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A Decision-Support Framework for Enhancing Industrial Chain Resilience through Green Finance: Evidence from China's Sports Industry

Dangsheng Wang[1], Qiuying Li[2,*], Wenxiang Zhou[3], Laibing Lu[4]

1 Department of Sports, Henan Institute of Technology, Xinxiang, China
2 Department of Sports Rehabilitation, Hunan University of Medicine, Huaihua, China
3 Qingdao Engineering Vocational College, Qingdao, China
4 School of Physical Education and Sport Science, Fujian Normal University, Fuzhou, China

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ABSTRACT

To examine the decision-making implications of green finance (Gre) development mechanisms in China on the resilience of the sports industry chain (SICR), this study utilises a sample drawn from 24 provincial-level regions within the country. Initially, evaluation index systems for both Gre and SICR are established. Subsequently, the study investigates the complex linear and non-linear interactions between the development of green finance and SICR in China, providing a decision-support framework aimed at optimising the allocation of green financial resources and enhancing SICR. The findings indicate that: (1) advancements in the level of green financial development exert a significant positive influence on the resilience of SICR; (2) Gre affects SICR partially through the channel of sports industry innovation, which functions as a partial mediator, with this mediation pathway accounting for 23.8% of the total effect; (3) the impact of Gre on SICR is characterised by non-linear dynamics, whereby Gre can bolster SICR only when regional economic level, digital economy development, market maturity, and residents' consumption capacity surpass specific threshold values.

1. Introduction

Against the backdrop of deepening sports globalization, China's sports industry has gained recognition as a strategic and emerging sector, playing an increasingly prominent role in driving national economic growth. It is tasked with dual objectives: promoting structural reforms on the supply side and establishing a renewed development framework. The industry has already become a major representation of national soft power and an emerging driver of economic growth. Nonetheless, multiple risk factors threaten the stability of China's sports industry chain, including uncertainties arising from ongoing geopolitical competition, the persistent influence of anti-globalization trends characterized by trade protectionism and barriers, constraints on the

* *Corresponding author.*
E-mail address: liqiuying@hnmu.edu.cn

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development of core technologies, and the global industrial chain's "de-Sinification" tendencies. Simultaneously, domestic challenges such as the need to improve supply-side quality, enhance factor service efficiency, and stimulate innovation and reform contribute to potential risks of disconnection and disruption within the sports industry chain [7]. Suboptimal resilience of the SICR imposes significant practical constraints on the advancement and high-quality development of the sports industry [38]. Consequently, the question of how to strengthen SICR to improve resilience and drive superior development has attracted considerable scholarly attention [22; 26; 34].

The concept of elasticity, which originated in the physical sciences, was initially used to describe a material's ability to resist deformation, as observed in metals like steel, a notion referred to as "engineering elasticity". Later, this concept was introduced into ecological studies, where it was defined as a system's capacity to surpass a threshold and, following external disturbances or shocks, potentially shift to an alternative developmental pathway [17]. Alongside the ongoing evolution of the global industrial division system, the notion of industrial chain resilience has emerged, capturing an industrial chain's ability to withstand market volatility while ensuring long-term growth [3]. Its dimensions—resistance, recovery, and transformation—possess relative independence while remaining functionally interdependent, collectively forming a defensive system for the industrial chain [18].

Scholarly attention has subsequently shifted to the SICR. The sports industry chain, centred on sports, links multiple components, including talent cultivation, event organisation, media communication, and sports goods manufacturing, through the production, circulation, and consumption of various sports products and services. It exhibits distinct hierarchical structures, dynamic interactions, value-adding processes, and cross-border integration [7]. The SICR has been defined as the capacity of upstream, midstream, and downstream enterprises within the sports industry to prevent chain breakage and decoupling when exposed to external shocks, and their sensitivity to anticipate and respond to environmental uncertainties within the industrial chain [26]. Despite certain advances in research on SICR [44; 49], the academic community faces dual challenges: a general lack of consensus on measuring resilience and its determinants, compounded in China by underdeveloped inter-regional analytical methodologies, which impedes effective comparisons.

As the world's second-largest economy Wu et al. [47], China has consistently emphasised sustainable development. Within the country, the Gre system has evolved into a key environmental regulatory instrument driving green economic growth [9; 37]. Following the 2016 release of the "Guiding Opinions on Establishing a Gre System," the green finance market expanded rapidly. By the end of 2024, China had achieved the global highest cumulative green loan balance of CNY 36.6 trillion, more than four times the CNY 8.2 trillion recorded in 2019. Additionally, China ranks as the world's second-largest issuer of green bonds, with cumulative domestic issuance reaching 4.79 trillion yuan and a total outstanding scale of 2.32 trillion yuan by July 2025.

Green finance, centred on environmentally sustainable investments, comprises a range of financial instruments, including green bonds and other dedicated tools [24; 30]. Its initiatives typically involve renewable energy, energy efficiency, waste management, and natural resource conservation. A key mechanism of Gre is mobilising public and private capital for environmentally conscious enterprises and initiatives, supporting progress toward the Sustainable Development Goals [16]. As a subset of sustainable finance Wright [46], Gre underpins industrial chain resilience. Unlike conventional financial policies, Gre prioritises environmental and social outcomes, supporting corporate deployment of technologies for pollution control and decarbonisation, and directing capital toward green, low-carbon manufacturing. In doing so, Gre serves as a strategic tool to strengthen supply chain development through targeted funding, safeguarding operational

resilience, a function particularly pronounced in China. Existing literature indicates that Gre can enhance industrial chain resilience [5; 40]; however, research on its impact within the sports industry remains limited. Consequently, investigating Gre's effectiveness in improving SICR in China warrants scholarly attention.

Overall, the literature provides a foundation for understanding the relationship between Gre and SICR, but certain empirical and theoretical conclusions require further validation. Key questions remain: how can SICR be comprehensively and accurately evaluated across Chinese regions? Can effective promotion of Gre significantly enhance SICR, and does this influence vary geographically? Are there mediating or threshold effects in the process through which Gre affects SICR? This study aims to contribute by addressing three dimensions: (1) constructing an assessment framework for SICR in China and measuring SICR across 24 provincial regions from 2014 to 2023, aligned with Gre development data to identify the specific impact of Gre on SICR; (2) examining the temporal and regional variability of Gre's influence on SICR; (3) exploring the mediating role of sports industry innovation and threshold effects of variables including economic growth, digital economy development, marketisation maturity, and residents' consumption capacity.

2. Literature Review and Research Hypotheses

2.1 Direct Decision Influence of Gre on SICR

Amid the global emphasis on sustainable development and high-quality economic growth, Gre operates as a strategic instrument to guide economic structures toward a greener trajectory and has increasingly been recognised for its capacity to strengthen industrial chain resilience. The sports industry chain, as a multifaceted system encompassing facility construction, event organisation, equipment manufacturing, talent development, and service operations, is exposed to environmental risks, resource supply fluctuations, and climate-related shocks. Within this context, resilience—conceptualised as the ability to withstand disruptions, recover promptly, and adapt to evolving conditions—assumes a crucial role. The deployment of Gre enhances financing for environmentally sustainable initiatives, thereby supporting the growth of the external green economy [48]. Implementation of green measures can generate social benefits, including job creation, improved public health outcomes, and reduced mortality from air pollution, while simultaneously fostering a technology-driven green economic structure that strengthens market integration and regional resilience [31; 45].

In addition, prior studies indicate that the establishment of Gre reform and innovation pilot zones has significantly enhanced the comprehensive resilience of regional economies at both urban and regional levels, particularly by mitigating financing constraints, optimising resource allocation, and bolstering green innovation capacity [8]. Gre also contributes to lowering corporate agency costs and improving production and investment efficiency, which in turn elevates corporate innovation potential, increases firm value, and facilitates industrial structural transformation. These processes collectively enhance resilience throughout the industrial chain [42]. Complementing these findings, evidence from Europe demonstrates that well-developed regulatory frameworks and mature financial markets enable Gre to substantially reinforce industrial resilience [41]. Empirical research specific to China's sports industry corroborates this relationship, revealing that Gre—including credit, investment, funding, and insurance mechanisms—exerts a statistically significant positive influence, at the 1% level, on the sector's high-quality development [14].

H1: Gre exerts a positively significant decision influence on the SICR.

2.2 Indirect Decision Influence of Gre on the SICR

Additional factors may serve as intermediaries in the process through which Gre influences SICR.

