Information Systems and Economics (2024)
Clausius Scientific Press, Canada

DOI: 10.23977/infse.2024.050424
ISSN 2523-6407 Vol. 5 Num. 4

Study on the Coupled and Coordinated Development of Green Finance and Circular Economy in Jiangsu, Zhejiang and Shanghai

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Keywords: Green finance; circular economy; coupling

Abstract: This article addresses the issue of the coordinated development of green finance and circular economy in the economically advanced provinces of Jiangsu, Zhejiang, and Shanghai in Chinese mainland. A comprehensive evaluation framework is constructed, drawing upon relevant theoretical research, to measure the development index of green finance and the status of circular economy. Based on the provincial-year panel data from 2013 to 2021 in the Jiangsu, Zhejiang, and Shanghai regions, the comprehensive indicators are calculated using the entropy method, and the coupling coordination model is employed to analyze the coordinated development relationship between the circular economy and green finance in the region. The theoretical analysis thoroughly examines the mechanisms of the coordinated development of green finance and circular economy in the three regions, while the empirical analysis further verifies the degree of coordination and coupling. Finally, based on the findings from the theoretical and empirical analyses, targeted policy recommendations are proposed.

1. Introduction

1.1 Background of the study

The current issues of severe environmental degradation, ecosystem deterioration, and near depletion of resources have become urgent global challenges that require immediate attention from all of humanity. These problems are crucial to the normal survival of human beings and the development of society. Since the implementation of China's reform and opening-up policy, the unsustainable development model has led to the brink of collapse of the ecosystem, the nearing of environmental capacity limits, and the escalating severity of ecological environmental problems. It has been proven that in order to achieve sustainable regional economic development, it is imperative to prioritize ecological civilization and environmental security. It is the collective responsibility of the entire society and all of humanity to actively respond to the calls from international organizations for inclusive, persistent, and sustainable development, strengthen the sense of responsibility, and strive to build a mutually beneficial and win-win community of shared

future for mankind. At the core of the circular economy lies the realization of multiple, repeated, and efficient utilization of resources to maximize benefits. It is an effective approach that harmonizes ecological environmental protection with economically efficient development. It aligns perfectly with the path of comprehensive green transformation and development of China's economy and society, providing a roadmap for sustainable economic development. Finance is not only the outcome of economic development but also a driving force behind economic evolution. Against the backdrop of an increasingly interconnected global economy and financial integration, finance occupies an irreplaceable strategic position in a country's sustainable and enduring development. Similarly, the high-quality development of the circular economy requires continuous financial support to provide sustainable momentum. Therefore, the delicate balance between environmental protection and effective resource allocation has given rise to the development of green finance in China. Green finance combines financial activities with the efficient utilization of resources and ecological civilization, aiming to achieve inclusive, stable, and sustainable socio-economic development. Unlike traditional finance, the most prominent characteristic of green finance lies in its requirement for the well-being of the human living environment as a development priority, with a focus on guiding capital flows toward enterprises with low energy consumption, low pollution, and high added value, emphasizing the healthy development of green industries. Green finance and the circular economy both share sustainable development as their fundamental starting point and are closely interconnected. The orderly development of the circular economy requires substantial funding as robust support, and in turn, the circular economy is a key driver of economic transformation, playing a crucial role in environmental governance and the innovation and upgrading of green financial products.

1.2 Research significance

Based on a comprehensive review of existing relevant literature, this paper provides an in-depth analysis of green finance, circular economy, and their coupling relationship in the Jiangsu, Zhejiang, and Shanghai regions of Chinese mainland. By combining theoretical and empirical dimensions, a detailed examination of the development levels of green finance and the circular economy in these three regions is conducted, along with an exploration of the coupling and coordination mechanisms between them. Finally, using a coupling coordination model, this paper measures the degree of coupling and coordination between green finance and the circular economy in the Jiangsu, Zhejiang, and Shanghai regions from both temporal and spatial perspectives. Based on the measurement results obtained from the coupling model, the interaction between the two systems is validated using indicators, leading to relevant conclusions. Moreover, to accelerate the synergistic development of green finance and the circular economy in the Jiangsu, Zhejiang, and Shanghai regions of Chinese mainland and achieve high-quality coupling coordination, practical recommendations are proposed. These suggestions are valuable for the coupling development of green finance and the circular economy in the three regions and contribute to promoting inclusive and sustainable economic development in the area. Furthermore, by drawing upon the theoretical and practical experience of the coordinated development of green finance and the circular economy in the Jiangsu, Zhejiang, and Shanghai regions, these findings can also facilitate the faster realization of coordinated and sustainable development of green finance and the circular economy in other parts of China.

