Analysis of the Coupled Development Relationship between Digital Economy and Rural Logistics

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Abstract: Thinking in terms of system coupling, article mainly adopts entropy weight TOPSIS method to measure the development level of digital economy and rural logistics in the three northeastern provinces.With help of the Coupled Coordination Model and Obstacle Degree Model, we explore the coupled developmental relationship that exists between the two and the main factors that influence their development. The research results show that development levels of the digital economy in the three northeastern provinces are gradually exceeding those of rural logistics. There is an obvious correlation between digital economy and rural logistics, and both of them have a lot of space for development. The obstacles constraining the development of digital economy and rural logistics change over time, and the two constitute a dynamically evolving coupled system.

Keywords: digital economy; rural logistics; coupling coordination; obstacle degree model;

1 Introduction

As an integral part of the real economy, logistics is playing an increasingly important supportive role in the process of economic and social development.The rise of the digital economy to help the transformation and upgrading of logistics, which is no longer transport in the traditional sense of the word, the digital technology in the logistics industry make it penetrate into all walks of life. With e-commerce as a major component of the digital economy and an average of about 100 million parcels going in and out of the countryside every day in 2022, the development of e-commerce has made rural logistics increasingly rich. With the advent of the digital economy, rural logistics will usher in new challenges and opportunities. How rural areas are to respond to the laws of the digital economy and the logistics industry to better promote the countryside is now an urgent issue to be explored.

As a hot topic of the times, digital economy has become a hot topic in academic circles. Statistical Classification of the Digital Economy and its Core Industries (2021) points out that the digital economy is a range of economic activities arising from the use of digitized knowledge and information as critical factors of production, the use of modern information networks as key carriers, and efficient use of information and communication technologies as an essential driving force for efficiency enhancement and optimization of the economic structure.Research on digital economy focuses on the connotation of digital economy[1][2], measurement and calculation on the level of development of digital economy[34], and dynamic evolution on digital economy development[5].

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Rural logistics is an important link between rural and urban economies, and an essential factor in promoting the modernization of agriculture and develop rural economy. Exploring the development of rural logistics to assist rural revitalization. Rural logistics refers to the sum of all activities such as transportation, packaging, loading and unloading for all kinds of material materials and products needed for the production and life of rural residents. Currently, academic research on rural logistics focuses mainly on the construction of rural logistics systems[67]. Rural logistics development[89], Rural Logistics Distribution[10], Urban and Rural Logistics[11], Logistics demand[12], etc.

In recent years, in the wake of the rapid emergence of the digital economy, scholars have explored relationships between the digital economy and other industries, such as the digital economy and forestry[13], manufacturing[14], tourism[15]. The majority of existing studies explore relationship between the digital economy and the logistics industry at the provincial [16]or city level[17], few scholars start from the rural perspective, and lack of quantitative exploration on the relationship between the two from the perspective of system coupling. As an important industrial and agricultural base in China, Northeast China plays an important role in national economic development. Developing rural logistics in Northeast China is of great significance to assist Northeast revitalization and promote northeast economic development. Therefore, this paper takes the three provinces in Northeast China as the research object, from the perspective of system coupling, brings digital economy and rural logistics into a unified framework, explores the relationship between them, and identifies the main obstacles affecting their development, which is particularly important for promoting rural revitalization and realizing common prosperity.

The article's main contributions are:(1) Select the three provinces in Northeast China as the research sample to make the research more representative; (2) From the perspective of system coupling, it is fully discussed how relationship exists between digital economy and rural logistics; (3) The article utilizes the obstacle degree model to diagnose the main obstacles affecting development and makes targeted and feasible recommendations

2 Research Methodology

2.1 Entropy weight TOPSIS model

Entropy weight-TOPSIS method is a synthesis evaluation method that can give full play to the original information and truly reflect the actual role of each indicator. The article quantifies the development level of digital economy and rural logistics by using the entropy weight-TOPSIS method on the basis of standardizing the indicators, in which entropy weight method is used to give the weight value of each indicator. Considering that the entropy weight TOPSIS model has been widely used in academic research, the detailed steps here can refer to the practice of Yu[18].