Firstly, in allocating instruments such as credit facilities, bonds, and capital pools, Gre predominantly supports low-carbon, energy-efficient, and environmentally sustainable projects. This approach not only encourages the sports industry to integrate green technologies and sustainable practices across infrastructure development, event management, and product research and development but also ensures a consistent funding stream for innovative activities within sports enterprises, thereby enhancing their innovation capacity while alleviating financing constraints [21].

Secondly, the policy incentives and capital preferences associated with Gre motivate sports enterprises to increase investment in research and development across areas such as green materials, intelligent equipment, and digital services. This promotes technological advancement and business model innovation, while fostering collaborative innovation and greater product differentiation along the sports industry supply chain [33]. Thirdly, Gre-driven innovation can simultaneously reduce resource consumption and environmental risks and improve the capacity of sports enterprises to respond to external shocks, including climate change, energy price volatility, and policy modifications [43]. Consequently, this strengthens both the flexibility and resilience of the industrial chain. Furthermore, it has been suggested that Gre can bolster economic resilience by mitigating information barriers, enhancing cooperation through information sharing, promoting technological reform, and reducing operational costs via innovation [27].

H2: The innovation capability of the sports industry acts as a pathway through which Gre enhances the SICR.

2.3 Non-Linear Decision Influence of Gre on the SICR

During the initial phases of economic development, small and medium-sized enterprises (SMEs) within the sports industry chain frequently encounter financing constraints, limiting their capacity to secure adequate funds for upgrading green technologies. For example, small-scale sports goods manufacturers may lack access to green credit facilities, hindering the adoption of energy-efficient production equipment. This situation results in elevated carbon emissions and inefficient resource utilisation during production, thereby weakening the industrial chain's responsiveness to changes in environmental policies [54]. As the economy advances and the diversity of green financial products expands, larger operators, such as organisers of major sports events, can mobilise capital through instruments like green bonds, reducing operational costs and improving resilience to risk [20]. The investment efficiency and innovation demands induced by economic development can offset externalities associated with Gre, creating mutually beneficial outcomes and providing sustained momentum for its advancement [52]. Moreover, Gre stimulates economic growth by promoting green technological innovation, which, in turn, generates a reinforcing feedback loop that strengthens its efficacy within the sports industry chain. This macro-level mechanism offers a framework for understanding the influence of Gre on SICR across different stages of economic development [32].

H3: The decision influence of Gre on the SICR exhibits a threshold effect based on the level of economic development.

2.4 Threshold Effect of Digitalisation Level

Digital finance reflects the sophistication of financial systems within a city or region and, by utilising internet-based technologies, establishes platforms for delivering green financial services. These platforms significantly broaden the accessibility of Gre, lower participation thresholds, expand operational reach, and enhance service efficiency [4]. Simultaneously, the digital economy provides a holistic support framework for Gre, facilitating advanced upgrading and modernisation of

the manufacturing sector. In the decision-making context, the widespread deployment of digital infrastructure and the integration of digital industrialisation enable big data analytics to perform risk evaluations and forecast returns for green projects. This process reduces the costs associated with project identification for both manufacturing firms and financial institutions, while improving the precision of resource allocation by mitigating information asymmetry.

At the production stage, continued industrial digitalisation allows the integration of digital solutions into manufacturing workflows, reshaping production models and enhancing interlinkages across industries, which in turn optimises capital utilisation efficiency [23]. Furthermore, the digital economy stimulates the creation of innovative green financial products. High digital penetration allows financial institutions to quickly accumulate insights, leverage artificial intelligence and big data to anticipate market demand accurately, and develop tailored products for individual investors, thereby energising the green finance sector [50].

H4: The decision influence of Gre on the SICR demonstrates a non-linear relationship that requires a minimum level of digital economy.

The growth of the sports industry is closely linked to the coordinated interaction between upstream and downstream sectors. In regions exhibiting higher levels of market orientation, financial resources are allocated more efficiently, allowing capital to be channeled swiftly and accurately toward green sports industry initiatives. Where capital markets are more advanced, sports enterprises can more readily access funding to strengthen their sustainability capabilities, thereby enhancing the resilience of the industrial chain [36]. Additionally, regions with well-developed market mechanisms are able to appropriately price green financial resources, reducing the financing costs associated with environmentally sustainable sports projects [55]. As the level of Gre rises, within a competitive market environment, sports enterprises can more effectively deploy financial resources to drive technological innovation and facilitate industrial upgrading. This, in turn, boosts their competitive position within the industrial chain and strengthens the overall capacity of the sports industry chain to withstand external shocks [1].

H5: The decision influence of Gre on the SICR exhibits a threshold effect based on market maturity.

At the heart of the sports industry is sports consumption. As residents' consumption capacity improves, the demand for green and health-oriented sports products and services has risen, alongside a growing preference for diversified offerings that priorities quality and environmental sustainability [39]. High-consumption groups exhibit strong demand for low-carbon sporting events and smart venue solutions, which in turn lowers the financing costs associated with green bonds. This dynamic amplifies the influence of Gre on SICR. Within this context, sports enterprises supported by Gre are able to adjust their investments in line with market demand, such as constructing additional green fitness facilities or organising environmentally sustainable sports events [51]. As the level of Gre increases, in markets characterised by strong consumer purchasing power, sports enterprises can gain enhanced market feedback, incentivising further improvements in product and service quality and enabling optimisation across all stages of the industrial chain, thereby strengthening SICR.

H6: The decision influence of Gre on SICR exhibits a threshold effect based on the level of residents' consumption.

3. Research Design

3.1 Variable Measurement and Explanation

3.1.1 Explained Variable: SICR

Building on existing frameworks for the construction of industrial resilience evaluation indices

[3; 26, 56], this study develops an assessment index system for SICR encompassing three key dimensions: the capacity of the sports industry chain to resist external shocks, its ability to recover and restructure, and its capability for ongoing renewal (Table 1).

Table 1
Assessment Indicator Framework for SICR

Secondary Indicators	Tertiary Indicators	Data Source (Indicator Description)	Unit	Attribute
Shock Resistance Capability	Sports Industry Added Value	Provincial-Level Sports and Statistics Authorities' Official Sites	10 Billion CNY	+
	Urban Employed Persons in the Sports Industry	Sourced from China's Statistical Yearbook on Tertiary Industry	10,000 Persons	+
	Mean Workforce in the Sports Goods Manufacturing Industry	Derived from China Industrial Industry Statistical Yearbook	10,000 Persons	+
	Number of Social Sports Instructors	China Sports Career Statistical Yearbook	10,000 Persons	+
	Count of Legal Organizations in the Sports Industry	Derived from China Tertiary Industry Statistical Yearbook	1,000 Entities	+
	Expenditure of Sports Lottery Public Welfare Funds (Sports Facilities, Mass Sports, and Youth Sports)	China Sports Career Statistical Yearbook	100 Million CNY	+
	Budget Expenditure of Sports System (Sports Competitions, Sports Venues, and Mass Sports)	China Sports Career Statistical Yearbook	100 Million CNY	+
Recovery and Restructuring Capability	Total Social Fixed-Asset Investment in the Sports Industry	Derived from China Tertiary Industry Statistical Yearbook	10 Billion CNY	+
	Diversification Level of the Sports Industry	Reciprocal of the Herfindahl-Hirschman Index (HHI)	-	+
	Upgrading of Sports Industry Structure	Industrial Level Coefficient	%	+
		Ratio of Sports Service Industry's Value-Added to that of the Sports Industry	%	+
	Rationalisation of Sports Industry Structure	Proportion of Sports Service Industry Added Value in Tertiary Industry Added Value	%	+
		Ratio of Sports Industry Value-Added to GDP	%	+
	Co-Agglomeration of the Sports Industry	E-G Co-Agglomeration Index	-	+
Continuous Renewal Capability	Number of Patents in the Sports Industry	Authorized Invention Patent Count for the Sports Industry	1,000 Items	+
	Number of Sports Research Institutions	China Sports Career Statistical Yearbook	Entities	+
	Budget Expenditure of Sports System (Science and Technology)	China Sports Career Statistical Yearbook	100 Million CNY	

Note: Sports industry patents were retrieved using the incoPat database with the search formula "CIC=(C2441 OR C2442 OR C2443 OR C2444 OR C2449 OR C2916 OR C1811 OR C1821 OR C2462)" based on Statistical Classification of Sports Industry (2019) and by reference to National Economic Industry Classification (GB/T 4754-2017).