2. Literature review

2.1 Green Finance Development

A comprehensive delineation of green finance has yet to be established. The initial characterization of green finance in China was postulated by in [1] and [2]. They contended that the foundation of green finance rests upon the principles of sustainable development, and the interdependence between the two is irrefutable. At its essence, green finance entails harmonizing financial progress with the construction of ecological civilization, thereby fostering a mutually beneficial and symbiotic relationship [3]. Furthermore, Gong S. W. et al. [4] outlined green finance as an emergent financial sector, whose delineation hinges upon the efficient allocation of resource elements while concurrently upholding ecological and environmental functions. Xiong Xue-ping [5] highlights that the genesis of green finance stems from the inadequacy of ecological safeguarding barriers. The prevailing policies and market mechanisms fail to effectively address the challenges encountered in the realm of environmental protection, characterized by elevated risks and uncertainties regarding future development prospects. Consequently, numerous industries find themselves disheartened by these circumstances, while the traditional financial sector confronts a similar predicament. This conundrum engenders a profound dichotomy between economic advancement and environmental preservation. Within this dichotomy, the interplay between finance and environmental protection assumes two contrasting roles: one characterized by facilitation, wherein financial progress contributes to the abatement of pollution emissions [6-8]; the other role manifests as suppression, whereby financial development engenders heightened pollution levels [9, 10]. Nevertheless, Wang W et al. [11] contend that the relationship between the two is not a mere linear one. With the expansion of financial scale and the enhancement of operational efficiency, the impact on different pollutants in urban areas exhibits diverse temporal patterns. Regardless of the nature of the relationship between finance and environmental preservation, the advancement of green finance is an inexorable course. The prevailing economic development model necessitates an urgent transition toward green and circular practices. Merely relying on end-of-pipe regulatory approaches to safeguard the ecological environment falls short; instead, fostering industrial restructuring through financial means assumes greater significance [12]. Han Fengxia et al. [13] advocate the imperative role of government departments in promoting green financial development within the context of the new economic normal, employing a game-theoretical perspective. While constructing an index system for the development of green finance, no definitive consensus has been reached. Some scholars have devised a framework for green financial indicators by considering the aspects of green financial instruments, such as green credit, green securities, green insurance, green investment, and carbon finance [14, 15]. Conversely, other scholars have proposed comprehensive evaluation criteria for green financial development, primarily encompassing environmental benefits, industrial structure, social progress, and economic growth [4, 16].

2.2 Circular Economy Research

The genesis of the circular economy concept can be traced back to the universal-ship economic theory, which serves as an early exemplar of circular economy [17]. The notion of circular economy was initially introduced by Pearce et al. The theory of resource scarcity constitutes the theoretical and practical foundation for the emergence of circular economy, while the externality of environmental pollution stands as one of the contributors to market failure and forms the theoretical essence of circular economy. As stated in [18], the circular economy attains the objective of resource efficiency and low emissions through material exchange between the natural ecosystem and the socio-economic system. It propels the repeated recycling of natural resources, thereby

establishing a state of harmonious symbiosis between the natural ecosystem and the socio-economic system, ultimately fostering a model of coordinated development encompassing economic growth and environmental protection. The substantial consumption of non-renewable resources exacts a toll on China's rapid economic progress [19], thus making resource recycling one of the fundamental aspects of circular economy. The comprehensive development of the remanufacturing industry represents an effective means to promote resource recycling [20]. In terms of evaluating the circular economy's development, several scholars have appraised its quality based on the "3R" principle and four dimensions: economic development level, resource reduction, resource recycling, and reuse capacity [21]. Furthermore, emphasis has been placed on resource reduction, resource recycling and reuse, economic efficiency, and preventive indicators [22]. Similarly, Kang et al. have constructed a comprehensive evaluation index for circular economy, considering three levels: social stability, economic development, and ecological protection, drawing reference from the evaluation system provided by the National Development and Reform Commission. The implementation of circular economy in China encounters a series of pressing challenges. For instance, taking the Chai Damu Circular Economy Pilot Zone as an example, Xue et al. [23] discovered that the development of a low-carbon economy is hindered by inadequate financial support, limited financing channels, difficulties in obtaining loans, and an unfavorable financial investment environment. Similarly, Zheng Yumei asserts that financial support for the circular economy exhibits weaknesses. Insufficient financing channels, capital shortages, and suboptimal capital utilization efficiency constrain the financial backing for circular economy initiatives. Additionally, the development of circular economy in specific regions is also influenced by local resource environments, as resource scarcity presents a hurdle to the robust advancement of circular economy practices.