2.2 Coupling coordination model

The coupling coordination model is a tool to quantitatively measure the strength of the interaction between the system as a whole or the internal elements of the research object, and to effectively test the coordinated development between the objects. Applying the coupling coordination model to the study of the coordinated development of rural logistics and the digital

economy, It can reduce influence caused by subjective factors and can objectively reflect coordination between the two. The steps of calculation are as follows:

$$C = \frac{2\sqrt{u_1 u_2}}{u_1 + u_2}; D = \sqrt{C \times T}; T = \lambda_1 u_1 + \lambda_2 u_2 \quad (1)$$

Where C stands for coupling degree; D stands for coupling coordination degree; T stands for coordination index; u1 and u2 stand for digital economy development index and rural logistics development index respectively; since digital economy and rural logistics development are equally important, $\lambda 1 = \lambda 2 = 0.5$.

After the above calculations, the degree of coupling coordination between the two systems is quantified and the coupling coordination level is classified with reference to previous studies [19]. The coupling coordination degree between digital economy and rural logistics is divided into three stages, and the specific classification and corresponding values are shown in Table 1:

Table 1. Criteria for classification of coupling coordination levels

Coupling coordination	D < 0.40	0.40 ≤ D < 0.70	0.70 ≤ D < 1.00
Coupling and coordination phase	Antagonistic phase	Breaking-in phase	Coordination phase

In order to better reflect the coordination difference characteristics of the coupled development of digital economy and rural logistics, this paper introduces the relative development degree g. According to the value of g, the three coupled coordination stages mentioned above are specifically in the state of system decline or optimization to be divided18, as shown in Table 2.

Table 2. Criteria for division into specific zones

D	g	Type	Features
0≤D<0.4	0≤g＜0.8	I	Digital economy lag, low antagonism
	0.8≤g<1.2	II	Balanced development, low antagonism
	1.2≤g	III	Digital economy ahead, high antagonistic
0.4≤D<0.7	0≤g<0.8	IV	Digital economy lag, low grind
	0.8≤g<1.2	V	Balanced development, highly honed
	1.2≤g	VI	Digital economy ahead, low grind
0.7≤D<1.0	0≤g<0.8	VII	Digital economy lag, low coordination
	0.8≤g<1.2	VIII	Balanced development, highly coordinated
	1.2≤g	IX	Digital economy ahead, low coordination

2.3 Obstacle degree model

After concluding the analysis of the coupling coordination degree, in order to further explore which indicators represent the main obstacles inhibiting the development of digital economy and rural logistics, this article introduces indicator deviation degree V_{ij}, factor contribution degree S_j, and indicator obstacle degree H_{ij} with reference to previous studies.

$$V_{ij} = 1 - Y_{ij}; H_{ij} = \frac{S_j \times V_{ij}}{\sum_{i=1}^{n} S_j \times V_{ij}} \times 100\%; P_k = \sum_{k=1}^{q} H_{ij} \quad (2)$$

where P_k represents the element layer barrier and q represents the number of indicators in element layer k.

3 Indicator construction

On the basis of the applicability, comparability and data quantifiability principles of the index system, the article builds the evaluation index system of digital economy and rural logistics by drawing on the research results of previous researchers[20][21][22][23]. Divide the digital economic system into digital infrastructure, digital industry scale, and digital development potential; rural logistics system is divided into rural logistics infrastructure, scale of rural logistics industry. Considering data availability, the rural logistics route is replaced by the rural postal delivery route. Therefore, the evaluation index system of digital economy and rural logistics includes 5 element layers and 16 index layers. The indicators are listed in Table 3:

Table 3. Evaluation index system of digital economy and rural logistics

System	Primary Index	Secondary Index	Weight
Figures Economy	Digital infrastructure	Optic cable density X_1 (km/km²)	0.11
		Capacity of Mobile Telephone Exchanges X_2 (10000 lines)	0.07
		Number of Domain Names X_3 (10000 unit)	0.07
		Websites Per 100 Enterprises X_4 (unit)	0.06
	Digital industry scale	Business Volume of Telecommunication Services X_5 (100 million yuan)	0.17
		Software Income X_6 (million yuan)	0.16
		Revenue from Express Services X_7 (million yuan)	0.10
		E-commerce sales X_8 (billion yuan)	0.15
	Digital development potential	Number of information technology practitioners X_9 (10,000 people)	0.07
		Digital Inclusive Finance Index X_{10} (%)	0.05
Rural Logistics	Rural logistics infrastructure	Rural Logistics Route X_{11} (km)	0.08
		Rural Highway Mileage X_{12} (km)	0.08
	Scale of rural logistics industry	Value added in the rural logistics sector X_{13} (billion yuan)	0.13
		Rural freight volumeX_{14} (million tons)	0.25

	Rural cargo turnover X_{15} (100 million tonnes km)	0.30
	Rural logistics practitioners X_{16} (10,000 people)	0.16

3.1 Data sources

Due to the late development of digital economy, the data of some indicators of the digital economy subsystem constructed in this paper are only available from 2013, considering the reliability and availability of data, the time range of measurement in this paper is 2013-2021, all data are from China Statistical Yearbook, Liaoning Statistical Yearbook, Jilin Statistical Yearbook, Heilongjiang Statistical Yearbook, Peking University Digital Inclusive Finance Index[24],and the website of the National Bureau of Statistics. For the missing data of individual indicators, this paper adopts the interpolation method and the mean value to fill in.