The formula used to quantify the diversification level within the sports industry is expressed as follows:

$$X_{it} = 1/HHI = 1/\sum_{m=1}^{3} {y_{itm}}^2 = 1/({y_{it1}}^2 + {y_{it2}}^2 + {y_{it3}}^2) \quad (1)$$

In Equation (1), Xit denotes the diversification level of the sports industry in province i during period t, while HHI represents the Herfindahl-Hirschman Index. As the sports industry excludes the primary sector, yit1 is set to 0. The variable yit2 represents the proportion of the combined added value from sports goods and related product manufacturing, as well as sports venue construction, in province i during period t relative to the total added value of the local sports industry. Yit3 indicates the proportion of the added value derived from the sports service sector in province i during period t relative to the overall added value of the local sports industry. Relevant data were obtained from the official websites of sports authorities and statistical bureaus across the sampled regions.

The industrial level coefficient is determined by evaluating the optimization of the sports industry structure [44], with the calculation expressed as follows:

$$S_{it} = \sum_{m=1}^{3} y_{itm} \times m = y_{it1} \times 1 + y_{it2} \times 2 + y_{it3} \times 3 \quad (2)$$

In Equation (2), Sit represents the level of structural upgrading of the sports industry in province i during period t, while yitm denotes the proportion of the value added by the m-th segment of the sports industry in province i at time t relative to the total added value of the sector. Consistent with Equation (1), yit1 is equal to 0; yit2 reflects the combined proportion of value added from sports goods and related product manufacturing, as well as the construction of sports venues and associated facilities, relative to the total added value of the local sports industry, and yit3 indicates the proportion of the sports service sector's value added within the overall sports industry in province i.

Based on the methodology in [45], the E-G co-agglomeration index is employed to assess the degree of synergy within the sports industry, with the calculation expressed by the following formulas:

$$R_{itab} = 1 - \frac{|S_{ita} - S_{itb}|}{|S_{ita} + S_{itb}|} + (S_{ita} + S_{itb}) \quad (3)$$

$$S_{ita} = \frac{e_{ita} / E_{ta}}{e_{it} / E_t} \quad (4)$$

In Equations (3) and (4), Ritab represents the level of internal synergetic agglomeration within the sports industry in province i during period t, specifically the synergetic agglomeration between the sports manufacturing sector (a) and the sports service sector (b). Sita and Sitb respectively denote the agglomeration levels of the sports manufacturing sector and sports service sector in province i during period t, measured using the location quotient as shown in Equation (4). Here, eita is employee count in the sports manufacturing sector of province i during period t; Eta is the employee count in the sports manufacturing sector across all provinces in China during period t; eit is the employee count in the sports industry of province i during period t; and Etis the employee count in China's sports industry during period t. The workforce in the sports manufacturing and service sectors for each province across different periods is calculated by disaggregating the "employee count in urban sports units." The disaggregation coefficient is defined as the proportion of value added by the sports manufacturing and sports service sectors in province i during period t relative to the total value added in the local sports industry. The "number of employees in urban sports units" is determined by applying the sectoral indicator proportion method to relevant data, following established procedures for disaggregating sports industry-related statistics [46].

3.1.2 Core Independent Variable: Gre

Following the methodologies outlined in [19; 24; 53], the development level of Gre at the

provincial level in China is assessed across seven dimensions: Green Credit, Green Investment, Green Insurance, Green Bonds, Green Support, Green Funds, and Green Equity (Table 2).

Table 2
Evaluation Index System for Gre

Secondary Indicators	Indicator Description	Calculation Method	Attribute
Green Credit	Share of Financial Support Dedicated to Environmental Protection Programmes	Eco-Protection Project-Related Total Credit in the Province / Provincial Aggregate Credit	+
Green Investment	Environmental Pollution Control Investment-to-GDP Ratio	Eco-Pollution Control Expenditure / GDP	+
Green Insurance	Extent of Popularization of Environmental Pollution Liability Insurance	Income from Environmental Pollution Liability Insurance / Total Premium Income	+
Green Bonds	Development Degree of Green Bonds	Sustainable Bond Issuance Volume / Overall Bond Issuance	+
Green Support	Ratio of Fiscal Expenditure Allocated to Environmental Protection	Eco-Protection Fiscal Spending / General Budget Expenditure	+
Green Funds	Ratio of Green Funds	Green Fund Total Market Capitalization / Aggregate Market Capitalization of all Funds	+
Green Equity	Ratio of Environmental Pollution Control Investment to GDP	Investment in Environmental Pollution Abatement / GDP	+

3.1.3 Mechanism Variable: Sports Industry Innovation Level (Sco)

Patents are widely recognised as a primary indicator for assessing the innovation capability of a given region [2]. Patent datasets encompass all innovation-related elements within a region, with the aggregated information reflecting the overall regional innovation level [35]. In comparison with simple counts of patent filings or granted patents, the quality of patents offers a more precise measure of the technical innovation capacity and sophistication of patent holders. Moreover, invention patents undergo more stringent substantive examination than utility model patents, possess greater stability, and contain higher technical content, thereby providing a more accurate representation of the technical capabilities within a specific industry. Consequently, the quality of invention patents in the sports industry is adopted as a proxy for evaluating the sector's innovation level. Building on this, a patent quality evaluation system for China's sports industry is developed across technical, economic, and legal dimensions, incorporating eight indicators, including the number of IPC classification numbers, to quantify innovation within the sector (Table 3). Finally, the innovation level of the sports industry across Chinese provinces from 2014 to 2022 is calculated using the panel entropy method.

Table 3
Comprehensive Evaluation Indicator System for Sports Industry Innovation Level

Secondary Indicators	Indicator Description	Calculation Method	Attribute
Technical Capability	Number of IPC Classification Codes	Classify patents according to the IPC classification number, and the number of such codes reflects the technical coverage of the patent.	+
	Number of National Economic Industry Classification Codes	*National Economic Industry Classification* specifies the classification and codes for economic activities across society, used for information processing and exchange. The number of these codes reflects the technical coverage of the patent.	+
	Number of Inventors	Natural persons who have made creative contributions to the substantive features of the patented invention, reflecting the scale of the research team and technical capabilities.	+
	Citation Frequency	The number of citations of other patent achievements in the patent writing, reflecting the solidity of the patent technology.	+

Table 3 (cont…)
Comprehensive Evaluation Indicator System for Sports Industry Innovation Level

Secondary Indicators	Indicator Description	Calculation Method	Attribute
Economic Value	Cited Frequency	The number of times a patent is mentioned in the background technology of other patents; a higher cited frequency indicates greater commercial value.	+
	Number of Patent Families	The number of patents with the same priority document that are filed and published in different countries or regions with similar content, reflecting the market prospects, product competitiveness, and coverage of strategic layout of the patent technology.	+
Legal Effect	Number of Claims	The number of patent rights requested for protection in a patent application, reflecting the scope of protection for the patented technology.	+
	Word Count of the First Claim	The number of words in the first claimed right of a patent application, reflecting the scope of protection for the patented technology.	+

3.1.4 Threshold Variables

1. Economic Development Level (Pgdp) is calculated using the natural logarithm of per capita gross domestic product, expressed in units of 10,000 CNY per capita.
2. Digital Economy Level (Dig) is evaluated using a dedicated assessment framework constructed across three dimensions: digital infrastructure, advancement of the digital industry, and inclusive digital finance (Table 4). The panel entropy weight method is applied to measure the digital economy development level for each province [13].
3. Marketisation Maturity (Ato) is measured using the Fan Gang Index, a widely recognised indicator frequently applied in studies of China's industrial system [12].
4. Residents' Consumption Capacity (Exp) is represented by the natural logarithm of per capita consumption expenditure, expressed in units of 10,000 yuan per person.

Table 4
Evaluation Index System for Digital Economy Level

Secondary Indicators	Tertiary Indicators	Unit	Attribute
Digital Infrastructure	Domain Name Count	1,0000 Items	+
	Volume of IPv4 Addresses	1,0000 Items	+
	Broadband Internet Access Port Quantity	1,0000 Items	+
	Mobile Phone Penetration Rate	Units per 100 Persons	+
	Length of Long-Distance Optical Cable Circuits	Km	+
	Number of Informatization Enterprises	Entities	+
	Number of Websites Per 100 Enterprises	Entities	+
Digital Industry Development	Percentage of Enterprises Involved in E-Commerce Business Transactions	%	+
	Telecom Business Revenue	100 Million CNY	+
	Information Technology Service Revenue	100 Million CNY	+
Digital Inclusive Finance	Multidimensional Coverage Breadth Index	/	+
	Depth of Usage Index	/	+
	Digitalisation Degree Index	/	+

3.1.5 Control Variables

Based on relevant studies [6; 53, 57], the following variables are incorporated as control variables: economic development level (Pgdp), marketisation maturity (Ato), urbanisation level (Tow), social consumption level (Con), per capita disposable income (Inc), and regional innovation capability (Lri). The urbanisation level is measured as the proportion of the urban population

relative to the total population, whereas social consumption is assessed by the ratio of total retail sales of consumer goods to regional GDP. Per capita disposable income is calculated as the total disposable income of residents divided by the permanent population. Regional innovation capability is quantified using the comprehensive regional innovation index as reported in the Report on Evaluation of China's Regional Innovation Capability [29].

