly, industrial agglomeration can realize scale effects in environmental governance, leading to lower governance costs (Andreoni & Levinson, 2001). Fourthly, industrial agglomeration promotes internal resource recycling within agglomerated regions, thus decreasing pollution emissions (Bressanelli et al, 2022). Fifthly, industrial agglomeration enhances production efficiency, subsequently raising local residents' income and fiscal revenue. The improved material living standards of residents inevitably lead to heightened demands for a pristine ecological environment, compelling governments to intensify environmental governance efforts, implement stricter environmental regulatory systems, and encourage enterprises to engage in green technological innovation and adopt clean production measures, ultimately leading to improved ecological conditions (Cheng, 2016; Feng et al., 2022)

Secondly, industrial agglomeration exacerbates environmental pollution. Scholars advocating this view argue that excessive agglomeration can lead to overcrowding, resulting in intensified environmental pollution. The localized expansion of production capacity and increased energy consumption owing to industrial agglomeration can lead to higher overall pollutant emissions, thereby increasing the difficulty of regional environmental governance. Although industrial agglomeration can promote technological improvements in enterprises, if these improvements focus on enhancing output efficiency, they may lead to increased unit output within the region and, paradoxically, worsen environmental pollution. Various studies have supported the reality of environmental pollution caused by industrial agglomeration. For instance, Virkanen (1998) empirically analyzed industrial agglomeration in southern Finland and concluded that manufacturing agglomeration exacerbates air and water pollution. De Leeuw et al. (2001) and Verhoef and Nijkamp (2002) employed empirical analyses using data from 200 European cities and European urban data, respectively, both arriving at a significant positive correlation between industrial agglomeration and environmental pollution. Cheng (2016) conducted empirical analysis using data from 285 Chinese cities at the prefecture level and above, concluding that economic agglomeration exacerbates environmental pollution; conversely, environmental pollution also inhibits further economic agglomeration.

Thirdly, there is a complex relationship between industrial agglomeration and environmental pollution. Tan et al. (2022) proposed an "N-shaped" relationship curve between manufacturing agglomeration, air pollution, and energy conservation and emission reduction. Zhu and Xia (2018) argued that there is an inverted U-shaped relationship between industrial agglomeration and environmental pollution, with marketization being a crucial determining factor for this relationship. Ren-f (2015) suggested a threshold feature in the relationship between industrial agglomeration and environmental pollution. Pang et al. (2021) posited that industrial agglomeration may act as a "resistance" to environmental governance in the short term, primarily due to the "concentrated emission" of polluting enterprises within a spatial area. The mechanism underlying this complex relationship can be summarized as follows. Influenced by external factors, such as the environment, geographical conditions, technological levels, and environmental regulations, the impact of industrial agglomeration on environmental pollution is characterized by instability (Zeng & Zhao, 2009). The combined effects of the positive and negative externalities from industrial agglomeration contribute to environmental pollution. When negative externalities dominate the agglomeration's environmental impact, they intensify pollution; conversely, the opposite is true (Chen et al., 2020).

Research on multi-participatory environmental governance systems is as follows: Earlier, environmental governance adopted an administrative-oriented management system that combined unified supervision and management with hierarchical and sectoral management. This management system was mainly based on the assumption that environmental problem makers would transfer the costs of environmental management to society (Mu & Liu, 2008). With the development of the social economy, deteriorating ecological and environmental problems are increasingly related to people's immediate interests, which even cause social conflicts to intensify (Dominelli, 2012). Since the administrative-oriented environmental governance system cannot effectively coordinate the environmental interests of enterprises and society, its shortcomings have gradually emerged. The latest research on environmental governance has begun to turn to a pluralistic co-governance system, in which the public, government, enterprises, and NGOs cooperate to achieve environmental governance. This value lies in the ability to achieve a consensual scale of public goods that cannot be provided by a single entity (Agranoff & McGuire, 2001). Ha et al. (2016) examined the factors affecting private sector participation in environmental co-governance in different regions. Provan and Kenis (2008) proposed the structural characteristics of a network of co-governance systems in the public sphere and their influencing factors. Feiock and Scholz (2010) systematically explored how factors characteristic of metropolitan areas (e.g., geographic space, population size, industrial structure and institutional base) influence collective institutional action in regional environmental governance.