2.3 Study on the Interconnection of Green Finance and Circular Economy

Presently, the provision of financial support for the circular economy encompasses two primary dimensions. On one hand, the development of the circular economy necessitates substantial capital investment as a driving force, and the establishment of a robust financial development system can address developmental challenges. The marketization drive has effectively mitigated issues of insufficient financial support and limited financing channels for the circular economy. From the standpoint of the benefits associated with circular economy development, the influx of funds has indeed played a facilitative role [24, 25]. On the other hand, circular economy development requires the optimization and advancement of financial services, as well as innovation in financial products, thereby propelling the progressive enhancement of the financial system [26]. Feng Zhihua et al. [27] investigated the role of green finance in supporting the circular economy, exemplifying their study with the Qaidam pilot circular economy zone. Similarly, Yang and Guo Long [28] summarized the relationship between green finance and circular economy as follows: green finance possesses the ability to direct the flow of funds, channeling resources towards environmental industries, supporting their development, and alleviating financial constraints on circular economy progress. Consequently, this facilitates industrial structure upgrades and fosters circular and sustainable development. Using agricultural development as a case in point, Zhou Shufen et al. [29] conducted a study focused on the agricultural sector, verifying that sufficient financial support, accurate investment guidance, and a well-defined financial structure serve as the foundation for sustainable circular economy development in agricultural regions. They further argued that a comprehensive financial strategy can expand the scope and magnitude of agricultural circular economy development to a certain extent. Drawing on theories related to green finance and circular economy, Zhu et al. [30] deconstructed the interconnected and coordinated development mechanism of green finance and circular economy. On one hand, a well-established and highly market-oriented green

financial system provides support for the high-quality development of the circular economy. On the other hand, sound circular economy development contributes, to a certain extent, to the enhancement of the green financial system, stimulating the proactive drive for financial innovation and upgrading. Kang et al. approaching from the perspective of the green finance subsystem and representative green investments, meticulously analyze the interconnected and coordinated development of green finance and circular economy. They underscore its crucial role in promoting coordinated and high-quality development across the realms of economy, society, and the environment, emphasizing the significant impact it carries. Furthermore, the circular economy represents an effective avenue to achieve the objective of "carbon neutrality" and holds remarkable advantages for accelerating the development of green finance and ecological civilization [31].

3. Analysis of the coupling and coordination mechanism between green finance and circular economy

Currently, China's circular economy is yet to establish a model of high-quality development. Firstly, certain enterprises lack awareness of green development or still adhere to traditional economic models due to insufficient financial support. Secondly, achieving high-quality development in the circular economy necessitates continuous technological innovation. New technologies and development concepts serve as drivers for promoting the high-quality development of the circular economy, with green finance providing the enabling conditions for the emergence of such innovations. Simultaneously, the circular economy represents a significant economic development model that prioritizes economic benefits while considering ecological development benefits, thereby creating a favorable external environment for the advancement of green finance. Achieving the high-quality coordinated development of green finance and the circular economy requires adaptation to the market, policy, industrial, and social environments, ultimately realizing the objective of coordinated and sustainable development. If green finance experiences prolonged stagnation, green industries may face challenges in accessing capital, manpower, and technology, impeding their development. This, in turn, would create resistance to change in the economic development model and undermine the sustainability of the circular economy. Similarly, if the circular economy encounters extended periods of sluggishness, it becomes difficult for green industries to achieve economic returns and scale expansion, hindering their development. Consequently, green finance-related policies cannot be effectively implemented, and the risk diversification capacity of green financial instruments is greatly reduced, thereby affecting the sustainable and sound development of green finance. The coordination mechanism between green finance and the circular economy primarily encompasses three dimensions: policy, market, and industry. Policy orientation can guide public sentiment, foster public confidence in the positive development of green finance and the circular economy, and address certain market failures. Policy guidance plays a direct role in the coordinated development of green finance and the circular economy. The policies of green finance specify that its service targets are green industries and projects, directly influencing fund allocation. As the core of circular economy development lies in green industries, the implementation of relevant policies directs capital flow from traditional resource-intensive and energy-intensive industries toward resource-efficient, energy-saving, and environmentally friendly green industries. This expands financing opportunities and channels for green industries, reduces financing difficulties and costs, and facilitates the rapid advancement of green industries. This can attract greater resource mobilization towards green industries, facilitate the optimization and advancement of industrial structure, establish a supportive framework of green financial policies for the virtuous cycle development of green industries, stimulate the proactive drive for technological innovation within green industries, and consequently contribute to the