3.2 Research Regions and Data Sources

Considering data availability and completeness, the temporal scope of the dataset is set from 2014 to 2022. Due to gaps in statistical reporting of sports industry data in certain Chinese provinces, for regions where sports industry added value is not publicly disclosed, the value is estimated from the tertiary industry added value of each province using the stripping coefficient calculated by [11]. Ultimately, based on data accessibility and reliability, 24 provincial-level units are selected as the focus of this study. Apart from the data required for the SICR index system presented in Table 1, additional relevant information is obtained from the official websites of provincial sports and statistics bureaus, government portals, meeting records, the incoPat database, and various statistical yearbooks of China. A minor portion of missing data is addressed using the linear interpolation method. Table 5 presents the descriptive statistics for all variables included in the study.

Table 5
Descriptive Statistical Results of Variables (N=240)

Variable Name	Mean	Standard Deviation	Minimum	Maximum
Sports Industry Chain Resilience (*SICR*)	0.173	0.117	0.03	0.518
Green Finance Level (*Gre*)	0.393	0.169	0.057	0.776
Sports Industry Innovation Level (*Sco*)	0.152	0.111	0.051	0.731
Economic Development Level (*Pgdp*)	7.178	3.526	2.987	19.031
Digital Economy Level (*Dig*)	0.195	0.135	0.056	0.695
Marketization Maturity (*Ato*)	9.031	1.695	5.509	12.864
Residents' Consumption Capacity (*Exp*)	2.943	0.319	2.330	3.762
Urbanization Level (*Tow*)	0.639	0.115	0.429	0.893
Social Consumption Level (*Con*)	0.252	0.161	0.020	0.526
Per Capita Disposable Income (*Inc*)	1.039	0.389	0.213	2.056
Sports Industry Innovation Level (*Sco*)	30.619	11.359	17.820	62.590

3.3 Model Construction

3.3.1 Benchmark Regression Model

To examine Hypothesis 1 and investigate the direct effect of Gre on the SICR, a panel regression model is formulated as follows:

$$SICR_{it} = \alpha_0 + \beta_0 Gre_{i_t} + \sum \gamma_i X_{it} + \varepsilon_{it} \quad (5)$$

3.3.2 Mediation Effect Model

To examine Hypothesis 2 and assess the indirect effect of Gre on SICR through the sports industry innovation level (Sco), the following mediation effect models (Equations (6) and (7)) are developed, based on Equation (5):

$$Sco_{it} = \alpha_1 + \beta_1 Gre_{i_t} + \sum \gamma_i X_{it} + \varepsilon_{it} \quad (6)$$

$$SICR_{it} = \alpha_2 + \beta_2 Gre_{i_t} + \beta_3 Sco_{it} + \sum \gamma_i X_{it} + \varepsilon_{it} \quad (7)$$

3.3.3 Threshold Effect Model

SICR develops progressively over the long-term, and the effect of Gre on SICR may demonstrate nonlinear characteristics. To examine Hypotheses 3 through 6, a panel data threshold regression model, as proposed by [15], is employed. Models are constructed with economic development level (Pgdp), digital economy level (Dig), marketisation degree (Ato), and residents' consumption capacity (Exp) serving as the threshold variables:

$$SICR_{it} = a_3 + \delta_1 Gre_{it} \times I(Pgdp_{it} \le \theta) + \delta_2 Gre_{it} \times I(Pgdp_{it} > \theta) + \sum \gamma_i X_{it} + \varepsilon_{it} \quad (8)$$

$$SICR_{it} = a_4 + \delta_3 Gre_{it} \times I(Dig_{it} \le \theta) + \delta_4 Gre_{it} \times I(Dig_{it} > \theta) + \sum \gamma_i X_{it} + \varepsilon_{it} \quad (9)$$

$$SICR_{it} = a_5 + \delta_5 Gre_{it} \times I(Ato_{it} \le \theta) + \delta_6 Gre_{it} \times I(Ato_{it} > \theta) + \sum \gamma_i X_{it} + \varepsilon_{it} \quad (10)$$

$$SICR_{it} = a_6 + \delta_7 Gre_{it} \times I(Exp_{it} \le \theta) + \delta_8 Gre_{it} \times I(Exp_{it} > \theta) + \sum \gamma_i X_{it} + \varepsilon_{it} \quad (11)$$

In Equations (5) and (7) to (11), SICRit denotes the sports industry resilience index for province i in year t, while Greit represents the level of Green finance development in province i for the corresponding year. Xit refers to the set of control variables; α is the intercept term, β and γ are the regression coefficients to be estimated, and ε signifies the error term. θ indicates the threshold value, and I(·) is a characteristic function that assumes a value of 1 when the specified condition within the parentheses is met, and 0 otherwise. The corresponding decision-support framework is illustrated in Figure 1.

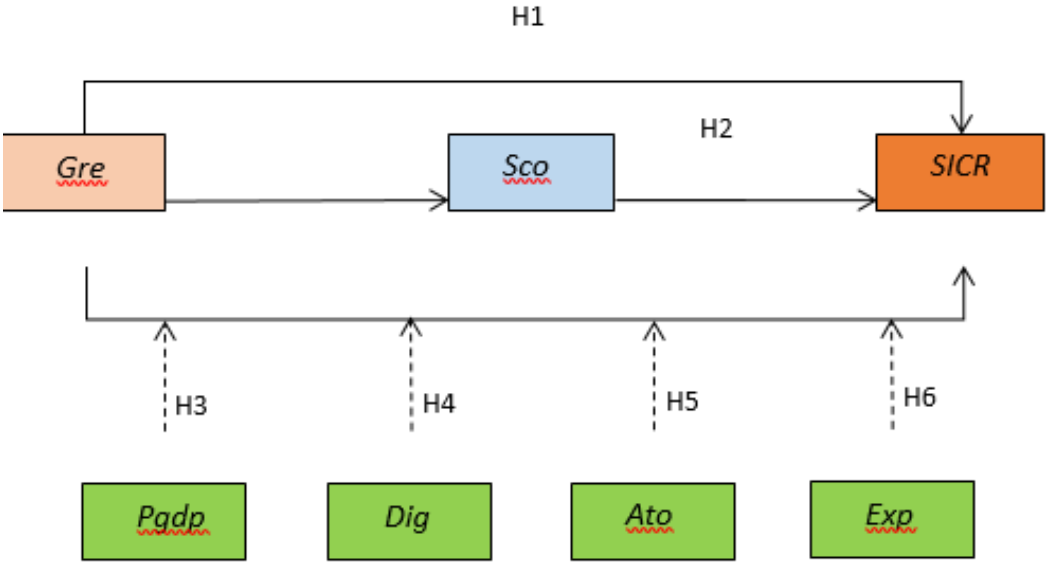

Fig.1: Decision-Support Framework

4. Results and Analysis

4.1 Analysis of Benchmark Regression Results

To mitigate the influence of extreme values, all variables are subjected to 1% winsorisation. Table 6 summarises the results of the regression analysis examining the effect of Gre on SICR. Column (1) presents the baseline model without inclusion of control variables or time effects. Building on this, Column (2) incorporates the control variables. Column (3) further accounts for time effects while excluding regional effects relative to Column (2), whereas Column (4) introduces regional effects without controlling for time. Column (5) simultaneously includes both control variables and joint controls for time and regional effects, with the corresponding results displayed therein. Across conventional significance thresholds, the coefficient of Gre is positive and

statistically significant, indicating that regional Gre development has a substantial effect in enhancing SICR. Furthermore, as control variables and time and regional effects are progressively incorporated, the model's goodness of fit improves, reflecting increased explanatory power and predictive accuracy. Collectively, these findings provide support for Hypothesis 1.