There have been extensive and in-depth studies on the relationship between industrial agglomeration and environmental quality, and on the multiple environmental governance system, but there are few studies on the relationship between industrial agglomeration and environmental pollution in provinces, cities, and industrial parks, and fewer studies on the role played by governance bodies in the coordinated development of industrial agglomeration and the ecological environment. This study intends to address the shortcomings in the research to propose the key factors affecting the green coordinated development between enterprises and parks and put forward corresponding policy suggestions for promoting the green transformation development of industrial parks. The paper contributes to the existing literature as follows. First, to the best of our knowledge, this is the first study to employ grey correlation analysis to evaluate the factors influencing green development in Guangdong Province, offering a new methodological direction for future studies in this domain. Second, this study expands the existing literature and provides evidence of green coordinated development using a sample from Guangdong Province. Finally, this study provides practical recommendations for policymakers to improve their green development management practices.

Research Methodology

Based on relevant data from Guangdong Province, China, spanning the years 2006 to 2019, this study employs grey relational analysis as an assessment index to analyze the factors influencing the green collaborative development of enterprises and industrial parks in the industrial undertaking regions. A gray system refers to an incomplete information system with partial information known and partial information unknown. Gray correlation analysis, which measures the degree of correlation between factors based on the similarity of the development trend between factors, reveals the characteristics and degree of dynamic correlation between factors. The measure of the correlation between two factors is called the grey correlation degree. When the relative changes in the two factors have basically the same trend of change, the two factors have a greater degree of gray correlation; otherwise, they have a smaller degree of gray correlation (Wu, 2002). In this study, green collaborative development was selected as the reference sequence, and various influencing factors were considered as subsequences. The correlation between each subsequence and the parent sequence was calculated to analyze the degree of influence of each factor on the results.

Simultaneously, China's Guangdong Province has become a major industrial undertaking in international industrial transfer by virtue of its coastal geographical advantage, undertaking many international industries, and achieving the leapfrog development of the economy. However, in recent years, through various modes of cooperation, such as industrial transfer and joint construction of parks, industries in Guangdong Province have completed upgrades, where low value-added industries have been removed to high value-added industries, promoting industrial transformation and upgrading and further upgrading of park capacity, improving the level of green development. According to the national industrial park provincial evaluation of the green dimension index value from 2012 to 2018, the green dimension index of national industrial parks in Guangdong province exceeded 0.4, which is at the leading level of the country (Shi, 2021).

Establishment of indicators

Determine the parameters

According to the policy guidance document of the 14th Five-Year Plan, the evaluation indicators of green collaborative development are as follows (Meng & Chi, 2018; Liu & Forrest, 2007).

Table 1 Evaluation indicators of green collaborative development

Indicator	Meaning	Indicator Function	Nature
Decrease in Unit GDP Energy Consumption	Reduction in energy consumption per unit of GDP compared to the base period	Enhances energy efficiency and transformation, driving industrial transition	Positive
Decrease in Unit GDP Carbon Dioxide Emissions	Reduction in carbon dioxide emissions per unit of GDP compared to the base period	Guides clean and efficient energy use, controls peak carbon emissions	Positive
Ratio of Good and Excellen Air Quality Days in Cities at or above Prefecture Level	Number of days with Air Quality Index (AQI) < 100 / Total days *100%	Reflects overall improvement in air quality	Positive

Proportion of Surface Wate Reaching or Exceeding Grade III	Number of nationally monitored surface water sections reaching or exceeding Grade III water quality / Total sections *100%	Strengthens water quality monitoring, reduces water pollution	Positive
Forest Coverage Rate	Forest area/Total land area *100%	Reflects forest resource abundance, land greening, and carbon sink capacity	Positive

Note: jAQI refers to the ambient air quality index of cities at prefecture level and above. kthe positive index refers to the value of the set index in the same direction as the level of green development; inverse index refers to index value opposite to green development (Liang & Luo, 2023).

This study employs the indicator of "Decrease in Unit GDP Energy Consumption" to represent the level of green collaborative development. According to the definition, relevant data on "Annual Energy Consumption in Guangdong Province" and "Annual Regional GDP of Guangdong Province" were extracted from the "China Energy Statistical Yearbook" and the "National Bureau of Statistics." By conducting calculations, the indicator of "Energy Consumption per Unit of Regional Gross Domestic Product (GDP)" was derived.

Furthermore, by utilizing the initial year (2006) as the baseline for "Energy Consumption per Unit of GDP," the data for "Decrease in Unit GDP Energy Consumption" were computed.