enhancement of the circular economy's industrial chain. Through the dual mechanisms of market and policy, it can effectively facilitate the aggregation of green financial capital. The development of the circular economy is intricately linked with capital support. Given the inherent characteristics of the circular economy, which entail substantial initial investments and extended cycles, subsequent progress necessitates significant financial backing across various aspects, including equipment, core technology research and development, and skilled personnel. As a financial activity, green finance possesses mechanisms that effectively optimize resource allocation efficiency, and when combined with a market-oriented financial support system as a robust funding provider, it can cater to the capital requirements of all facets within the circular economy industry's development. Green finance provides indispensable financial service support for research and development investment and technological innovation, aiding in the formation of the circular economy industry chain and further promoting industrial transformation and upgrading. The development of multiple industries engenders healthy competition, fostering the rational allocation of resources and creating conditions for the advancement of green finance and the circular economy, thus stimulating innovation within these realms. Economic development establishes the fundamental conditions for various other activities, with the state of economic development largely influencing the state of finance. Aligned with the strategic objective of constructing an ecological civilization, China is accelerating the establishment of a circular economy industrial system and driving the transformation and upgrading of traditional resource-intensive, energy-intensive, and emission-intensive industries. The rapid and orderly development of the circular economy not only improves the economic and financial development environment, social development environment, and natural environment but also fosters the sustainable growth of green finance. Moreover, it contributes to the transformation of the economic development model, provides assurances for the goal of sustainable social and economic development, stimulates greater aggregation of financial resources, integrates financial resources across multiple domains, and propels the development of green finance. The rapid growth of the circular economy leads to enhanced efficiency and efficacy of green finance services. Undoubtedly, the expansion of the circular economy will attract additional financial resources, prompting financial institutions to pursue higher-quality green financial development. These institutions must effectively integrate and innovate diverse accessible financial resources, provide tailored green financial services to distinct target groups, continuously innovate the supply side of green finance, enhance the quality of their own financial services and green financial innovation capabilities, cater to the demand for green financial services, and attract a wider recipient base. Ultimately, the development of the circular economy industry drives continuous innovation and improvement within the green financial system. With the ongoing advancement of the circular economy, the growing demand for green financial services and the benefits derived from improved green financial service levels necessitate a more comprehensive green financial system to align with it. Green financial innovation encompasses not only the creation of green products but also the innovation of green financial services and structures. This series of innovations propels the development and adaptation of the green financial system, further advancing its completeness.

4. Measurement and analysis of green finance and circular economy indicators in Jiangsu, Zhejiang and Shanghai

4.1 Indicator system construction

The advancement of the circular economy embodies the fundamental characteristics of ecological civilization and sustainable development, characterized by minimal consumption, minimal emissions, minimal pollution, and maximal output. Adhering to the "reduce, reuse, and

recycle" principle, the indices are formulated based on existing research methodologies and the national circular economy index. Through the selection of a range of representative indicators, a comprehensive circular economy development index system has been established, encompassing innovation-driven development, coordinated development, environmental development, open development, and shared development. Comprising five categories, the index system comprises a total of 18 indicators. Figure 1 shows the construction framework of the circular economy index system.

Tier 1 indicators	Secondary indicators	Tertiary indicators	Indicator Description
Circular Economy	Innovative developments	GDP growth rate (+)	Regional GDP growth rate
		R&D investment intensity (+)	R&D expenditure of industrial enterprises above scale/regional GDP
		Investment efficiency (-)	Incremental Capital Output Rate (ICOR) = Investment Rate / Regional GDP Growth Rate
		Technology trading activity (+)	Technology transaction turnover/regional GDP
	Coordinated development	Demand structure (+)	Total retail sales of consumer goods/regional GDP
		Urban and rural structure (+)	Urbanisation rate
		Industrial structure (+)	Increase in the share of tertiary sector in regional GDP
		Government debt burden (-)	Government debt balance/regional GDP
	Green development	Energy consumption per unit of GDP (I)	Standard coal/regional CDP
		Energy consumption elasticity factor (-)	Growth rate of energy consumption/gross regional product
		Wastewater per unit of output (-)	Total wastewater discharge/regional GDP
		Exhaust gas per unit of output (-)	Sulphur dioxide emissions/regional GDP
	Open Development	External trade dependence (+)	Total imports and exports / Regional GDP
		Share of foreign investment (+)	Actual Utilisation of Foreign Investment / Regional GDP
		Degree of marketability (+)	Regional Marketability Index
		Level of financial development (+)	Growth in various loans/regional GDP
	Shared Development	Share of workers' remuneration (+)	Worker compensation/regional GDP
		Income growth elasticity of the population (+)	Growth rate of disposable income per inhabitant/regional CDP
		Urban-rural consumption gap (-)	Per capita consumption expenditure of urban residents / per capita consumption expenditure of rural residents
		Share of fiscal expenditure on people's	Share of local expenditure on education, health care, housing, social security and employment in local budget expenditure