Table 6
Baseline Regression Outcomes

	(1)	(2)	(3)	(4)	(5)
Variable	***SICR***	***SICR***	***SICR***	***SICR***	***SICR***
Gre	0.3026***	0.0956**	0.0930*	0.0919**	0.1441**
	(0.0305)	(0.0387)	(0.0487)	(0.0400)	(0.0595)
pgdp		0.0064***	0.0042	0.0064***	0.0118***
		(0.0022)	(0.0026)	(0.0022)	(0.0042)
Ato		0.0085*	0.0126**	-0.0007	0.0028
		(0.0048)	(0.0053)	(0.0050)	(0.0057)
Tow		0.0432	-0.1463	0.3439***	0.5351**
		(0.1019)	(0.1144)	(0.1171)	(0.2319)
Con		0.1211**	0.0434	0.0656	0.0073
		(0.0562)	(0.0609)	(0.0741)	(0.0793)
Inc		0.0239	0.0062	0.0135	0.0132
		(0.0150)	(0.0157)	(0.0145)	(0.0152)
Lri		0.0035***	0.0045***	0.0025***	0.0030***
		(0.0008)	(0.0009)	(0.0009)	(0.0010)
Time Fixed	No	No	Yes	No	Yes
Region Fixed	No	No	No	Yes	Yes
Constant	0.0541**	-0.1787***	-0.0989	-0.2294***	-0.4202***
	(0.0246)	(0.0558)	(0.0688)	(0.0580)	(0.1474)
N	240	240	240	240	240
R^2	0.3037	0.4775	0.5028	0.4990	0.5289

4.2 Heterogeneity Analysis

To examine potential regional and temporal heterogeneities in the effect of Gre on SICR, the 24 provinces are first categorised into eastern and central-western regions according to conventional geographical divisions. From a temporal perspective, 2018 represents a key juncture, as China's Pilot Gre Reform and Innovation Zones (established in 2017) began substantive operations, with provinces such as Zhejiang and Jiangxi initiating the application of green credit and green bonds in sports infrastructure. In the same year, the issuance of the Guiding Opinions on Accelerating the Development of the Fitness and Leisure Industry explicitly advocated for "promoting the integration of fitness and leisure facilities with ecological protection" and "supporting green fitness and leisure projects," embedding "green development" within the development requirements of sports industry segments and providing a policy foundation for the deployment of Gre. Accordingly, the sample period is divided into two intervals—2014–2018 and 2019–2023—for further analysis. Regression outcomes are reported in Table 7.

Columns (6) and (7) indicate that Gre exerts no statistically significant effect on SICR in either the eastern or central-western regions. This outcome reflects regional disparities in the development of China's sports industry chain. Despite the eastern region possessing abundant green financial resources, SICR enhancement depends more heavily on high-end technological innovation, brand development, and other factors, which dilute the capital support effect of Gre. Additionally, homogenised competition within the eastern sports industry has intensified, resulting in Gre investments potentially being channelled into redundant infrastructure rather than translating effectively into resilience improvements. In contrast, central-western regions face a

weaker Gre foundation and limited capital scale, which is inadequate to support the full spectrum of the sports industry—from infrastructure construction to format innovation. Moreover, the predominance of resource-dependent projects with short industrial chains and low value-added limits the capacity of central-western provinces to leverage Gre effectively, preventing the formation of scale effects.

Columns (8) and (9) reveal that Gre had a significant positive influence on SICR during 2014–2018, but this effect becomes statistically insignificant in the 2019–2023 period. During 2014–2018, China's sports industry experienced rapid expansion, bolstered by the issuance of State Council Document No. 46 in 2014, which facilitated the growth of sports infrastructure and the proliferation of events. At this stage, improvements in Gre were particularly effective in supporting the foundational construction of the sports industry chain; for instance, green credit funded venue construction incorporating energy-saving technologies and sustainable building materials, while green bonds supported the initial organisation of green events, establishing the infrastructure and operational basis for industrial chain resilience. By contrast, in 2019–2023, the sports industry transitioned into a phase of high-quality development and structural adjustment. At this point, the construction of resilience depended on multiple factors including technological innovation, market expansion, and industrial integration, which limited the capacity of Gre alone to enhance industrial chain resilience. The emergence of new formats, such as online sports services and smart sports equipment, further dispersed the impact of Gre, diminishing its direct influence on SICR.

The comprehensive heterogeneity analysis suggests that the positive effect of Gre development on SICR emerges only over a broad geographical scope and extended temporal horizon. This observation aligns with the functional characteristics of Gre in supporting industrial resilience. Geographically, the spillover of green financial resources and the coordinated operation of industrial chains often require cross-regional collaboration to overcome the limitations of local factor endowments, enabling Gre to effectively provide capital, technological guidance, and risk mitigation at a larger spatial scale. Temporally, the accumulation of industrial resilience involves sustained processes such as infrastructure upgrading, format innovation, and institutional optimisation, which depend on prolonged investment and gradual realisation of effects. Only through continuous input and dynamic adjustment can Gre align with the developmental trajectory of the sports industry, thereby generating a stable and significant positive effect on SICR.

Table 7
Results of Heterogeneity Analysis

	(6)	**(7)**	**(8)**	**(9)**
Variable	Eastern	Central and Western	2014—2018	2019—2023
Gre	0.0721	-0.010	0.1965*	0.0507
	(0.1103)	(0.0726)	(0.1127)	(0.0592)
Control	Yes	Yes	Yes	Yes
Constant	-0.7976	-0.5918	-0.0895	-0.9733
	(0.2453)	(0.2355)	(0.1449)	(0.5420)
Time/Region Fixed	Yes/ Yes	Yes/ Yes	Yes/ Yes	Yes/ Yes
N	100	140	120	120
R^2	0.7174	0.5313	0.7158	0.4244

Note: The eastern regions in this study sample include Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong and Guangdong, while the central and western regions include Shanxi, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan, Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan and Ningxia.

4.3 Robustness Tests and Endogeneity Issues

To assess the robustness of the regression results, six approaches are employed to address both

robustness and potential endogeneity issues. First, the core explanatory variable is replaced. Given that green bonds constitute a central component of Gre, following [58], the ratio of total green bond issuance to overall bond issuance is adopted as an alternative measure (Gre') for Gre, and the analysis is re-conducted. Second, the sample size is adjusted. Municipalities directly under the Central Government possess resource allocation advantages that may distort the effect of Gre on the green development of the digital economy [25]; therefore, these municipalities are excluded for robustness verification. Third, multi-dimensional joint fixed effects are considered. Beyond controlling for regional and temporal effects, the interaction term "region × time" is additionally incorporated. Fourth, the econometric method is substituted. To address heteroscedasticity and autocorrelation-consistent standard errors, a non-parametric covariance matrix estimation approach [10] is employed to re-estimate the baseline model. The results, presented in Columns (10)–(13) of Table 8, indicate that the effect of Gre on SICR remains statistically significant, confirming the reliability of the baseline regression outcomes.

Fifth, an instrumental variable approach is applied. The green coverage ratio (Cov) reflects a city's capacity for green development, environmental governance, and environmental awareness, aligning with the concept of green development and satisfying the correlation requirement. The lagged green coverage ratio for the preceding three periods is historical and unlikely to directly influence current SICR, rendering it exogenous [52]. As shown in Columns (14)–(15) of Table 8, the first-stage regression coefficient is highly significant at the 1% level, with a first-stage F-statistic of 27.82, surpassing the 10% threshold for weak instrument testing. The KP-LM statistic equals 12.31, rejecting the null hypothesis of insufficient instrument identification, thus confirming the validity of the selected instruments. In the second-stage regression, the coefficient of Gre remains significantly positive at the 5% level, indicating that Gre continues to be a significant determinant of SICR after accounting for endogeneity.

