Study on the Synergistic Effect of Regional Electronic Commerce and Regional Economy from the Perspective of Coupling

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Abstract. To measure the coordinated development level of a regional e-commerce and regional economy. Based on the analysis of the synergistic effect of a regional e-commerce and regional economic development, this paper constructs the index system, adopts the coupling method based on the analytic hierarchy process and entropy weight method (AHP-EWM), and selects the order parameters of 9 regional e-commerce subsystems reflecting the development scale and development potential of e-commerce and 11 regional economic system order parameters reflecting the total economic output, economic structure, and economic benefits, constructs the synergy theory and synergy model), and uses the panel data samples of Beijing from 2013 to 2020 as the analysis. The results show that the degree of synergy between regional e-commerce and regional economy in Beijing presents an M-shaped development trend alternating increase and decrease and is generally in a low-level synergy state.

Keywords: Analytic hierarchy process, entropy weight method, regional e-commerce, regional economy, degree of order, coordination degree.

1. Introduction

The popularity of e-commerce in 2000 has made e-commerce one of the most frequently repeated nouns in that year. E-commerce is a product of high technology. Its emergence and existence are inseparable from the information society and the network world. The concept of a new economy is proposed in the 13th Five-Year Plan of China. As a new economy, e-commerce has significantly improved its status and role in adjusting economic structure. With the improvement of China's economic level and living standard, China's national economic development has entered a new stage. The growth of e-commerce can further promote the development of the regional economy. Regional e-commerce and regional economy depend on each other, encourage each other and show 'synergistic effect'. Coordinated development between regional e-commerce and regional economy helps to promote high-quality development of the regional economy further.

In recent years, the continuous development and maturity of network technology, government support and promotion, and relatively low investment in e-commerce entrepreneurship costs have promoted the rapid development of regional e-commerce in China. Many experts and scholars use the synergy method, dynamic game method, grey correlation analysis method, the establishment of coupling coordination model theory, and method to study the relationship between regional e-commerce and regional economy. For example, Mei et al. [1] adopted the method of multi-case study following the replication rule, through the actual investigation of the sample, discussed the mechanism of coordinated development of rural e-commerce industry agglomeration and regional economy in different stages; Wang et al. [2] used principal component analysis method based on entropy method to measure the development of rural e-commerce and used spatial model for empirical analysis. The dynamic game method was used for empirical prediction to investigate the

coordinated development direction of rural e-commerce and regional economy. Wang et al. [3] used the grey correlation analysis method to study the correlation between the cross-border e-commerce industry and regional economic development in Guangdong Province and put forward suggestions from policy, industry, and mode perspectives to promote the coordinated development of cross-border e-commerce in Guangdong Province. Jiang et al. [4] through the establishment of rural e-commerce industry agglomeration and regional economic coupling coordination model, analysis of the comprehensive development of the two, and calculation of the system coordination degree.

Although China's e-commerce technology is developing rapidly and maturing, it is still unable to achieve the expected goal due to the impact of investment costs, sales models, tax issues, and other aspects. Therefore, it is imperative to focus on the coordinated development of regional e-commerce and regional economy. Previous studies have only examined the development level of e-commerce in China, and have paid insufficient attention to the synergistic effect between regional e-commerce and the regional economy. The innovation of this paper is to use the AHP-EWM coupling perspective for index weighting, and on this basis, to study the synergistic effect of a regional e-commerce and regional economy. This paper first constructs two system index systems of regional commerce and regional economy and uses the AHP-EWM coupling method to give the synergy theory and synergy model. By studying the synergistic effect of a regional e-commerce and regional economy, we can not only evaluate the degree of synergy between regional e-commerce and regional economic development, but also predict the future development trend of synergy between e-commerce and regional economy, and take appropriate measures to improve the level of synergy at this stage.

