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DYNAMIC COUPLING ANALYSIS BETWEEN SCALE OF NETWORK RETAIL MARKET AND GREEN CIRCULATION EFFICIENCY

Abstract: A sound circulation system is an important carrier for the development of the retail industry, and the promotion of green circulation efficiency (GCE) plays an important role in driving the market scale expansion of network retail (NR). This study uses the development status of China's NR and circulation industries as basis to estimate the total carbon emissions (CE) of the circulation industry by using the system dynamics method. Moreover, this research measures China's GCE by combining data envelopment analysis (DEA) and Malmquist index to construct a coupling analysis model to empirically investigate the dynamic coupling relationship between the NR scale and green circulation efficiency. Results indicate that China's GCE is generally increasing, but growth rate fluctuates significantly. Additionally, the improvement of the quality and efficiency of China's circulation industry has not yet formed a steady green path. China's NR market scale continues to expand, but NR at this stage is still mainly concentrated in the eastern region. The efficiency of green circulation and scale of the NR market show a good coupling trend, but there is still a significant gap between the central and western regions. Accordingly, this study proposes that the construction of a green circulation system should be strengthened, and that the development of a green and efficient circulation industry should be taken as the engine of the NR scale expansion.

Keywords: network retail, circulation efficiency, carbon emissions, coupling effect

Introduction

Owing to the popularisation of Internet applications and the emergence of platform payment, digital finance and other transaction modes, network retail (NR) has gradually become an important component of the national economy in recent years. The modern retail industry with NR as the core is a bridge connecting production and consumption and also plays a leading role in social and economic development, thereby helping enhance China's participation and influence in international division of labour and cooperation [1-6]. As a supporting industry sector of NR, the circulation industry has a profound impact on the overall scale and future development direction of NR, especially in the macro context of low-carbon transformation; moreover, the efficiency of logistics system and green transformation development are important support for NR scale expansion [7-11]. Therefore, of immense practical significance for the coordinated development of NR and green circulation is to clarify their internal correlation mechanism and coupling situation. This study aims to investigate the development status of China's NR market and the actual situation of the green productivity level of the circulation industry. Thereafter, the current

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research intends to judge their coupling development state to realise the deep integration of the construction for green circulation system and expansion of NR scale.

The development of the Internet economy has led to the continuous evolution of retail formats. The 'new retail' represented by e-commerce is an important product of network economy. Kirom et al. [12] and Zhang et al. [13] sorted out the development process of e-commerce NR in China and divided it into the following development stages: germination, emergence, outbreak and integration. They likewise explained the internal driving force of the development of NR sales from the aspects of service quality, convenience and customisation. Generally, existing studies focus on the internal relationship and practical evidence between the development of the Internet and transformation of retail formats. Internet development enabled retail enterprises to actively develop online sales channels and also significantly improved the retail industry's operation efficiency.

With the continuous expansion of NR scale and constant increase of consumers, the development of NR also presents high requirements for the development of logistics industry. Moreover, some scholars are beginning to focus on the internal relationship between the development of logistics industry and NR. Wang et al. [14] used the Vector Autoregression model test and found that Internet penetration and circulation efficiency are the most important factors affecting the development of NR. Improving e-commerce logistics and distribution system and building digital and intelligent logistics system are important aspects of NR development. Anderson et al. [15] believed that the long-term low efficiency of the circulation industry is a significant bottleneck restricting the sustainable development of NR in China. Widjajanti et al. [16] used the data envelopment analysis (DEA) method to measure China's circulation efficiency and established regression analysis between circulation efficiency and NR scale. The results show that the improvement of circulation efficiency has a significant role in promoting NR development. Although the operation efficiency of the circulation industry affects the NR scale, the green attribute of its own development also has an impact on itself. 'Green circulation' was developed with the continuous prominence of environmental problems. Its specific connotation is a green development mode relying on clean production technology and enterprise energy saving and emission reduction strategy to realise green transformation from raw material procurement, product manufacturing and green consumption. Liu et al. [17] indicated a close relationship between the development of green circulation and green consumption. They implied that the promotion of green circulation consumption can form a guiding role in online consumption behaviour, eventually affecting NR development.