Figure 1: Circular Economy Index System

Based on an analysis of current policy documents and incorporating insights from scholarly research on green finance, this study assesses the various dimensions of green finance. The evaluation framework encompasses seven key aspects, namely green credit, green investment, green insurance, green bonds, green support, green funds, and green equity. The construction table of the green finance index system is presented in Figure 2.

Tier 1 indicators	Secondary indicators	Tertiary indicators	Indicator Description
Green Finance	Green Credit	Percentage of credit for environmental projects	Total credit for environmental projects in the province/total credit in the province
	Green Investment	Investment in environmental pollution control as a proportion of GDP	Investment in environmental pollution control/GDP
	Green Insurance	Extent of promotion of environmental pollution liability insurance	Environmental pollution liability insurance income / total premium income
	Green Bond	The extent of green bond development	Total green bond issuance / Total all bond issuance
	Green Support	Percentage of financial environmental protection expenditure	Fiscal environmental protection expenditure / Fiscal general budget expenditure
	Green Fund	Green Fund Green Fund Percentage	Total market capitalisation of green funds / Total market capitalisation of all funds
	Green Rights	Green equity development in depth	Total carbon trading, energy use rights trading, emission rights trading/equity market trading

Figure 2: Green Finance Index System

4.2 Indicator measurement

Because of the inconsistency of the magnitudes among the indicators, in order to eliminate the influence of the magnitudes, the data are first dimensionless, where for the positive indicators the formula is used as.

$$y_{ij} = \frac{x_{ij} - x_j^{min}}{x_j^{max} - x_j^{min}}$$

For the negative indicator the formula is used as.

$$y_{ij} = \frac{x_j^{max} - x_{ij}}{x_j^{max} - x_j^{min}}$$

The entropy method, as an objective assignment approach, is utilized in this study to determine the weights of indicators. This method evaluates the indicators based on their degree of differentiation, taking into account the distribution of indicators when assigning weight coefficients. By doing so, it aims to eliminate subjective biases and objectively capture the relative importance of each indicator. Therefore, the entropy method is employed in this research to determine the weights of indicators.

The calculation procedure for obtaining the weights is as follows:

In the first step, calculate the weight of the index value for the ith evaluation object of the jth index.

$$z_{ij} = \frac{y_{ij}}{\sum_{i=1}^{m} y_{ij}}$$

Herein, let m represent the total count of evaluation objects, while zij signifies the weight of the index value for the jth index's ith evaluation object.

Moving to the next step, we compute the entropy value for the jth indicator.

$$c_j = -k\sum_{i=1}^{m} z_{ij} \ln z_{ij}$$

where cj is the entropy value of the jth indicator, where k=(lnm)-1 is a constant greater than 0.

In the third step, the coefficient of variation of the jth indicator is calculated.

$$d_j = 1 - c_j$$

Whereas dj represents the coefficient of variation for the jth indicator, it is noteworthy that the significance of the jth indicator is directly proportional to dj.

Moving forward to the fourth step, we proceed to calculate the weight coefficient for the jth indicator.

$$e_j = \frac{d_j}{\sum_{j=1}^{n} d_j}$$

The fifth step is to calculate the comprehensive evaluation value based on the product of indicator weights and indicator dimensionless values.

$$S_{ij} = \sum_{j=1}^{n} y_{ij} \cdot e_j$$

n is the number of evaluation objects, and sij is the comprehensive evaluation value of the ith evaluation object.

The trajectory of the green finance development index is depicted in Figure 3. As observed from the diagram, an ascending pattern in green finance is evident across the provinces of Jiangsu, Zhejiang, and Shanghai throughout the period of 2013-2021. This noteworthy progression can be attributed to a plethora of government-enforced ecological preservation initiatives, alongside the persistent growth of the green finance market and the escalating magnitude of environmentally conscious advancements.