2. Regional Business and Regional Economic Index System Construction

2.1. Regional Business Index System Construction

Table 1. Order Parameters of Regional Electronic Commerce

Order parameter	Level 1 indicators	Lever 2 indicators	Type
Regional E-commerce subsystem	E-commerce Infrastructure	Number of enterprises engaged in e-commerce	Positive correlation
		Number of computers used at the end of the period	positive correlation
		Number of computers used per 100 persons	positive correlation
		Number of websites owned by enterprises	positive correlation
	E-commerce development scale	Number of websites owned per 100 enterprises	positive correlation
		Number of enterprises with e-commerce transactions	positive correlation
		The proportion of enterprises with e-commerce transactions	positive correlation
		E-commerce sales	positive correlation
		E-commerce purchase amount	positive correlation

Since the reform and opening-up, China's development speed and achievements in information technology have been universally recognized. At the same time, the economic growth driven by network technology in the information age should not be underestimated. E-commerce has become an essential component of China's national economy. Some scholars put forward the use of data technology to get e-commerce enterprise-related data and value information, help strengthen the

enterprise supply chain cost control, intelligent, digital analysis method for enterprise core competitiveness has a significant improvement [5]. In this paper, the indicators related to the development of e-commerce are shown as follows. China's e-commerce model has gradually developed in the direction of e-commerce. The number of enterprises, websites, and the proportion of e-commerce transactions in all aspects have also increased. In summary, the regional business system constructed in this paper is shown in Table 1.

2.2. Construction of regional economic index system

The design and formulation of a regional economic index system must first have a clear purpose and pay attention to its relevance, scientific, feasibility, comparability, and unity. When selecting an index according to the research purpose, whether in the economic index system or in a single index, the position and role of the index in the whole index system should be considered. The qualitative regulation of index names must have a scientific basis in theory and be feasible and effective in practice. On the premise of a certain purpose, the economic indicators are required to be scientific, linked, and unified for comparability and feasibility since only comparable economic indicators can provide accurate information [6]. In summary, the regional economic system constructed in this paper is shown in table 2.

Table 2. Order parameters of regional economic system

Order parameter	Level 1 indicators	Lever 2 indicators	Type
Regional economic subsystem	economic structure	first industrial output	positive correlation
		second industrial output	positive correlation
		third industrial output	positive correlation
	economic aggregate	GDP	positive correlation
		total retail sales of consumer goods	positive correlation
		the total volume of import and export trade	positive correlation
		the permanent population at the end of a year	positive correlation
	economic benefits	per capita GDP	positive correlation
		GDP growth rate	positive correlation
		financial revenue	positive correlation
		per capita budgetary income	positive correlation

3. Coupling Solution Based on Analytic Hierarchy Process Method and Entropy Weight Method

3.1. Analytic Hierarchy Process

In the early 1970s, the American operations researcher, professor Saaty of Pittsburgh, proposed the Analytic Hierarchy Process (AHP), a multi-criterion, multi-level, multi-objective evaluation decision. Its principle is roughly through multiple factors decomposing a fuzzy and complex problem,

and then grouping its factors to form a hierarchically ordered hierarchy. Based on weight calculation analysis, ranking different risk factors [7]. In this process, we can establish the layers of all elements, simplify the calculation procedures, and make up for the shortage of existing data. The general steps are as follows:

The first step is to establish the systematic hierarchical structure and the fuzzy evaluation matrix $B(b_{ij})n\times n$ according to the relationship between the factors, where the b_{ij} represents the importance of indicator i relative to indicator j, satisfying the following equation, where n is the number of indicators in the same layer.

$$b_{ii}=1,\ b_{ij}\frac{1}{b_{ji}} > 0=,\ i,j = 1, 2, \ldots, n \tag{1}$$

The second step, normalize the judgment matrix according to the formula $z_j = \sum_1^n b_{ij}$, in which z_j represents the sum of the elements of the normalized judgment matrix j, then form a vector z. Next, over normalize the vector z and get the result according to the element normalization result of the vector z, that is, the relative weight of index i to the superior index. In addition, the ranking and consistency test of each index based on the AHP model are conducted. The consistency calculation formula is as follows, where CI is the consistency degree of the index:

$$CI = \frac{\lambda_{max}-n}{n-1} \tag{2}$$

In the third step, calculate CR -- the consistency ratio of the AHP model based on CR=CI / RI, where RI is the standard reference value of the consistency index. When the CR calculated value is <0.1, indicating a satisfactory agreement between the two indicators. Finally, the superior index of index i is k, and the superior index of index k is l. The relative weight Z_i of the indicator i to the indicator k and the relative weight of the Z_k of the indicator k against the indicator l is calculated by the above steps. Then the relative weight of index i to index l is $Z_i \times Z_k$. Similarly to the relative weight of the indicator i on the total target, namely the subjective weight W-AHP_i.