In the dynamic landscape of the retail industry, a robust circulation system stands as the lifeblood, powering growth and vitality. A well-structured and efficient circulation system is paramount for seamless operations, ensuring that products move rapidly from manufacturers to consumers. This situation enhances customer satisfaction and also optimises inventory management, reduces costs and fosters overall business resilience. That is, a sound circulation system is the linchpin for sustained development and competitiveness in the retail sector. Generally, existing studies have verified the correlation between the development of NR and the improvement of circulation efficiency. However, these studies have failed to investigate their coupling effect to further clarify whether the circulation efficiency and expansion of the NR scale match. Moreover, these studies have disregarded the green attribute of the circulation industry's efficiency improvement, failing to consider the internal relationship between GCE improvement and NR development.

Additionally, only a few studies have focused on the spatial heterogeneity of the correlation between the improvement of circulation efficiency and development of NR. Accordingly, this study estimates the total carbon emissions (CE) in the circulation process, measures China's GCE by using DEA and the Malmquist index, and empirically investigates the dynamic coupling effect and spatial heterogeneity between GCE and NR scale by using the coupling analysis model.

Analysis of the NR market scale - Total scale of the NR market

Due to the widespread development of the Internet and the popularisation of digital payment methods in China, the annual growth of Non-Performing Receivables (NR) in the country has consistently exceeded 500 billion yuan since the beginning of the 21st century. Furthermore, the annual growth rate has remained consistently above 70 % for an extended period. As the turning point of China's NR development in 2005, the total transaction volume and growth rate have been significantly improved. As of 2019, the total amount of NR sales in China was over 9 trillion yuan, and the NR industry has become an important component of national economic growth [18, 19]. Moreover, the vigorous development of the NR industry has relatively occupied the development space of physical retail industry. In 2019, the proportion of NR in the total retail sales of consumer goods exceeded 25 %, and this proportion still shows an increasing trend. With the promotion of Internet information technology and mobile Internet technology, China's retail industry has begun to develop from traditional offline sales as the main body to the online and offline integration mode. Additionally, some traditional fixed retail markets have begun to transform and upgrade. Particularly under the promotion of the large-scale development of China's network, the retail industry network has become the main development trend of the retail industry, and the corresponding NR has also become the main driving force for the development of China's retail industry [20, 21]. According to the statistics report on China's Internet development, the number of Internet users in China by the end of December 2018 had reached 8285.1 million, with a penetration rate of 59.6 %. Compared with 2017, the number of Internet users in 2018 increased by 56.53 million, a year-on-year increase of 3.8 percentage points. Amongst Internet users, the scale of mobile terminals reached 817 million (98.3 %). The development of the retail industry has provided an immense opportunity for network development.

The development of China's NR market has withstood the test of economic slowdown and still maintains a relatively stable growth. The proportion of NR in social consumer goods retail continues to increase. However, note that the growth rate of NR market is gradually declining. Therefore, the growth momentum of the NR industry must be tapped further [22, 23] to ensure the steady and sustainable development of the NR market. Regional differences in the development of the NR market are relatively prominent, and NR commodities are uneven (the complaint rate of NR is high every year). Hence, the government's supervision and policy support for the NR market are still insufficient. In terms of the total amount, the scale of China's NR market has shown a significant upward trend, and the scale of NR in various provinces and cities has also increased. However, a horizontal comparison indicates that there are significant differences in the scale of China's inter-provincial NR market, showing evident spatial distribution of 'strong in the East and weak in the West of China [24]. The NR market scale in Eastern China, represented by Guangdong, Zhejiang and Shanghai, is generally high, with total retail sales

exceeding 300 billion. By contrast, the total amount of NR sales in the central and western regions is relatively low, and the gap in the NR market scale amongst the eastern, central and western regions is further widening (Fig. 1).