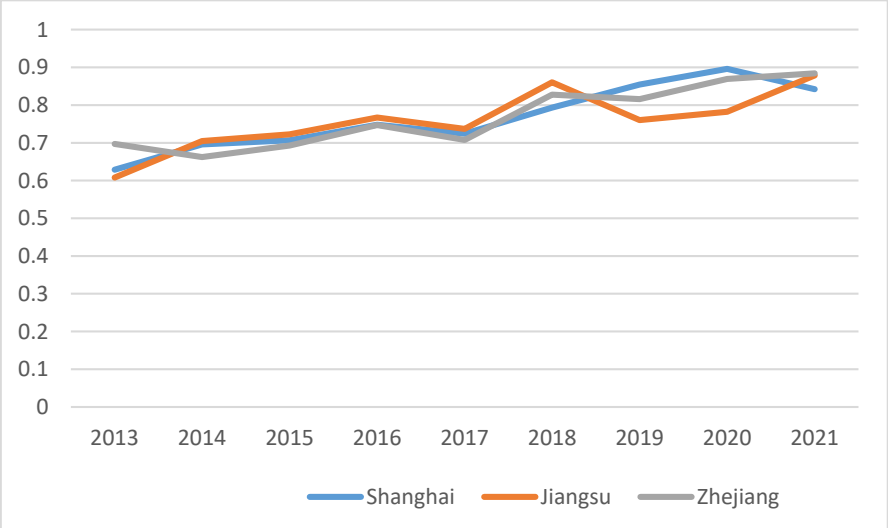

Figure 3: Development trend of green finance in Jiangsu, Zhejiang and Shanghai

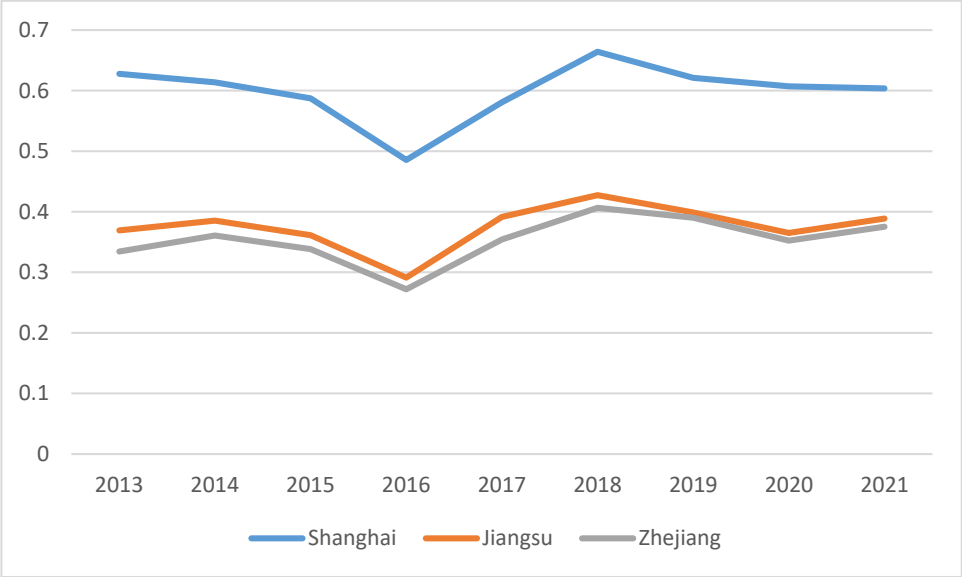

Figure 4: Development trend of circular economy in Jiangsu, Zhejiang and Shanghai

The fluctuation pattern of the circular economy index is depicted in Figure 4. As illustrated, the circular economy index of Jiangsu, Zhejiang, and Shanghai demonstrates a declining trajectory from 2013 to 2016, followed by an amelioration in the circular economy index of the aforementioned provinces from 2016 to 2018. Subsequently, a descending trend in the circular economy index is observed across Jiangsu, Zhejiang, and Shanghai from 2018 to 2021. The oscillation in the circular economy index can be attributed to factors encompassing residents' environmental consciousness, governmental policies pertaining to both the environment and economy, and the volatility within the economic cycle.

5. Empirical study

5.1 Establishment of coupled evaluation model

This paper utilizes the coupling coordination model to examine the interrelationship between the circular economy and green finance, with the calculation of the degree of coupling presented as follows:

$$C_t = 2\left[\frac{SE \times SF}{(SE + SF)^2}\right]^{\frac{1}{2}}$$

Where Ct represents the coupling degree linking the circular economy and green finance, with a range between 0 and 1. A higher value indicates a stronger coupling degree between the circular economy and green finance, while a lower value suggests a weaker coupling degree. SE and SF denote the comprehensive evaluation indices for the circular economy and green finance, respectively. The coupling degree characterizes the intensity of mutual coordination and reciprocal influence between the circular economy and green finance systems. However, it does not encompass the level of coordinated development between the two systems. To assess the degree of coordinated development, the concept of coupling coordination degree is introduced. The coupling coordination degree serves as a measure to gauge the level of coupling coordination between the circular economy and green finance. Its calculation is expressed as follows:

$$\begin{cases} R_t = \sqrt{C_t \times T_t} \\ T_t = \alpha \times SE + \beta \times SF \end{cases}$$

Where Rt denotes the coupling coordination degree between the circular economy and green finance. Tt represents the comprehensive coordination index, which evaluates the overall synergistic effect of the two systems. In this study, specific coefficients a and β are considered, and after careful consideration, a=β=0.5 is selected.