3.2. Entropy Weight Method

The entropy weight method is an objective empowerment method, which reflects the potential role of each index in the evaluation results under certain values. The specific steps are as follows:

The first step is to standardize each index according to a specific classification, and then to calculate the proportion of the index i in the sample j in this index:

$$u_{ji} = \frac{a_{ji}}{\sum a_{ji}} \tag{3}$$

In the second step, calculate the entropy of the index i:

$$e_i = -k \sum u_{ij}\, ln\, u_{ij}, k = \frac{1}{ln\, m} \tag{4}$$

In the third step, calculate the different coefficients of the evaluation index i:

$$g_i = 1 - e_i \tag{5}$$

The fourth step, calculate the weight of the evaluation index:

$$w_i = \frac{g_i}{\sum g_i}, (i = 1, 2, \ldots, n) \tag{6}$$

Finally, the entropy weight W-EWM_i is obtained.

3.3. Coupling Method

To clarify the dynamic development relationship between regional e-commerce and regional economy, we conduct the coupling degree analysis, and the mean method is used to obtain the final weight of each index:

$$W_{ae} = \frac{(W-AHP_i+W-EWM_i)}{2} \tag{7}$$

4. Synergetics and Synergy Model

4.1. Determine the Order Parameters of Regional E-commerce and Regional Economic System

This paper regards regional e-commerce and regional economy as a composite system composed of two subsystems with different properties and structures. The parameter variable in the system to determine its macroscopic behavior and characterize the degree of order of the system is the order parameter, which determines the final structure and degree of order of the system. This paper follows the principle of scientific rigor and determines the order parameters of a regional e-commerce and regional economic system based on the studies of Song [8], and Yang [9]. Specifically, the regional e-commerce sub-system is divided into nine sequence parameters reflecting e-commerce infrastructure and e-commerce development scale, and the regional economic subsystem is divided into 11 parameters reflecting economic structure, economic aggregate, and economic benefits.

4.2. Subsystem Order Degree Model

Consider regional e-commerce and regional economy as complexes of two systems s= {s_1, s_2}. s_1 Represents the regional e-commerce subsystem, and s_2 Represents the regional economic subsystem. Consider the subsystem S_j(j [1, 2]), let its order parameter be ej=(e_{j1}, e_{j2}, , e_{jn}), among which α_{ji}, β_{ji} are the critical value of e_{ji} when the system is stable.

$$\beta ji \le eji \le \alpha ji, \quad n \ge 1, i = 1,2, ,n \tag{8}$$

Suppose (e_{j1}, e_{j2},…, $e_{ji.}$) as a positive indicator, and the value is positively correlated with the order degree; (e_{ji}+1, e_{ji}+ 2,…, e_{jn}) is the reverse index, and the value is negatively related to the degree of system order. The system order degree of the system $u_j(e_{ji})$ of e_{ji} is the order parameter component of the subsystem S_j is:

$$u_j(e_{ji}) = \begin{cases} \frac{e_{ji}-\beta_{ji}}{\alpha_{ji}-\beta_{ji}}, i \in [1.l] \\ \frac{\alpha_{ji}-e_{ji}}{\alpha_{ji}-\beta_{ji}}, i \in [l+1.n] \end{cases} \tag{9}$$

Based on synergetics, the contribution of order parameters to the system can be calculated by "integrating" various order parameter components. This paper uses a linear weighting model to integrate, that is, the system order degree of the order parameter variable e_j is:

$$u_j(e_j) = \sum_1^n w_j u_j(e_{ji}), w_j \ge 0 \tag{10}$$

w_j is the weight of each order parameter.