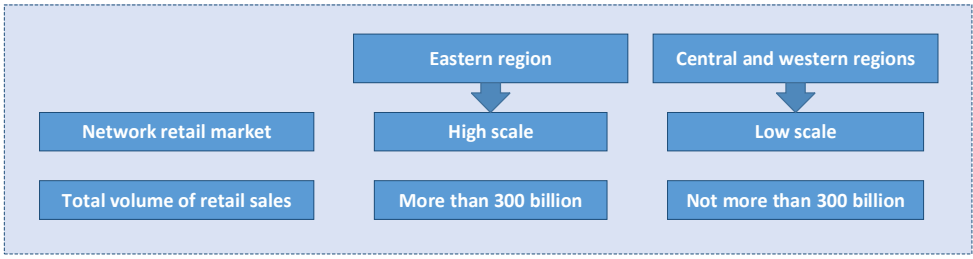

Fig. 1. Comparison of the NR markets in the eastern and central western regions of China

Measurement of GCE

CE measurement of the circulation industry

The circulation industry, which is different from the traditional industrial energy consumption sector, has a long industrial chain, many links and has difficulty in conducting comprehensive and real-time monitoring of pollution emissions. This situation results in difficulty estimating CE of the circulation industry. To simplify the calculation, this study mainly uses the system dynamics method to simulate CE generated in the transportation and packaging links. Considering that small- and medium-sized objects account for over 90 % of the logistics transportation [25], this study focuses on the calculation of CE generated by air and road transportation but does not consider the small amount of CE generated by the use of electric vehicles in terminal distribution. Additionally, this study mainly investigates paper and plastic bag packaging materials with relatively high frequency, and assumes that logistics packaging is a one-off cycle [26, 27].

This study refers to existing research experience and uses the software Vensim to simulate the carbon emission system dynamic model of an e-commerce logistics system. Specifically, this research sets the carbon emission accounting cycle as 2010-2020, in which 2020 is the model prediction year, and the step size is set as one year. For convenience of calculation, this study assumes that the average growth rate of China's circulation industry sector has been maintained for nearly five years, and the predicted values of other parameters are estimated by regression analysis. Owing to space limitations, the module causality diagram, stock flow diagram and specific parameter settings of the carbon emission accounting model are not presented in this paper [28].

The results of CE from 2010 to 2019 measured by system transportation and packaging use are shown in Figure 2. CE from the circulation industry indicates that transportation and packaging CE increased significantly. In 2010, CE of China's e-commerce logistics system was about 1.967 million tonnes ([t] = tonne = 10^6 g = Mg), but increased to 36.981 Mt in 2020. Growth rate is also close to 20 times, which reveals the current situation of China's e-commerce development scale expansion but low degree of green development. Compared with the different sources of CE from the circulation industry, CE from the transportation sector is the main component of the circulation

industry, accounting for over three quarters of the total. At the present stage, although CE from the transportation sector accounts for a relatively low proportion and a relatively small total amount, the absolute and relative proportions show an evident upward trend. In the long run, e-commerce product packaging has serious potential environmental threat.

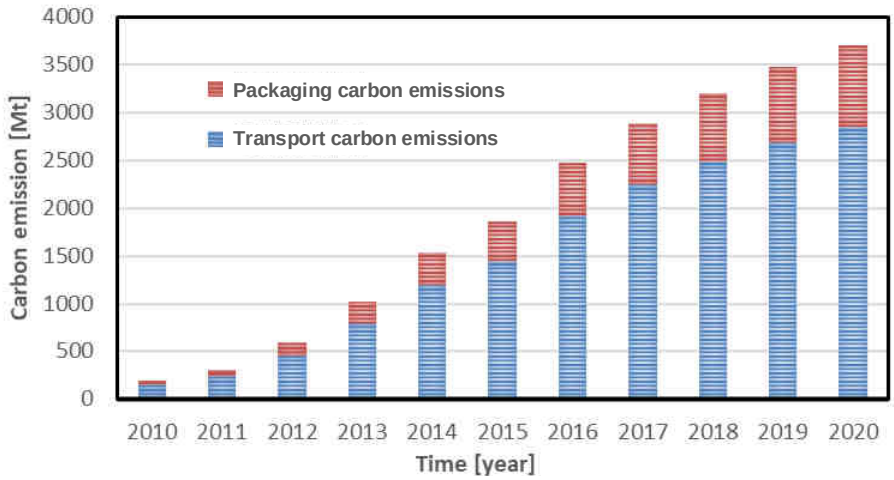

Fig. 2. Development of carbon emission accounting results of e-commerce transportation and packaging links