Table 2 Green Collaborative Development Data for Guangdong Province (2006-2019)

year	Total energy consumption (10,000tons/standard coal)	Annual Regional GDP of Guangdong Province (100 million yuan)	Energy Consumption per Unit of Regional GDP (Equivalent) (tons of standard coal/10,000	Decrease in energy consumption per unit of GDP
2006	19971	25961.2	0.7693	Base year
2007	22217	31742.6	0.6999	9.02%
2008	23476	36704.2	0.6396	16.86%
2009	24654	39464.7	0.6247	18.79%
2010	26908	45944.6	0.5857	23.87%
2011	28480	53072.8	0.5366	30.24%
2012	29144	57007.7	0.5112	33.54%
2013	28480	62503.4	0.4557	40.77%
2014	29593	68173.0	0.4341	43.57%
2015	30145	74732.4	0.4034	47.56%
2016	31241	82163.2	0.3802	50.57%
2017	32342	91648.7	0.3529	54.13%
2018	33330	99945.2	0.3335	56.65%
2019	34142	107986.9	0.3162	58.90%

Identification of variables

In line with Lin and Zhou (2022) study on green development, this study conducted an analysis of key influencing factors. The selected variables for the critical influencing factors are listed in the following table:

Table 3 Selection of Influencing Factors in Green Development

Influencing factors	Key references
Investment in Capital	Wang et al. (2020) ; Jianhua (2014)
Industrial structure	Du et al. (2021) ; Zhu et al. (2019)
Technological progress	Magnani and Tubb (2012) ; Wen and Dai (2021)

Investment in Capital: Represented by local fiscal expenditure on environmental protection. China is currently in a period of transition from rapid economic development to high-quality development. The government has shown considerable commitment to green fiscal expenditures to promote regional economic coordination and green development. Environmental pollution leads to serious negative externalities, which require the government to play a central role in environmental management. Fiscal environmental expenditure can address environmental pollution at the source, promptly identify environmental issues, and carry out effective management. However, it also induces social investment in environmental protection. An increased fiscal environmental expenditure indicates the government's preference for the environment, and social capital reflects this preference, thereby achieving the goal of industrial green development.

Industrial Structure: Indicated by the proportion of the value-added of the secondary industry to GDP and the proportion of the value-added of the tertiary industry to GDP. Based on existing research, industrial structure, particularly the composition of the industrial sector, directly influences the green development of industrial parks. This influence was observed during both the production and pollution treatment stages. Industries with high pollution, high energy consumption, and high emissions contribute to increased regional environmental pollution and substantial pollutant emissions. An increased proportion of such industries in the sector intensifies environmental pollution. Therefore, promoting the upgrading of the industrial structure to the tertiary sector or facilitating the transition of resource-intensive industries to knowledge- and technology-intensive industries aids the green development of industries.

Technological Progress: Selected indicators include annual patent authorizations and the annual volume of technological market transactions. Technological progress is a pivotal factor in enhancing economic development efficiency and positively driving green development, to some extent. It provides crucial resources and reserves for supporting green development in industrial parks. Increasingly stringent environmental protection requirements have led producers to incorporate ecological protection costs into production costs, resulting in an increased demand for clean production technology and green technology equipment by enterprises. Technological advancements make the production process cleaner, more environmentally friendly, and intelligent, subsequently driving various industries towards environmentally friendly production, management, and services. Therefore, technological progress fosters green development of industries. The annual number of patent authorizations serves as the primary output of an enterprise's innovative knowledge production process, measuring the potential market benefits and output efficiency of technological innovation. As patents do not accurately reflect the conversion efficiency of technological innovation achievements, the annual technology market transaction volume was additionally chosen as an indicator to measure the economic benefits of technological innovation.

The three major influencing factors and their indicators are specifically shown in Figure 1.