Regarding the criteria for dividing the coupling degree and coupling coordination degree, this paper incorporates the insights of Zhou Shufen et al. [29] and combines the distinctive attributes of the circular economy, economy, and green finance. Based on these considerations, the division criteria are determined as presented in Table 1.

Table 1: Coupling degree stage division

Coupling degree taking value	Coupling level	Coupling coordination degree organization	Coordination level
0<Ct ≤0.2	Low coupling stage	0<Rt ≤0.2	Very low coordination
0.2<Ct ≤0.5	fly down stage	0.2<Rt ≤0.5	Low level of coordination
0.5<Ct ≤0.8	Breaking-in stage	0.5<Rt ≤0.8	Basic Coordination
0.8<Ct ≤0.9	Benign coupling stage	0.8<Rt ≤0.9	Moderate coordination
0.9<Ct ≤1.0	High coupling stage	0.9<Rt ≤1.0	Highly coordinated

5.2 Examination of Coupling Degree and Coupling Coordination Degree Measurement Results

The measurement outcomes for the coupling degree of green finance and the circular economy are presented in Table 2. The data reveals that Shanghai has consistently exhibited a high level of coupling between green finance and the circular economy from 2013 to 2021. Similarly, Jiangsu and Zhejiang have predominantly experienced a high degree of coupling, with the exception of 2016, when they entered a phase of favorable coupling.

Table 2: Coupling degree

Coupling degree	2013	2014	2015	2016	2017	2018	2019	2020	2021
Shanghai	0.9999996	0.998036	0.995726	0.977111	0.993935	0.996065	0.987427	0.981374	0.986294
Jiangsu	0.969682	0.956132	0.94281	0.89321	0.95197	0.941735	0.95016	0.931501	0.922319
Zhejiang	0.936182	0.955545	0.939111	0.884589	0.942941	0.939939	0.935627	0.905969	0.914821

The outcomes of the coupling coordination degree between green finance and the circular economy are illustrated in Table 3. While the coupling degree assesses the intensity of mutual coordination and reciprocal influence between the circular economy and green finance systems, it does not adequately portray the level of coordinated development between these systems. To address this limitation, the concept of coupling coordination degree is introduced to evaluate the degree of coordinated development between the two systems. As evident from the table, the green finance and circular economy in Jiangsu and Zhejiang demonstrate a fundamental level of coordination during the period of 2013-2021. Conversely, Shanghai exhibits a moderate level of coordination in all years except for 2013 and 2015.

Table 3: Coordination degree of coupling

Coupling coordination	2013	2014	2015	2016	2017	2018	2019	2020	2021
Shanghai	0.792656	0.808411	0.802708	0.776207	0.805258	0.852012	0.853499	0.858813	0.844325
Jiangsu	0.688301	0.721878	0.714796	0.687473	0.732812	0.77867	0.742035	0.73094	0.764454
Zhejiang	0.694824	0.699199	0.695793	0.671346	0.707603	0.761694	0.751111	0.743882	0.759026

The analysis of Table 2 and Table 3 indicates that the coupling degree between green finance and the circular economy in Jiangsu, Zhejiang, and Shanghai exhibits both benign coupling and high coupling stages. Meanwhile, the coupling coordination degree in Jiangsu and Zhejiang demonstrates basic coordination, while Shanghai primarily achieves a moderate coordination level. In terms of the coupling degree, Shanghai demonstrates a higher level between green finance and the circular economy, accompanied by a coupling coordination degree that mainly resides in the moderate coordination level. Notably, Jiangsu, Zhejiang, and Shanghai have made remarkable advancements in sustainable development, showcasing notable achievements and overall coordination. However, in comparison to Jiangsu and Zhejiang, Shanghai has achieved more significant and impactful outcomes concerning environmental preservation and resource utilization. Through the guidance of green finance and the implementation and development of the circular economy, Shanghai has successfully struck a balance between economic growth and environmental sustainability.