Measurement model

The current study utilises the DEA-Malmquist method to assess the efficiency of green circulation in China. In contrast to other efficiency analysis methods, the DEA method proves effective in mitigating subjective factors associated with model setting in parameter analysis methods. This method ensures objective and accurate efficiency analysis results. DEA evaluates the efficiency of each decision-making unit (DMU) by comparing its input-output performance relative to others in the set.

The Malmquist index takes multifactor input-output as the research basis and analyses the evolution of circulation efficiency by comparing the current technical level and production frontier of production units in different periods

$$\theta_i = UY_i/VX_i \tag{1}$$

where Y_i ($Y^T > 0$) represents the output vector, X_i ($X^T > 0$) represents the input vector and U_i ($U^T > 0$) and V_i ($V^T > 0$) are their weights. By solving the circulation efficiency θ_i, the formula of the Malmquist index can be obtained:

$$M_0(x_t, y_t, x_{t+1}, y_{t+1}) = \left[\frac{D_0^{t+1}(x_{t+1}, y_{t+1})}{D_0^{t+1}(x_t, y_t)} \cdot \frac{D_0^t(x_{t+1}, y_{t+1})}{D_0^t(x_t, y_t)}\right] \tag{2}$$

where D_0^t (X_t, Y_t) and D_0^{t+1} (X_{t+1}, Y_{t+1}) reflect the respective gaps between the current production level and production frontier of DMUs in t and $T + 1$ periods, in which the difference is the improvement potential of circulation efficiency, and D_0^{t+1} (X_t, Y_t) and D_0^t (X_{t+1}, Y_{t+1}) represent the inefficiency of DMU production in the mixed period. Furthermore, ML index can be decomposed into technical progress change (GTECH) and technical

efficiency change (GEFFCH). The former reflects the production effects caused by economies of scale, institutional innovation and experience absorption. The latter is embodied in the impact of production process innovation on production efficiency. When M_0 is above 1, circulation efficiency shows an upward trend; otherwise, it decreases.

Index description

This study uses three indicators to measure the efficiency of green circulation: circulation industry employees, fixed assets investment and total logistics transportation mileage. The two output indicators are expected output value of circulation industry and carbon dioxide emission of unexpected output circulation industry. Circulation industry output value data mainly come from *China logistics statistical yearbook*. Owing to lack of direct access to data on circulation industry employees and fixed assets investment, this research uses data on transportation and warehousing postal industry employees and fixed assets investment as replacements. Data on the total logistics transportation mileage are obtained by weighted calculation based on the line length of railway, highway and water transportation, and the proportion of freight volume of different transportation modes as weight. Original data are from the official website of the National Bureau of Statistics.

Decomposition results

Figure 3 presents the changes of the GCE index and its decomposition results from 2010 to 2019. Note that in the study area, the overall GCE in China shows an upward trend with a significant increase, indicating that the green development prospect of China's circulation industry is relatively optimistic. However, the change of the GCE index has significant fluctuations. That is, green efficiency improvement of China's circulation industry has not yet formed a stable and reliable development path. The decomposition results indicates that the change of technological progress maintains a relatively stable trend. Meanwhile, the change of technical efficiency presents a markedly significant upward trend, reflecting that the GCE improvement in China generally depends on the change of technical efficiency. Additionally, technological progress has not yet played its role in promoting the efficiency of green circulation.