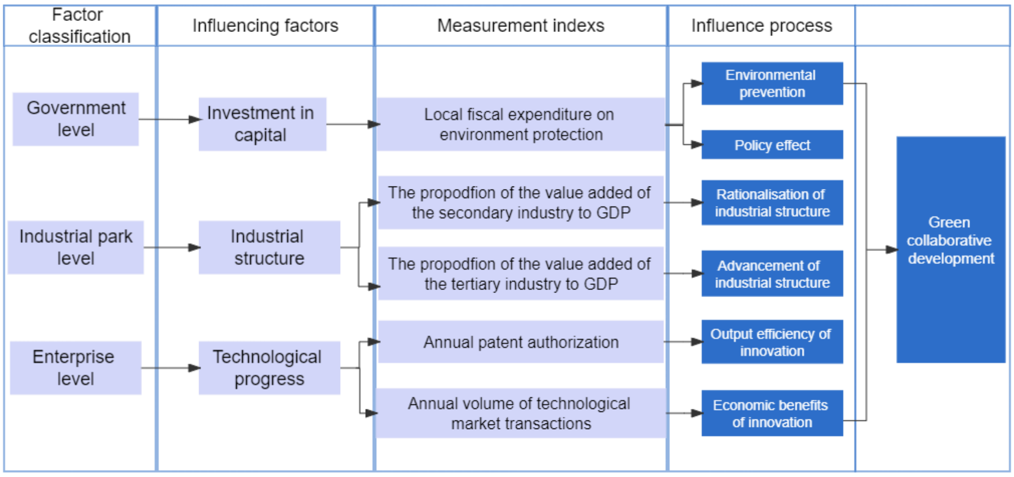

Figure 1 Establishment of Influencing Factor Indicators

Given the establishment of environmental protection fiscal expenditure by the Ministry of Finance starting in 2007, indicator data related to "Factors influencing the Green Collaborative Development between Enterprises and Industrial Parks in industrial undertaking areas" have been selected from 2007.

Data processing

Dimensionless

Table 4 Parametric data

Year	Reduction in Energy Consumption per	Annual patent authorizations (Influencing	Annual volume of technological market transactions	Proportion of secondary industry to GDP	Proportion of tertiary industry to GDP	Local fiscal expenditure on environmental
	X0	X1	X2	X3	X4	X5
2007	0.0902	56451	132.84	0.5048	0.4428	26.71
2008	0.1686	62031	201.63	0.5046	0.4431	47.09
2009	0.1879	83621	170.98	0.4926	0.4581	100.8
2010	0.2387	119343	235.89	0.4988	0.4533	239.16

2011	0.3024	128413	275.06	0.4929	0.4590	232.62
2012	0.3354	153598	364.94	0.4797	0.4727	235.44
2013	0.4077	170430	529.39	0.4695	0.4845	307.78
2014	0.4357	179953	413.25	0.4684	0.4871	259.04
2015	0.4756	241176	662.58	0.4538	0.5035	322.33
2016	0.5057	259032	758.17	0.4321	0.5253	297.45
2017	0.5413	332652	937.08	0.4205	0.5401	433.23
2018	0.5665	478082	1365.42	0.4142	0.5474	567.41
2019	0.5890	527390	2223.08	0.4016	0.5581	747.44

Following the steps of gray correlation analysis, the reference sequence was selected as X0, and the remaining variables were comparison sequences. Because the data in the columns of the factors in the system may differ in magnitude and size of the values, it is not easy to compare, or it is difficult to obtain the correct conclusion when comparing. Therefore, dimensionless processing of the data was performed.

Table 5 Data after homogenization process

year	X0	X1	X2	X3	X4	X5
2007	0.2419	0.2628	0.2088	1.0876	0.9030	0.0910
2008	0.4523	0.2888	0.3169	1.0872	0.9036	0.1604
2009	0.5042	0.3893	0.2688	1.0614	0.9342	0.3434
2010	0.6404	0.5556	0.3708	1.0748	0.9244	0.8146
2011	0.8115	0.5979	0.4324	1.0621	0.9359	0.7924
2012	0.9001	0.7151	0.5736	1.0336	0.9640	0.8020
2013	1.0939	0.7935	0.8321	1.0115	0.9880	1.0484
2014	1.1692	0.8378	0.6496	1.0092	0.9932	0.8824
2015	1.2763	1.1229	1.0415	0.9778	1.0268	1.0979
2016	1.3570	1.2060	1.1918	0.9310	1.0713	1.0132
2017	1.4524	1.5488	1.4730	0.9060	1.1014	1.4757
2018	1.5201	2.2259	2.1463	0.8925	1.1163	1.9327
2019	1.5805	2.4555	3.4944	0.8653	1.1381	2.5460

Absolute difference sequence

The ABS function was used to calculate the absolute differences between each variable indicator in each row, and X0. Subsequently, the minimum and maximum values of the absolute difference sequence were determined, which yielded the following data:

Table 6 Data after absolute difference processing

Year	Minimum of Absolute Difference Sequence	Maximum of Absolute Difference Sequence	Absolute Difference Sequence				
			Δ_1	Δ_2	Δ_3	Δ_4	Δ_5
2007	0.0209	0.8457	0.0209	0.0331	0.8457	0.6611	0.1509
2008	0.1354	0.6349	0.1635	0.1354	0.6349	0.4513	0.2919
2009	0.1149	0.5571	0.1149	0.2355	0.5571	0.4299	0.1609
2010	0.0848	0.4343	0.0848	0.2697	0.4343	0.2840	0.1742
2011	0.0191	0.3791	0.2136	0.3791	0.2506	0.1244	0.0191
2012	0.0639	0.3264	0.1850	0.3264	0.1335	0.0639	0.0981
2013	0.0456	0.3004	0.3004	0.2618	0.0824	0.1059	0.0456
2014	0.1600	0.5196	0.3313	0.5196	0.1600	0.1760	0.2868
2015	0.1534	0.2985	0.1534	0.2348	0.2985	0.2496	0.1784
2016	0.1510	0.4261	0.1510	0.1653	0.4261	0.2858	0.3438
2017	0.0206	0.5464	0.0964	0.0206	0.54	0.35	0.02
2018	0.4039	0.7058	0.7058	0.6262	0.62	0.40	0.41
2019	0.4424	1.9139	0.8750	1.9139	0.71	0.44	0.96

Find the minimum value of the "Minimum of Absolute Difference Sequence" column and the maximum value of the "Maximum of Absolute Difference Sequence" column and obtain the following data.

Table 7 Minimum value of the column "Minimum of Absolute Difference Sequence" and maximum value of the column "Maximum of Absolute Difference Sequence"

Minimum value of the "Minimum of Absolute Difference Sequence"	Maximum value of the "Maximum of Absolute Difference Sequence"
0.0191	1.9139

Calculated correlation coefficient

$$\zeta_i(k) = \frac{\min_i \min_k |x_0(k) - x_i(k)| + \rho \cdot \max_i \max_k |x_0(k) - x_i(k)|}{|x_0(k) - x_i(k)| + \rho \cdot \max_i \max_k |x_0(k) - x_i(k)|}$$

The formula above was applied to the absolute difference sequence to calculate the correlation coefficient. Resolution coefficient ρ = 0.5.

Table 8 Calculation of correlation coefficient ξi

Year	Δ1	Δ2	Δ3	Δ4	Δ5
2007	0.9982	0.9859	0.5415	0.6033	0.8810
2008	0.8712	0.8936	0.6132	0.6931	0.7816
2009	0.9107	0.8186	0.6447	0.7038	0.8732
2010	0.9370	0.7958	0.7016	0.7866	0.8629
2011	0.8339	0.7306	0.8083	0.9027	1.0000
2012	0.8548	0.7606	0.8951	0.9561	0.9252
2013	0.7763	0.8009	0.9391	0.9184	0.9737
2014	0.8791	0.8190	0.7775	0.8090	0.8598
2015	0.8810	0.8698	0.7058	0.7854	0.7504
2016	0.9267	0.9985	0.6493	0.7463	0.9958
2017	0.5870	0.6166	0.6160	0.7173	0.7127
2018	0.5328	0.3400	0.5838	0.6975	0.5077
2019	0.5224	0.3333	0.5723	0.6838	0.4978

Correlation degree

The degree of correlation was computed as the arithmetic mean of all the correlation coefficients within each variable. The resulting degrees of correlation for the various indicators are presented in Table 9.

Table 9 Correlation Degrees of different indicators ξi

Variables	X1	X2	X3	X4	X5
ξi	0.8266	0.7762	0.7192	0.7832	0.8391
Rank	2	4	5	3	1

Results and Discussion

The calculated degrees of correlation, arranged from highest to lowest, are as follows: X5 > X1 > X4 > X2 > X3. This implies that: Local fiscal expenditure on environmental protection> Annual patent authorizations> Proportion of tertiary industry to GDP > Annual volume of technological market transactions > Proportion of secondary industry to GDP. By summing up the relevant variables and computing their average, the magnitude of the correlation of the relevant first-level indicators (technological progress, industrial structure, and capital investment factors) can be obtained.

Table 10 Correlation degree for Primary Indicators

Variables	Sub-variables	ξ i for secondar	ξ i for primary indicators	Rank
Technological Progress	Annual patent authorizations	0.8266	0.8014	2
	Annual volume of technological market transactions	0.7762		
Industrial Structure	the proportion of the value added of the secondary industry to GDP	0.7192	0.7512	3
	the proportion of the value added of the tertiary industry to GDP	0.7832		
Investment in Capital	Local fiscal expenditure on environmental protection	0.8391	0.8391	1

Consequently, the sequential order of influencing factors is as follows: Investment in Capital > Technological Progress > Industrial Structure. In other words, Investment in Capital is the most crucial factor affecting green collaborative development of enterprises and parks in the region.