4 Results and analyses

4.1 The digital economy and the current situation of the development of rural logistics

The development level of digital economy and rural logistics is the basis for exploring the coupled and coordinated relations between the two, and the development level of digital economy and rural logistics in the three northeastern provinces of China is presented in Table 4.

From an integral perspective, the digital economy development index of the three northeastern provinces shows an irregular upward trend during the observation period from 2013 to 2021, and the average annual growth rate is 6.05%; During the observation period, there was a clear downward trend in the Rural Logistics Development Index, due to the fact that with the increasing demand for logistics in rural areas, the supply of rural logistics does not match the actual demand, which has a negative impact on rural logistics, resulting in the Rural Logistics Development The rural logistics development index decreased. In terms of specific provinces, Liaoning led the digital economy development from 2013 to 2021, with the Digital Economy Development Index increasing from 0.404 to 0.766, with an average annual growth rate of 5.17%, while the average annual growth rate of rural logistics was -5.06%. 2013-2018, the Digital Economy Development Index for Liaoning and Heilongjiang was lower than the Rural Logistics Development Index, and from 2019-2021, the two provinces The level of rural logistics development lags behind that of the digital economy due to the impact of the epidemic, leaving rural logistics in an indirect state of stagnation; Jilin's digital economy and rural logistics show fluctuating growth from 2013-2021, but the two do not develop at exactly the same pace.

The above is only an analysis of the changing trends in the development of digital economy and rural logistics in the three northeastern provinces, and the relationship between the two is only a preliminary inference. The next part of the article will further examine how the relationship between the two exists and explore its dynamic evolution with the help of a coupled coordination degree model.

Table 4. Digital economy and rural logistics development index in northeast China

Year	u_1				u_2			
	Liaoning	Jilin	Heilongjiang	Average	Liaoning	Jilin	Heilongjiang	Average
2013	0.40	0.10	0.17	0.22	0.74	0.06	0.21	0.33
2014	0.45	0.13	0.19	0.26	0.77	0.07	0.20	0.34
2015	0.52	0.14	0.19	0.29	0.75	0.06	0.20	0.33
2016	0.44	0.12	0.16	0.24	0.77	0.07	0.20	0.34
2017	0.49	0.16	0.20	0.28	0.78	0.19	0.20	0.39
2018	0.59	0.24	0.23	0.35	0.77	0.22	0.20	0.40
2019	0.71	0.30	0.31	0.44	0.67	0.24	0.19	0.37
2020	0.77	0.34	0.34	0.48	0.52	0.26	0.17	0.32
2021	0.57	0.21	0.22	0.33	0.51	0.3	0.17	0.33

4.2 Analysis of coupling coordination degree between digital economy and rural logistics

Based on the previous analysis of the level of development, the coupling coordination degree and relative development degree of the two were further calculated. Specific calculation results in Table 5.

From the perspective of coupling coordination degree, the coupling degree of digital economy and rural logistics in the three northeastern provinces stays between [0.91-1.0] from 2013 to 2021, which is a state of high intensity coupling.The coupling coordination of the three northeastern provinces as a whole is in the range of [0.48, 0.61], and they are all in the teething stage during the measurement time. Since the magnitude of coupling coordination depends on the development index of both digital economy and rural logistics subsystems, a high coupling degree is not accompanied by a high coupling coordination degree. In terms of specific provinces, Liaoning's digital economy and rural logistics both reached a state of coordination in 2013-2021, with the coupling coordination degree in the interval [0.74, 0.83], and although there was a temporary decline or slowdown in some years, Liaoning had the highest coupling coordination degree among the three provinces; Jilin developed from antagonism to the grinding stage during the sample period, and Heilongjiang's two systems of digital economy and rural logistics were 2013-2021 are in the grinding stage.