4.3. Composite System Synergy Model

The synergy degree of a regional e-commerce and the regional economic composite system reflects the comprehensive coordination degree of regional e-commerce development and regional economic system operation, namely:

$$U_{(t)} = sig(\cdot)\sqrt{|U_1(t) - U_1(t-1)| * |U_2(t) - U_2(t-1)|} \tag{11}$$

$$sig(\cdot) = \begin{cases} 1, U_1(t) - U_1(t-1) \ge 0, U_2(t) - U_2(t-1) \\ -1, else \end{cases} \tag{12}$$

U_1(t) is the orderly contribution degree of the regional e-commerce subsystem at time t, and U_2(t) is the orderly contribution of the regional economic subsystem at time t. The closer U(t) to 1, the greater the synergy between regional e-commerce and regional economy and the more effective

coordinated development between regional e-commerce and regional economic systems or internal elements. The smaller the U(t) is, the opposite happens.

5. Evaluation of the synergy between regional e-commerce and regional economic development

5.1. Research Objects and Data Collection

5.1.1 Research Objects

Beijing is the capital of the People's Republic of China, a municipality directly under the Central Government and a national central city, with 16 districts and a total area of 16,410.54 square kilometers. In 2021, there were 21.886 million permanent residents in Beijing, with a regional GDP of 426.96 billion yuan. the resident population of Beijing was 21.886 million, with a total regional output value of 426.96 billion yuan. Among them, the added value of primary industry was 11.130 billion yuan, that of the secondary industry was 726.86 billion yuan, and that of the tertiary industry was 3288.96 billion yuan, with a per capita GDP of 183,963 yuan. With the rapid development of e-commerce in Beijing, creating new consumer demand and promoting the interactive and synergistic development of regional e-commerce and industrial chains play an important role in achieving high-quality regional economic development.

5.1.2 Data Collection

The data of regional e-commerce and regional economic system sequence covariate indicators in Beijing are obtained from the Beijing Statistical Yearbook 2013-2020 and the statistical bulletin on the national economic and social development of the corresponding years, and the specific indicators are shown in Table 3.

Table 3. Beijing Regional E-Commerce and Regional Economic System Sequential Parametric Indicator Data

Index	2013	2014	2015	2016	2017	2018	2019	2020
X1	34519	34669	31346	31523	31778	31534	38309	38865
X2	3162341	3595998	3756167	4033558	4302114	4581161	4859824	5032437
X3	57	61	62	66	67	70	72	77
X4	20525	20632	19725	20305	20812	20286	22124	22366
X5	59	60	63	64	65	64	58	58
X6	2576	4361	5350	5661	6028	6536	8516	8877
X7	7.5	12.6	17.1	18	19	20.7	22.2	22.8
X8	7467.6	9012.4	10530.5	12026.7	18385.7	18261.2	23235.9	25831.8
X9	4877.7	7563.9	9534.1	9340.6	11055.8	10623.6	13420.5	15296.4
Y1	159.8	159.2	140.4	129.8	121.9	120.6	114.4	107.61
Y2	4168.3	4433	4419.8	4665.8	5049.4	5477.4	5667.4	5716.4
Y3	16806.5	18333.9	20218.9	22245.7	24711.7	27508.1	29663.4	30278.6
Y4	21134.6	22926	24779.1	27041.2	29883	33106	35445.1	36102.6
Y5	8872.1	9638	12271.9	13134.9	13933.7	14422.3	15063.7	13716.4
Y6	428995812	415518593	319440570	282348960	324017423	412487938	416456752	336478080
Y7	2125	2171	2188	2195	2194	2192	2190	2189
Y8	99456.94	105601.11	113250	123194.53	136203.28	151031.02	161849.77	164927.36
Y9	0.111	0.085	0.081	0.091	0.105	0.108	0.071	0.019
Y10	3661.11	4027.16	4723.86	5081.26	5430.79	5785.92	5817.1	5483.89
Y11	17228.75	18549.79	21589.85	23149.25	24752.92	26395.62	26562.10	25052.03

5.2. Indicators for weighting

5.2.1 Subsystem parametric judgment matrix

Regional e-commerce and regional economies were analyzed using hierarchical analysis, and the judgment matrix calculated in the method was as follows.