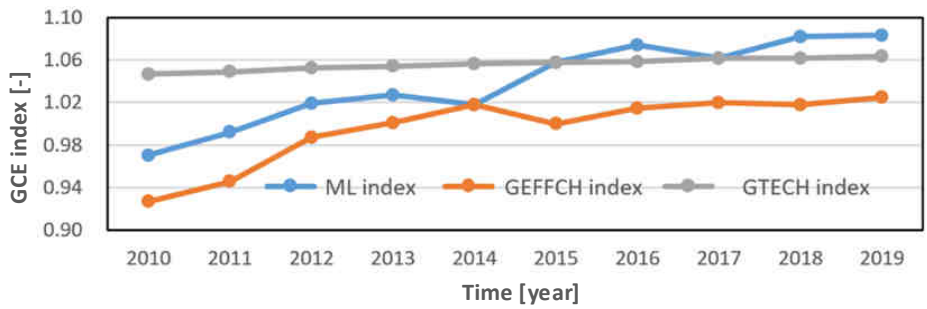

Fig. 3. GCE and the change of decomposition results

Coupling analysis of the NR market scale and GCE

Model setting

To test the dynamic coupling characteristics between the circulation GCE and NR market scale evolution, this study examines their relationship in two steps. The first step is to establish a capacity coupling model to examine the coupling effect of GCE and NR market scale from the static and dynamic aspects. The model is as follows:

$$C = 2\sqrt{\frac{f(x)\cdot g(y)}{[f(x)+g(y)]^2}} \tag{3}$$

where C is the coupling index, $f(x)$ is the standard value of GCE and $g(y)$ is the comprehensive standard value of the NR market scale. Considering that formula (3) leads to difficulty in reflecting the dynamic coupling change trend of GCE and NR market scale, this study further establishes the following coupling development index D:

$$D = \sqrt{C\cdot[0.5f(x)+0.5g(y)]} \tag{4}$$

Data sources

This research utilises provincial panel data spanning from 2011 to 2019 as the research sample. Primary data sources include the monitoring report of China's industrial e-commerce market, monitoring report of China's NR market data, statistical bulletin of civil aviation industry development and the China energy statistical yearbook. Additional data are sourced from the research centre of e-commerce and the prospective database. The data set is completed through the mean method for any missing or incomplete information. The use of provincial panel data assumes a certain level of homogeneity within provinces. Variability in economic, regulatory or other factors across regions may not be fully captured.

Analysis and discussion

The coupling effect analysis results of GCE and NR market scale are shown in Table 1. On the dynamic level, the trend is generally good, but the coupling level of the two is still low, which is closely related to the extensive development and inefficient management of China's circulation industry for a long time. However, the coupling development degree of GCE and NR market scale also shows strong potential. Coupling growth rate has remained at a high level for a long time, showing a good industrial development trend. At the static level, the coupling degree of the two is stable at a high level for a long time, but its coupling development level is relatively low. That is, the coordinated promotion of GCE and NR scale expansion still needs additional external support.

To investigate the spatial differences of coupling effect between GCE and NR market scale, this research examines the dynamic coupling effect in the eastern, central and western regions. The results are shown in Table 2. Disparities in the dynamic coupling effect amongst the eastern, central and western regions are apparent. The eastern region distinctly outpaces the central and western regions in terms of coupling and coupling development degrees. This discrepancy can be attributed to various factors. Firstly, the eastern region boasts a high level of maturity in logistics technology, logistics equipment and circulation

management. Notably, GCE is markedly advanced in the eastern region, reflecting a comprehensive integration of logistics capabilities.

Table 1

Coupling effect of GCE and NR market scale

Dynamic level	**Year**							
	2005	**2007**	**2009**	**2011**	**2013**	**2015**	**2017**	**2018**
Coupling degree [-]	0.3882	0.3872	0.3980	0.4121	0.4291	0.4471	0.4780	0.4955
Coupling development degree [-]	0.3423	0.3970	0.4022	0.4459	0.4571	0.5415	0.6329	0.7052
Static level	**Year**							
	2005	**2007**	**2009**	**2011**	**2013**	**2015**	**2017**	**2018**
Coupling degree [-]	0.6225	0.6239	0.6095	0.6453	0.6233	0.6084	0.6421	0.6619
Coupling development degree [-]	0.2727	0.2827	0.2933	0.2982	0.2906	0.3151	0.3624	0.3671

Secondly, the eastern region excels owing to the substantial scale of the NR market, thereby fostering deep integration between logistics and market dynamics. This synergy further reinforces the region's dominance in the coupling effect. By contrast, the central and western regions lag behind on multiple fronts. Their logistics construction and NR development are comparatively underdeveloped, resulting in a lower dynamic coupling effect at the current stage.