Table 8
Results of Robustness Tests

Variable	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	Replace the Core Explanatory Variable	Adjust the Sample Size	Replace the Econometric Method	Multi-Dimensional Joint Fixed Effects	IV-2sls		SYS-GMM
					The First Stage	The Second Stage	
Gre'	1.0913**	0.2122***	0.1441**	0.1375**			
	(0.4397)	(0.0654)	(0.0489)	(0.0591)			
Gre						0.1965**	0.2861**
						(0.0817)	(0.1333)
Cov					0.6627***		
					(0.1838)		
L.*SICR*							1.2463**
							(0.6687)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time/Region Fixed	Yes/ Yes	Yes/ Yes	Yes/ Yes	Yes/ Yes	Yes/ Yes	Yes/ Yes	Yes/ Yes
Kleibergen-Paap rk Wald F					27.82[16.38]		
Kleibergen-Paap rk LM					12.31***		
N	240	200	240	240	240	240	216
AR(2)							0.941
Hansen							0.266
R^2	0.5270	0.5330	0.5289	0.5388	0.5117	0.096	-

Sixth, a dynamic panel model employing the system GMM method is constructed, following Liu et al. [28], by including the first-order lag of SICR (denoted as L.SICR). The results, reported in Column (16) of Table 8, demonstrate that the p-value of the Sargan test exceeds 0.1, confirming that the model passes the over-identification test. Additionally, the AR(2) p-value is greater than 0.1, supporting the null hypothesis of no autocorrelation in the error term and confirming that the model passes the serial correlation test. Consequently, the system GMM estimates are valid, and the regression coefficient of the digital economy level remains strongly positive. Collectively, these robustness and endogeneity analyses further substantiate Hypothesis 1.

4.4 Mechanism Analysis

Building on the preceding analysis, regional innovation capacity is introduced as a mediating variable to examine its role in the relationship between the digital economy and the upgrading of the sports industry structure (Table 9). The empirical findings indicate that Model (15), which evaluates the effect of Gre development on innovation levels within the sports industry, produces a positive regression coefficient that is statistically significant. In Model (16), where the mediating variable is incorporated into the regression framework, the coefficient remains positive and attains significance at the 10% level. To assess the robustness of these findings, the Bootstrap method was employed to test the mediating effects (Table 10), with 500 resampling iterations conducted.

Table 9
Regression Results of Mediation Effect

	(5)	**(15)**	**(16)**
	SICR	*SICR*	*SICR*
Gre	0.1441**	0.0940**	0.1048*
	(0.0595)	(0.0454)	(0.0577)
Sco			0.3474***
			(0.0891)
Control	Yes	Yes	Yes
Time/Region Fixed	Yes/ Yes	Yes/ Yes	Yes/ Yes
N	240	240	240
R^2	0.5289	0.2176	0.5717

The results reveal that neither the direct effect nor the indirect mediating effect includes zero within the 95% confidence interval, thereby confirming the validity of the mediating role. Notably, 23.8% of the total effect of Gre on SICR is transmitted via improvements in innovation capacity within the sports industry, providing empirical support for Hypothesis 2.

Table 10
Results of Bootstrap Test

Item	**Effect**	**Coefficient**	**Std. Error**	**95% Confidence Interval**		**Mediation Effect Ratio**
	Indirect Eff	0.0344	0.0035	0.0055	0.0851	
Gre-Sco- SICR	Direct Eff	0.1096	-0.0101	0.0102	0.2856	23.8%
	Total Eff	0.1441	-0.0067	0.0399	0.3521	

4.5 Threshold Effect Analysis

Based on the preceding analysis, a heterogeneous panel threshold model is constructed, with per capita economic development level (Pgdp), digital economy level (Dig), marketization maturity (Ato), and residents' consumption capacity (Exp) serving as threshold variables. As reported in Table 11, Pgdp and Exp satisfy the single threshold test but do not pass the double threshold test, with estimated threshold values of 8.5757 and 0.2299, respectively. In contrast, Ato and Exp pass the

double threshold test but fail the triple threshold test; the threshold estimates for Ato are 9.333 and 11.076, while those for Exp are 2.9705 and 3.2988. Additionally, likelihood ratio (LR) trend plots (Figures 2–5) are presented, in which the minimum LR statistic corresponds to the identified single threshold value.

Table 11
Results of Threshold Effect Tests

Explained Variable	Threshold Variable	Threshold Setting	*F*-Value	Critical Value			Threshold Value
				10%	5%	1%	
SICR	*Pgdp*	Solo Threshold	29.422***	11.492	14.64	23.006	8.5757
		Dual Threshold	7.591	10.676	13.376	23.867	—
	Dig	Solo Threshold	69.345***	15.777	19.140	33.765	0.2299
		Dual Threshold	12.378	14.821	18.136	24.975	—
	Ato	Solo Threshold	16.866**	10.608	12.542	20.271	9.3330
		Dual Threshold	10.878***	9.631	11.945	14.920	11.0760
		Triple Threshold	5.424	16.589	18.322	23.581	—
	Exp	Solo Threshold	34.166***	13.417	16.380	23.336	2.9705
		Dual Threshold	31.571***	8.746	10.366	15.478	3.2988
		Triple Threshold	6.240	13.803	15.440	20.928	—

Further examination of the threshold regression outcomes (Table 12) reveals that, after incorporating control variables and accounting for regional and temporal effects, Models (17) and (18) demonstrate that when Pgdp ≤ 8.5757 or Dig ≤ 0.0191, the effect of Gre on SICR is not statistically significant.

Table 12
Threshold Regression Results

(17)		**(18)**		**(19)**		**(20)**	
SICR	**Coefficient**	***SICR***	**Coefficient**	***SICR***	**Coefficient**	***SICR***	**Coefficient**
(*Pgdp*≤8.5757)	0.0495	(*Dig*≤0.0191)	0.0191	(*Ato*≤9.3330)	0.0197	(*Exp*≤2.9705)	0.0355
	0.0490		(0.0446)		(0.0527)		(0.0414)
	0.3443**		0.2270***	(9.3330＜	0.0718	(2.9705＜	0.1136**
(*Pgdp*＞8.5757)	0.0597	(*Dig*＞0.2270)	(0.0529)	*Ato*≤11.0760)	(0.0482)	*Exp*≤3.2988)	(0.0413)
				(*Ato*＞11.0760)	0.1495**	(*Exp*＞3.2988)	0.2489***
					(0.0587)		(0.0564)
Control	Yes	Control	Yes	Control	Yes	Control	Yes
Time/Region Fixed	Yes/Yes	Time/Region Fixed	Yes/Yes	Time/Region Fixed	Yes/Yes	Time/Region Fixed	Yes/Yes
N	240	*N*	240	*N*	240	*N*	240
R^2	0.5585	R^2	0.6207	R^2	0.5497	R^2	0.6214

Conversely, when Pgdp > 8.5757 or Dig > 0.2270, Gre exhibits a positively significant effect on SICR. This indicates that as economic development and digital economy levels increase, the enhancing influence of Gre on SICR becomes more pronounced, thereby supporting Hypotheses 3 and 4.

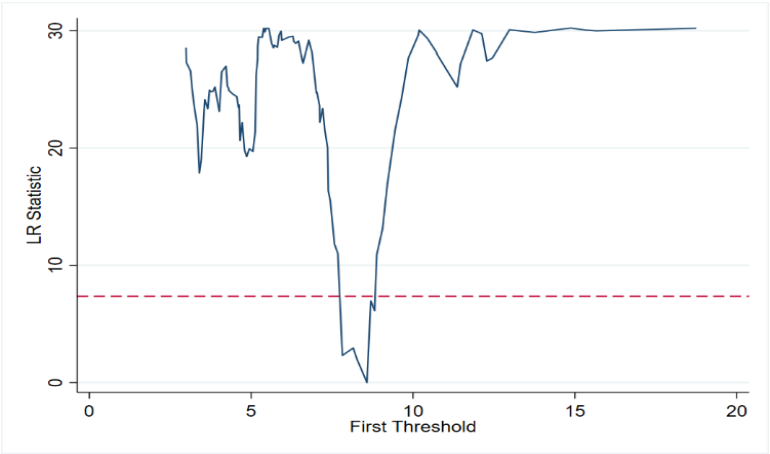

Fig.2: LR Trend Chart with Pgdp

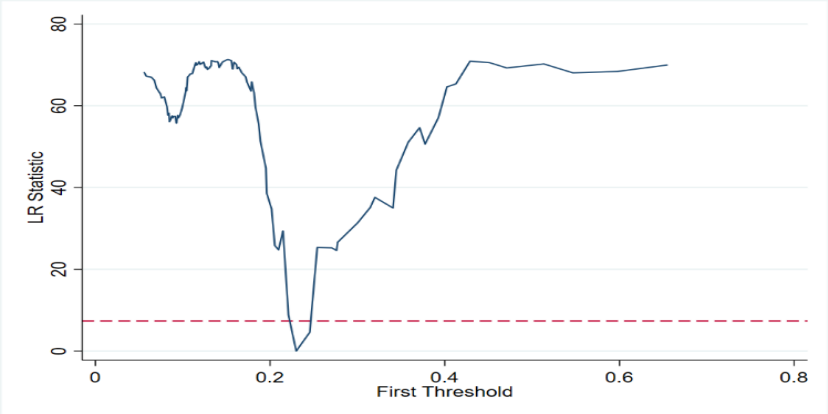

Fig.3. LR Trend Chart with Dig

In Model (19), Ato displays a double threshold effect. Specifically, when Ato ≤ 9.3330 or 9.3330 < Ato ≤ 11.0760, the effect of Gre on SICR is insignificant; however, when Ato > 11.0760, Gre's promoting effect on SICR is positive and statistically significant at the 5% level. These results suggest that improvements in marketisation maturity amplify the impact of Gre, corroborating Hypothesis 4.