Table 4. E-commerce subsystem parametric judgment matrix

	X1	X2	X3	X4	X5	X6	X7	X8	X9
X1	1	4	2	4	2	1.33	4	1	1.33
X2	0.25	1	0.5	1	0.5	0.33	1	0.25	0.33
X3	0.5	2	1	2	1	0.67	2	0.5	0.67
X4	0.25	1	0.5	1	0.5	0.33	1	0.25	0.33
X5	0.5	2	1	2	1	0.67	2	0.5	0.67
X6	0.75	3	1.5	3	1.5	1	3	0.75	1
X7	0.25	1	0.5	1	0.5	0.33	1	0.25	0.33
X8	1	4	2	4	2	1.33	4	1	1.33
X9	0.75	3	1.5	3	1.5	1	3	0.75	1

Table 5. Economic subsystem parametric judgment matrix

	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11
Y1	1	0.67	0.67	0.5	0.5	0.67	2	0.67	1	0.5	0.67
Y2	1.5	1	1	0.75	0.75	1	3	1	1.5	0.75	1
Y3	1.5	1	1	0.75	0.75	1	3	1	1.5	0.75	1
Y4	2	1.33	1.33	1	1	1.33	4	1.33	2	1	1.33
Y5	2	1.33	1.33	1	1	1.33	4	1.33	2	1	1.33
Y6	1.5	1	1	0.75	0.75	1	3	1	1.5	0.75	1
Y7	0.5	0.33	0.33	0.25	0.25	0.33	1	0.33	0.5	0.25	0.33
Y8	1.5	1	1	0.75	0.75	1	3	1	1.5	0.75	1
Y9	1	0.67	0.67	0.5	0.5	0.67	2	0.67	1	0.5	0.67
Y10	2	1.33	1.33	1	1	1.33	4	1.33	2	1	1.33
Y11	1.5	1	1	0.75	0.75	1	3	1	1.5	0.75	1

5.2.2 Determination of indicator weights

Table 6. Beijing regional e-commerce and regional economic system sequence covariate indicator weights

Index Number	Index Name	AHP	EWM	AHP-EWM
Regional e-commerce subsystem	Number of enterprises engaged in e-commerce	0.190	0.219	0.205
	Number of computers used at the end of the period	0.048	0.084	0.066
	Number of computers used per 100 persons	0.095	0.090	0.092
	Number of websites owned by enterprises	0.048	0.111	0.080
	Number of websites owned per 100 enterprises	0.095	0.153	0.124
	Number of enterprises with e-commerce transactions	0.143	0.075	0.109
	Proportion of enterprises with e-commerce transactions	0.048	0.064	0.056
	E-commerce sales	0.190	0.129	0.160
	E-commerce purchase amount	0.143	0.075	0.109
Regional economic subsystem	First industrial output	0.063	0.116	0.089
	Second industrial output	0.094	0.114	0.104
	Third industrial output	0.094	0.106	0.100
	GDP	0.125	0.107	0.116
	Total retail sales of consumer goods	0.125	0.082	0.103
	Total volume of import and export trade	0.094	0.091	0.093
	Permanent population at the end of a year	0.031	0.050	0.041
	Per capita GDP	0.094	0.116	0.105
	GDP growth rate	0.063	0.054	0.058
	Financial revenue	0.125	0.080	0.102
	Per capita budgetary income	0.094	0.084	0.089

The indicators were calculated using hierarchical analysis and entropy value and then averaged to derive the weight of the regional e-commerce and regional economic system covariates in Beijing. The results of the calculation are shown in Table 6.

5.3. Synergy analysis

The hierarchical analysis method and entropy value method were used to calculate the orderliness of the regional e-commerce and regional economy subsystems; on this basis, the synergy degree of the regional e-commerce and regional economy composite system was calculated using equation 11. The changes in the orderliness and synergy degree of e-commerce and the regional economy in Beijing are shown in Figure 1.