Addressing the aforementioned regional imbalances is crucial for achieving a markedly equitable and efficient national logistics network. The central and western regions must prioritise investments in logistics infrastructure and technological advancements to enhance their coupling effects. By bridging these gaps, the entire country can benefit from a considerably harmonised and integrated logistics landscape, propelling economic development across all regions.

Table 2

Spatial difference of dynamic coupling effect between GCE and NR market scale

Region	**Dynamic level**	**Year**							
		2005	**2007**	**2009**	**2011**	**2013**	**2015**	**2017**	**2018**
East	Coupling degree [-]	0.5278	0.5264	0.5411	0.5603	0.5834	0.6079	0.6498	0.6737
	Coupling development degree [-]	0.4654	0.5397	0.5469	0.6063	0.6215	0.7365	0.8605	0.9588
Central section	Coupling degree [-]	0.4013	0.4002	0.4114	0.4260	0.4436	0.4622	0.4941	0.5122
	Coupling development degree [-]	0.8463	0.8483	0.8287	0.8773	0.8474	0.8271	0.8730	0.8999
West	Coupling degree [-]	0.3708	0.3844	0.3988	0.4054	0.3951	0.4284	0.4928	0.4991
	Coupling development degree [-]	0.3539	0.4104	0.4158	0.4610	0.4726	0.5598	0.6543	0.7290

The investigation highlights the pivotal role of consumer perception and demand in shaping the causal dynamics between GCE and NR scale. As environmental consciousness becomes increasingly ingrained in consumer behaviour, retail networks that prioritise sustainability tend to attract a significantly large and loyal customer base. This heightened consumer demand drives the need for markedly efficient green circulation and also provides the impetus for the expansion of the retail network to meet growing market expectations.

Conclusion and policy recommendations

For the coordinated development of the promotion of GCE and scale expansion of the NR market, this study uses the development status of the NR and circulation industries in China as basis to investigate GCE, specifically by measuring CE in the circulation process. Thereafter, this research establishes a coupling analysis model to analyse the coupling state and spatial differences between the two. The results show that China's GCE is on the rise, but the growth rate fluctuates significantly. Hence, a sound path for the development of green circulation must be further established. Overall, the coupling state of GCE and NR market scale tends to be optimised, but there is still considerable room for improvement at this stage. The coupling effect of the two is relatively different between the eastern and western regions, and the coupling state of the central and western regions is relatively backward. This empirical investigation underscores the interplay between the efficiency of green circulation and scale of NR, revealing a complex web of causal relationships. The adoption of sustainable practices enhances operational efficiency and also serves as a catalyst for the expansion of retail networks, driven by economic benefits, consumer demand, and regulatory imperatives. As businesses navigate this intricate landscape, a strategic alignment with green circulation practices emerges as an ethical imperative and a pragmatic pathway towards achieving environmental sustainability and retail success.

To promote the vigorous development of the NR industry, we should vigorously improve the construction of a circulation system and development of green logistics. On the one hand, we should actively improve logistics channels, including the green renewal of vehicles, overall improvement of transportation efficiency and intelligent distribution technology. On the other hand, environmental pollution caused by logistics packaging can be minimised by improving packaging reduction, promoting green and degradable packaging materials and strengthening logistics waste recycling. Additionally, the construction of efficient logistics system should be guaranteed by an ideal logistics industry management system. Therefore, government departments should strengthen the policy guidance of green transformation and efficiency improvement of the circulation industry. We should also focus on the gap between the efficiency improvement of the circulation industry and development of online retailing in the eastern, central and western regions. Such an improvement and development can guide more development resources to avoid further widening of the gap in the central and western regions.

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