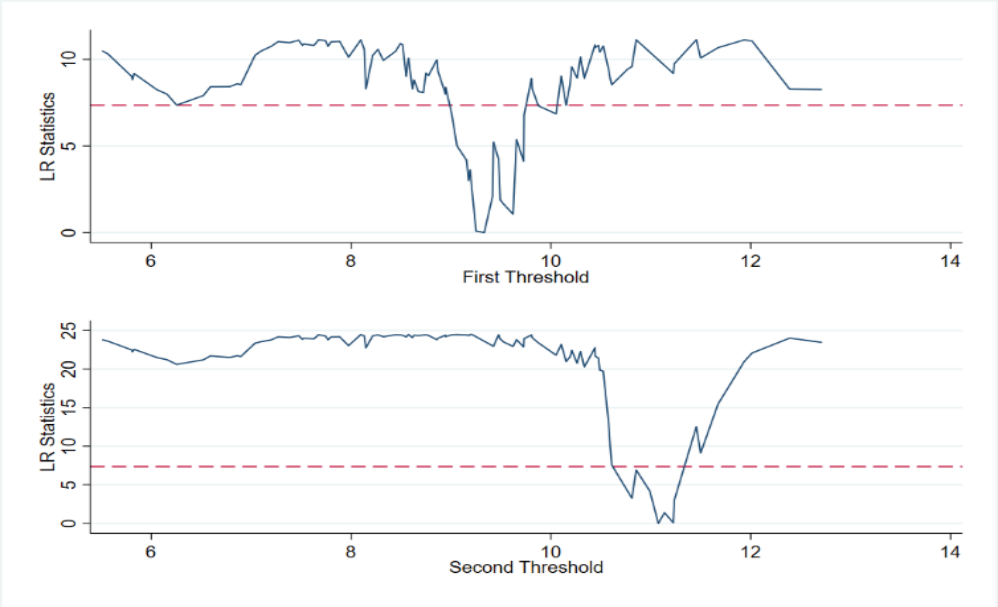

Fig.4. LR Trend Chart with Ato

Similarly, Model (20) indicates that Exp exhibits a double threshold effect. When Exp ≤ 2.9705, Gre has no significant effect on SICR; when 2.9705 < Exp ≤ 3.2988, the effect of Gre on SICR is significantly positive, with a coefficient of 0.1136; and when Exp > 3.2988, the promoting effect strengthens further, with a coefficient of 0.2489. These findings demonstrate that as residents' consumption capacity rises, the positive effect of Gre on SICR becomes increasingly substantial, confirming Hypothesis 5.

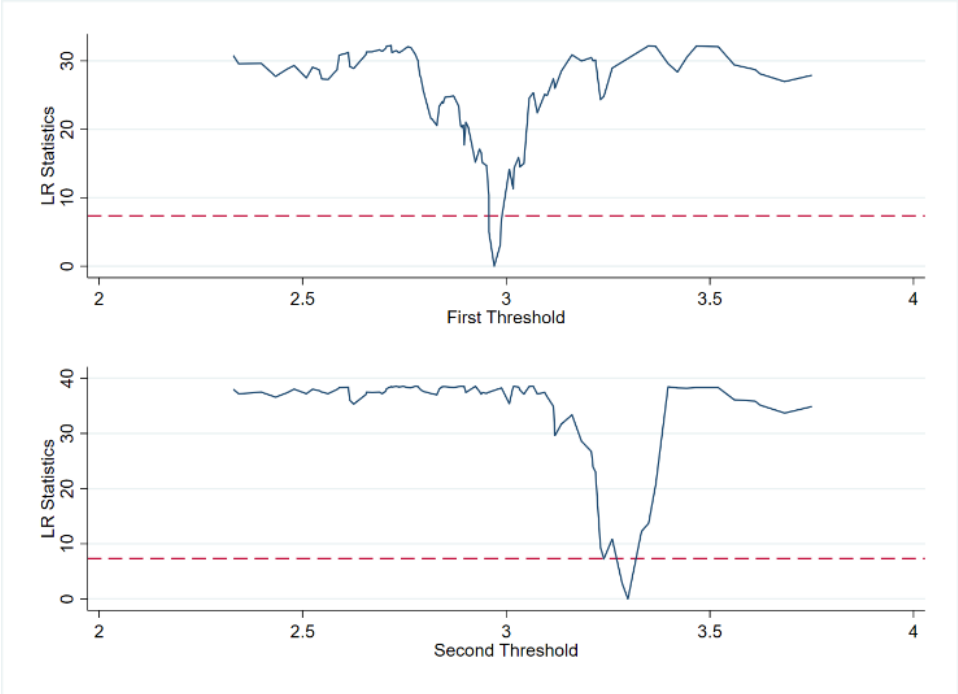

Fig.5: LR Trend Chart with Exp

5. Conclusions and Decision-Making

5.1 Conclusions

Using data from 24 provincial-level regions in China spanning 2014–2023, this study quantifies the levels of Gre and SICR and systematically investigates the effect of Gre on SICR through a two-way fixed effects model, a structural equation mediating model, and a multi-threshold effect model. The analysis yields the following key findings:

1. Enhancements in Gre exert a statistically significant positive impact on the overall resilience of China's sports industry chain. This effect remains robust across multiple robustness and endogeneity checks. Nevertheless, the magnitude of this impact exhibits temporal heterogeneity.
2. The innovation capacity within the sports industry functions as a partial mediator in the pathway through which Gre influences SICR, with the mediating effect accounting for 23.8% of the total effect.
3. The influence of Gre on SICR is non-linear. Gre contributes to improvements in SICR only when the regional economic level, digital economy development, marketisation maturity, and residents' consumption capacity exceed their respective threshold values.

5.2 Decision-Making

Building on the findings outlined above, Table 13 presents targeted policy and decision-making recommendations from the perspectives of government agencies, enterprises, and financial institutions across different regions in China. Detailed explanations of these recommendations are

provided in Sections 5.2.1–5.2.3.

Table 13
Decision Implications for Governments, Enterprises, and Financial Institutions

Subject	Decision-Making	Specific Measures
Governments	Building a Policy Support System	Formulate differentiated Gre support policies Breaking multi-dimensional threshold constraints Strengthening innovation incentives and regulatory guarantees Activate the intermediary effect of green innovation
Enterprises	Focusing on Innovation and Resilience Building	Optimize industry chain management Strengthen green information disclosure and credit construction Innovate the green financial product system
Financial Institutions	Innovate the Green Financial Service Model	Improve the risk assessment mechanism Enhance digital empowerment and cross-institutional cooperation

5.2.1 For Governments: Building a Policy Support System to Break Down Threshold Constraints

Provincial and municipal authorities should develop differentiated Gre support policies to account for temporal heterogeneity in its impact. Given that the influence of Gre on SICR varies across time periods, dynamic policy adjustments should be implemented according to the regional stage of development and the maturity of the sports industry. In eastern provinces, where the sports industry has a longer history and a more complete industrial chain, emphasis should be placed on innovating green financial instruments, such as “green bonds for the sports industry” and “carbon-neutral sports project special loans,” while prioritising support for high-end sectors, including energy-efficient renovations of sports venues and eco-friendly event operations. For central and western provinces, the focus should be on enhancing basic financial services by establishing “Gre + sports industry” special subsidy funds and offering interest subsidies and tax incentives to support green technology research, development, and procurement of sustainable raw materials by small and medium-sized sports enterprises, thereby reducing financing costs in the early stages of industrial chain development. Concurrently, a cross-regional policy coordination mechanism should be formulated to facilitate the transfer of green financial resources from eastern to western regions via industrial relocation and technological cooperation, mitigating regional disparities in Gre empowerment.