6. Conclusions and Recommendations

6.1 Conclusion

Drawing upon theoretical analysis and empirical research, this study delves into the interconnectedness between green finance and the circular economy, uncovering a coupled coordination mechanism that mutually reinforces these two systems. Theoretical analysis reveals that green finance, functioning as a financial activity, plays a pivotal role in facilitating the circular economy through market and policy mechanisms. It provides information feedback, substantial financial support, and diverse financing channels, thereby driving the enhancement of the circular economy's industrial structure and fostering proactive technological innovation. Simultaneously, green finance leverages various financial instruments and effectively employs risk-avoidance mechanisms to mitigate potential risks associated with technological innovation in the circular economy, thereby promoting industrial upgrading. Conversely, the robust development of the circular economy facilitates the shift from an unsustainable economic development model to a sustainable one, consequently fostering improvements in the financial, socio-economic, and natural environments. Consequently, this progress spurs a demand for novel green financial services and a pursuit of elevated quality levels, thus fueling further green financial innovation and enriching the green financial system. Empirical analysis utilizes the entropy method to measure the composite index of green finance and the circular economy. Additionally, the coupling degree model is employed to gauge the coupling degree and coupling coordination degree between green finance and the circular economy. The findings reveal that Shanghai consistently operates within a high coupling stage from 2013 to 2021, with the coupling coordination degree predominantly residing in the moderate level, except for 2013 and 2016, which exhibit a basic coordination level. Similarly, Jiangsu and Zhejiang exhibit a high coupling stage in terms of the coupling degree, excluding 2016, which demonstrates a benign coupling stage. Moreover, both Jiangsu and Zhejiang consistently exhibit a basic coordination level across all years in terms of the coordination degree.

6.2 Recommendations

6.2.1 Enhance policy reinforcement and regulatory frameworks

Governmental policies wield a paramount influence in fostering the interdependent progression of circular economy and green finance. To fortify policy reinforcement, the government can devise incentivizing policies and preferential measures, encompassing tax exemptions, loan subsidies, and grants, with the aim of incentivizing financial institutions and enterprises to escalate their investments and financing endeavors in the circular economy. Furthermore, it is imperative for the government to bolster regulatory frameworks to ensure congruence between the functioning of green finance and circular economy and the principles underpinning sustainable development, thus averting financial hazards. By means of proactive policy reinforcement and efficacious regulatory frameworks, robust support and assurance can be provided for the intertwined advancement of green finance and circular economy.

6.2.2 Improve the mechanism of action

China should enhance the collaborative framework, proactively propel the dismantling of administrative divisions' limitations, fully leverage market mechanisms, and harness the fundamental role of the market in the optimal allocation of resources, thus rectifying the antiquated notion of fragmentation and unilateralism. By means of synergy and systematic governance, we shall accomplish regional resource sharing. Emphasizing digital infrastructure, we shall augment the efficacy of information exchange among the tripartite regions, promptly identify challenges, employ scientific decision-making and expeditious implementation, and ensure the harmonized advancement of circular economy and green finance.

6.2.3 Promote regional synergy

Devise appropriate policies based on contextual factors to facilitate the harmonized advancement of the tripartite regions. As a pivotal hub for economic and technological innovation at the national level, Shanghai must seize the current unparalleled transformation of this century, steadfastly adhering to the guiding principles of novel developmental ideologies. By propelling the synchronized progress of the circular economy and green finance, Shanghai will assume a preeminent position in driving the high-quality economic growth both domestically and globally. Presently, the development of the circular economy in Jiangsu and Zhejiang is sluggish, necessitating a paradigm shift in economic growth patterns, encompassing reduced resource consumption and intensified efforts to combat water and air pollution. Augmenting investments in environmental preservation, elevating the level of circular economy development, harmonizing the interplay between circular economy and green finance, and evading the quagmire of "stagnated progress" are imperative. Concurrently, an enhanced sense of social responsibility among financial institutions and enterprises, alongside the reinforced supportive role of green finance in fortifying the economy, will contribute to the advancement of the Jiangsu, Zhejiang, and Shanghai regions, thereby propelling the interdependent progress of the circular economy and green finance.

Acknowledgement

The research was supported by project grant form “2022 Guangdong Province Higher Education Youth Innovation Talent Project” "Research on the Coupled and Coordinated Development of Circular Economy and Green Finance Supported by Supply Chain Finance: A Case Study of Guangdong Province" (Project No. 2022WQNCX097). 2023 Guangzhou Nanfang College

University-Level Research Project "Analysis and Forecast of the Coupling Coordination Between Circular Economy and Green Finance in the Guangdong-Hong Kong-Macao Greater Bay Area Under the Dual Carbon Goals" (Project No. 2023XK028).

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