According to Table 10, it is evident that collaborative green development varies in terms of the gray correlation degrees with each primary indicator, yet the correlations are consistently strong, primarily ranging between 0.75 and 0.85. The sequence of descending degrees of correlation between each primary indicator and green collaborative development is as follows: funding input, technological progress, and industrial structure. Each secondary indicator demonstrated a correlation exceeding 0.7, predominantly distributed within the range of 0.7 to 0.9. This shows that these five indicators play an important role in green coordinated development and have a strong influence on the green coordinated development of an industry. Among these, local fiscal expenditure on environmental protection had the greatest impact on the green collaborative development of enterprises and parks in the industrial undertaking area, with a correlation degree of 0.83913. Subsequently, in descending order, the annual number of patent grants, proportion of value-added of the tertiary industry to GDP, proportion of annual technology market transactions, and proportion of value-added of the secondary industry to GDP. The effect of the proportion of secondary industry value-added to GDP on green collaborative development is relatively minor, yet its correlation remains noteworthy at 0.7192. These five influencing factors were positively correlated with green collaborative development.

Financial support for environmental protection has the most significant influence on green collaboration, underscoring the indispensability of financial funding for the collaborative development of enterprises and parks in pursuit of eco-friendly goals. Particularly within industrial undertaking areas, where initial financial support might have been limited, a shift towards increased funding to facilitate the transformation of traditional industries and the growth of emerging sectors suggests a gradual reallocation of financial resources in favor of the green industry. Industries characterized by high energy consumption and pollution are compelled to undergo green transformation; otherwise, they risk obsolescence due to the continual outflow of funds.

The correlation of the proportion of secondary industry value-added to GDP is relatively modest, in alignment with the Pedi-Clark theorem. With the further development of the economy, people's pursuit of quality of life, including the improvement of environmental quality, makes the relative proportion of value-added of the secondary industry in GDP decline, while the relative proportion of value-added of the tertiary industry in GDP begins to rise.

Conclusion and Recommendations

Conclusion

After undertaking polluting industries, industrial parks require green transformation to meet the needs of sustainable development. The green transformation of parks requires the cooperation and coordination of enterprises, industrial parks, and governments in many aspects. The key variables affecting the degree of enterprise-park collaboration are capital input, technological progress, and industrial structure. Capital investment has the greatest impact, followed by technological progress and the industrial structure. This study emphasizes the concept of green collaborative governance and explores its influencing factors in three dimensions: enterprises, industrial parks, and the government.

Policy Recommendations

The findings of this study indicate that capital input, technological progress, and industrial structure have notable positive impacts on the sustainable development of industrial parks in industrial undertakings. To strengthen these effects, the government should play an active role in providing policy support.

Firstly, Implement the concept of green ecology and provide green financial support. Financial support can play a guiding role of the government and bring about the effect of attracting social capital. The concept of green ecology will be carried out throughout, and the guiding role of the government will be launched to promote the green transformation of the park. Learn from the experience and lessons of green development of foreign industrial parks, actively encourage parks that carry out green transformation to participate in domestic carbon market trading, formulate fiscal and tax incentive policies, and promote the development of green finance, thereby providing financial support and facilitation. Comprehensively consider the tax types and tax rates of energy, environment, and carbon emissions, guide the behavior of enterprises and parks, and develop a long-term mechanism for the green development of parks.

Secondly, increase scientific and technological support to promote technological progress of enterprises. Advancements in technology can lead to cleaner and more energy-efficient production, thereby reducing pollution and energy consumption. Technological innovation is the core, promoting the research and development and promotion of high energy efficiency and low emission technologies in the fields of production and consumption; gradually establishing a diversified green technology chain system, such as energy conservation and consumption reduction, clean energy, renewable energy and new energy, and carbon sequestration; and carrying out relevant technical research in the fields of intensive land use, sustainable energy use, low-carbon buildings, and low-carbon transportation. Support the development of green parks at a technical level.

Finally, adjust the industrial structure and promote the ecological development of enterprises. The advancement and rationalization of industrial structure can lead to green modes of production. Build "industrial chain, product chain, waste chain" to create a clean and efficient green industrial system. Upgrade existing pillar industries, encourage enterprises to carry out ecological management, improve the circular economy industrial chain of pillar industries, and build an industrial symbiotic network. Promote green development of enterprises and parks.

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