Removing multi-dimensional threshold constraints is critical to activating the positive effects of Gre. To enhance economic development, Gre and sports industry advancement should be integrated into local economic performance indicators, and local governments should be encouraged to attract social capital through public-private partnerships to develop integrated industrial parks combining sports events, fitness and leisure, and green services, thereby stimulating regional growth through industrial agglomeration. In the context of digital economy empowerment, a “National Sports Industry Gre Big Data Platform” should be established to consolidate data on enterprise green credit, industrial chain operations, and financial product offerings, employing blockchain technology to enable precise alignment of financing needs with financial resources.

Additionally, targeted subsidies should support digital transformation initiatives within sports enterprises to increase industrial chain digitalisation. For market maturity optimisation, market-oriented reforms in the sports industry should be deepened, including easing restrictions on sports event approvals and venue operations, and implementing a market-based pricing mechanism for Gre services to guide financial institutions in dynamically adjusting interest rates according to enterprise resilience. Regarding residents’ consumption capacity, green sports consumption

vouchers should be issued, and “sports + culture and tourism” consumption scenarios promoted to stimulate demand for eco-friendly sports products. Furthermore, improvements to the income distribution system should be made to increase consumption capacity among middle- and low-income groups, providing a robust market foundation for Gre to enhance SICR.

Strengthening innovation incentives and regulatory frameworks is essential to fully harness the mediating effect of the sports industry’s innovation capacity. The government should intensify support for innovation projects in the sports sector, including research and development of green materials and intelligent venue technologies, while providing market promotion subsidies for innovative products that achieve green certification. Enterprise investment in innovation and resultant achievements should be incorporated as key criteria in green credit evaluations, directing financial resources toward innovative sports enterprises. Simultaneously, Gre regulatory oversight should be enhanced, including the improvement of Gre standards, clarification of recognition criteria, and the establishment of information disclosure requirements for green projects in the sports industry. A risk compensation mechanism for Gre should be implemented to cover a proportion of potential non-performing loans arising from financial institutions’ support of green projects, thereby incentivising participation and ensuring the sustained positive impact of Gre on SICR.

5.2.2 For Enterprises: Focusing on Innovation and Resilience Building, and Proactively Engaging with Gre

Prioritising green innovation to activate the mediating effect. Sports enterprises should intensify investment in green innovation, concentrating on the critical gaps and green transformation needs within the industry chain. At the production stage, enterprises ought to develop environmentally sustainable sports equipment and materials, including biodegradable fabrics for sports apparel and energy-efficient lighting systems for stadiums, thereby reducing the environmental footprint of the industrial chain. At the operational level, enterprises should innovate eco-friendly event management models, incorporating low-carbon transportation, green catering, and renewable energy sources to establish a "carbon-neutral event" brand that strengthens the industry chain’s green competitiveness. At the service level, they should advance intelligent sports service platforms that integrate sports data, health management, and eco-conscious consumption functions, while designing innovative “online + offline” green service scenarios. Simultaneously, enterprises are encouraged to reinforce collaboration with universities and research institutions by establishing industry-academia-research joint innovation systems, accelerating the translation of green innovation outcomes into practical applications, and transforming innovation advantages into drivers for enhancing SICR, thereby providing a foundational support mechanism for the implementation of Gre.

Optimising industry chain management to enhance resilience and align with Gre. Sports enterprises should strengthen industry chain integration and risk management capabilities to increase their attractiveness to green financial resources. In terms of integration, leading enterprises should assume a coordinating role by consolidating upstream and downstream resources through mergers, acquisitions, and strategic alliances, constructing a comprehensive green industrial system that improves collaborative efficiency and overall risk resistance. Small and medium-sized enterprises should target niche markets, developing specialised green products and services that complement leading enterprises and enrich the diversity of the industry chain. Regarding risk control, enterprises should establish early warning mechanisms within the industry chain, utilising big data technologies to monitor supply, market demand, and policy fluctuations in real time, and preparing contingency strategies in advance. Furthermore, enterprises should

enhance supply chain management, develop long-term partnerships with green suppliers, ensure a stable supply of sustainable raw materials, and reduce the likelihood of disruptions. By bolstering SICR, enterprises can more readily meet Gre's credit criteria and secure financial support.

Strengthening green information disclosure and credit mechanisms to lower financing costs. Sports enterprises should establish comprehensive green information disclosure systems in accordance with Gre standards, routinely reporting on green production practices, innovation investments, and environmental performance to improve transparency and credibility. Enterprises should actively pursue green certifications, such as environmental management system certification and green product certification, to elevate their green credit ratings. Concurrently, internal green financial management systems should be implemented to standardise fund allocation and accounting, ensuring that green finance is directed to designated projects and improving the efficiency of fund utilisation. By reinforcing green credit infrastructure, enterprises can mitigate information asymmetry with financial institutions, access more favourable interest rates for green financial products, obtain higher credit limits, and create a virtuous cycle whereby green innovation, enhanced industrial chain resilience, and financial support mutually reinforce one another.

5.2.3 For Financial Institutions: Innovate Service Models and Precisely

5.2.3.1 Match the Demands of Gre

(1) Innovating the green financial product system to satisfy the diverse needs of the sports industry. Financial institutions should develop differentiated green financial products tailored to the financing characteristics of enterprises across different segments and scales within the sports industry. For long-term projects, including the construction of large-scale sports venues and the operation of eco-friendly events, instruments such as "Green Project Revenue Bonds" and "Green REITs" can be introduced to expand financing channels through asset securitisation. To address the short-term funding needs of small and medium-sized sports enterprises, such as green technology research and development or equipment renewal, products like "Green Credit Loans" and "Green Supply Chain Finance" should provide targeted support to upstream and downstream SMEs connected to core enterprises via credit mediation. Furthermore, considering the mediating effect of innovation within the sports industry, "Green Innovation Loans" can be established, integrating indicators such as enterprise innovation investment and patent counts into credit assessment procedures, while offering preferential interest rates to enterprises engaging in green innovation. The implementation of a "green insurance + credit" linkage model can further cover environmental and operational risks during project construction and operation, mitigate financial institutions' credit risk, and enhance their willingness to extend green finance.

(2) Improving the risk assessment mechanism to address threshold effects and heterogeneity. Financial institutions need to incorporate the "multi-dimensional threshold" and "temporal heterogeneity" characteristics identified in the research to construct a dynamic, differentiated risk assessment framework. At the regional level, credit standards should be calibrated according to local economic development stages, digital economy levels, and other threshold conditions. Regions exceeding the thresholds may receive higher credit limits and risk tolerance for green sports projects, whereas regions below the thresholds should prioritise support for smaller-scale green projects aligned with local characteristics, such as rural sports tourism initiatives or community-based green fitness facilities. Adopting a phased "point-to-surface" approach enables regions to progressively reach the threshold conditions. Temporally, credit policies should be adjusted dynamically in response to variations in the promoting effect of Gre. During peak periods of the sports industry or windows of policy support, the intensity of credit provision should be increased,

with phased interest rate discounts introduced. Conversely, during periods of industrial adjustment, enhanced risk monitoring, loan extensions, and renewal measures should be implemented to assist enterprises in overcoming temporary challenges and maintaining industrial chain stability.

(3) Enhancing digital empowerment and cross-institutional collaboration to improve service efficiency and coverage. Financial institutions should leverage digital technologies to optimise the precision and effectiveness of green financial services. Establishing a "Green Financial Service Platform for the Sports Industry" would allow integration of enterprise green credit data, industrial chain information, and consumption metrics, while employing big data and artificial intelligence to construct resilience assessment models for intelligent financing allocation and real-time risk monitoring. Online financing application and approval processes should be streamlined to shorten loan approval cycles and accommodate the urgent funding needs of sports enterprises. Additionally, collaboration with government agencies, industry associations, and research institutions should be strengthened: sharing enterprise green data with government departments allows utilisation of governmental risk compensation mechanisms to reduce credit risk; partnering with industry associations facilitates rigorous project screening and evaluation, enhancing the accuracy of green project selection; cooperation with research institutions can further develop Gre risk assessment models, improving the identification and management of risks associated with green sports projects.

In conclusion, governments should establish a coherent policy framework to remove threshold constraints; enterprises must connect with financial resources through innovation and resilience-building; and financial institutions should continuously innovate service models and precisely align financial provision with the demands of Gre. The coordinated efforts of these three actors can fully unlock the positive effects of Gre on SICR, driving the high-quality, sustainable development of China’s sports industry and strengthening the competitiveness of the industrial chain in responding to market volatility and environmental challenges.

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