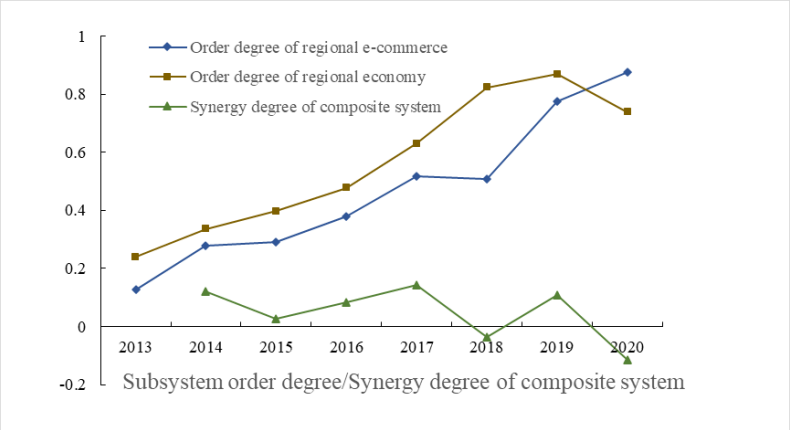

Figure 1. Changes in the orderliness and synergy of e-commerce and the regional economy in Beijing, 2013-2020

5.3.1 Subsystem orderliness analysis

As can be seen from Figure 1, the overall orderliness of the regional e-commerce subsystem and the regional economic subsystem in Beijing is on the rise, and the orderliness of the regional e-commerce subsystem is growing faster than that of the regional economic subsystem. The orderliness of the regional e-commerce subsystem grew from 0.128 in 2013 to 0.876 in 2020, and the orderliness of the regional economy subsystem grew from 0.240 in 2013 to 0.738 in 2020, with the peak of the orderliness of the regional economy subsystem at 0.868 in 2019, indicating that the contribution of the two subsystems to the composite system is increasing. By comparing the orderliness of the regional e-commerce subsystem and the regional economy subsystem, it can be seen that from 2013~2019, the orderliness of the regional economy subsystem was significantly higher than that of the regional e-commerce subsystem. It shows that the regional economy is ahead of regional e-commerce and has a supporting and boosting effect on regional e-commerce; i. In 2020, the orderliness of the regional e-commerce subsystem is obviously higher than that of the regional economy subsystem, and the orderliness of the regional e-commerce subsystem is increasing.

5.3.2 Analysis of the synergy of composite systems

As shown from Figure 1, the degree of synergy between regional e-commerce and regional economic development in Beijing shows an M-shaped development trend of alternating increase and decrease and is generally at a low level of synergy. The overall trend of the synergy degree of the composite system can be divided into four stages.

Stage 1: From 2013 to 2017, both regional e-commerce and the regional economy showed an upward trend, and the economic system was slightly more orderly than the e-commerce system, and its development was ahead of the e-commerce system; at this time, the composite system synergy has been in a positive value, indicating that the two subsystems have been in a synergistic state.

Phase 2: In 2018, the regional economic orderliness is growing, while the regional e-commerce orderliness is showing a downward trend; the composite system synergy is negative, and the two subsystems are in a state of disorder, unable to produce a synergistic state.

Stage 3: In 2019, both regional economic and regional e-commerce orderliness is growing, and regional e-commerce orderliness is growing faster than regional economic orderliness, but regional economic orderliness is still higher than regional e-commerce orderliness; the composite system is positive, and the development trend is good.

Phase 4: In 2020, the regional economic orderliness decreases, but the regional e-commerce orderliness is still increasing, and the regional e-commerce orderliness is higher than the regional economic orderliness; the composite system synergy is negative, and the two subsystems appear to be uncoordinated.

6. Conclusion

(1) From the perspective of system analysis, nine sequential parameters representing regional e-commerce subsystems reflecting e-commerce infrastructure and e-commerce development scale and 11 sequential parameters representing regional economic subsystems reflecting economic structure, economic volume, and economic efficiency are selected to evaluate the level of synergistic development of regional e-commerce and regional economy.

(2) According to the principles of constructing the sequential parameters of a regional e-commerce and regional economic system, the sequential parameters of a regional e-commerce and regional economic system are determined, the evaluation model of the synergy between regional e-commerce and regional economy is established, and the measurement method of the level of synergy between regional e-commerce and regional economy isndetermined.

(3) Taking Beijing as an example, the model is applied to evaluate the synergy between regional e-commerce and regional economic development. The results show that the synergy between regional e-commerce and the regional economy in Beijing shows an M-shaped development trend of alternating increase and decrease and is generally at a low level of synergy.

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