From the perspective of relative development, the overall relative development value of the three northeastern provinces in 2013-2021 is in the range [0.770,1.334], except for 2018 and 2020, the overall relative development of the three northeastern provinces is type V, indicating that the digital economy and rural logistics are in a highly abrasive stage, but the two are synchronized and the whole system tends to be in an optimized state. In terms of specific provinces, Liaoning's coupling and coordination type from 2013-2018 is type VII, Which means that the digital economy and rural logistics are in a state of coordinated development, but the digital economy is lagging behind relatively; the coupling and coordination type develops to type VIII in 2019, and the development of the digital economy and rural logistics develop simultaneously. 2013-2016 Jilin's coupling and coordination type is type III, which is at the antagonistic stage; In 2017, it enters the grinding stage, and the coupling coordination type changes to type V, indicating that the development of the digital economy is synchronized with the development of rural logistics; in 2019, it turns to type VI, in the low grinding stage, and by

2021, it changes from type VI to type VII, with the development of the digital economy lagging behind the development of rural logistics. Heilongjiang 2013-2018 coupling coordination type V, in the grinding state, since 2019 to develop to type VI.

Table 5. Degree of coupling, coordination and relative development of the digital economy and rural logistics

Year	C			D			g		
	Liaoning	Jilin	Heilongjiang	Liaoning	Jilin	Heilongjiang	Liaoning	Jilin	Heilongjiang
2013	0.96	0.97	0.99	0.74	0.27	0.43	0.55	1.64	0.80
2014	0.97	0.94	1.00	0.77	0.31	0.44	0.59	2.08	0.93
2015	0.98	0.91	1.00	0.79	0.30	0.44	0.70	2.42	0.97
2016	0.96	0.96	1.00	0.76	0.30	0.42	0.57	1.74	0.83
2017	0.97	1.00	1.00	0.79	0.42	0.45	0.63	0.83	1.00
2018	0.99	1.00	1.00	0.82	0.48	0.47	0.76	1.08	1.17
2019	1.00	0.99	0.97	0.83	0.52	0.49	1.06	1.26	1.59
2020	0.98	0.99	0.94	0.79	0.55	0.49	1.49	1.29	1.98
2021	1.00	0.99	0.99	0.74	0.50	0.43	1.12	0.72	1.30

4.3 Analysis of obstacles

Exploring the main obstacles to development and their magnitude will help to find paths to promote development. Based on the calculation, the indicators at the indicator level were ranked in order of magnitude, and the top three indicators in the three northeastern provinces were selected as the main obstacles, as shown in Table 6.

In terms of the frequency of occurrence of the indicator-level barriers, the three northeastern provinces were ranked according to the frequency of occurrence of the indicator-level barriers: Rural cargo turnover (X15) >Business Volume of Telecommunication Services (X5) >Rural freight volume (X14) >Rural logistics practitioners (X16) >E-commerce sales (X8). In terms of specific provinces, the number of rural logistics employees X16 occurred most frequently in Liaoning, with nine occurrences; the business volume of telecommunication services (X5) occurred seven times; e-commerce sales X8 appeared 4 times. In Jilin and Heilongjiang, rural cargo turnover X15 and rural freight volume X14 appear with the same frequency, both appearing nine times; X5 appears six times and X6 appears twice.

From the perspective of barrier factors in each province, the top barrier factor in Liaoning Province from 2013-2017 was the total amount of telecommunication business (X5), whose barrier degree was increasing year by year, followed by e-commerce sales (X8) and the number of people in the rural logistics practitioners (X16); from 2015-2017 the number of people in the rural logistics practitioners (X16) rose from the third place to the second place, and the barrier degree value gradually increased; in 2018 the rural logistics The number of people in the industry (X16) becomes the primary barrier factor, Business volume of telecommunication services (X5) drops from the previous first place to the second place, and software business revenue (X6) is in the third place and continues until 2019; Rural cargo turnover (X15) is the primary barrier factor in 2019-2021. Rural cargo turnover (X15) and rural freight volume (X14) are the main barrier factors affecting Jilin Province in 2013-2021, respectively occupying the top two positions, with the business volume of telecommunication services (X5) in third position

for 2013-2017 and 2021, and e-commerce sales (X8) replacing total telecommunication services (X5) in third position for 2018. Rural cargo turnover (X15) is the top barrier factor constraining the digital economy and rural logistics in Heilongjiang Province for 2013-2017 and 2019-2021, followed by rural freight volume (X14) and business volume of telecommunication services (X5). In 2018, Rural cargo turnover (X15) dropped from first to second place, rural freight volume (X14) rose from second to first place, and the number of people in the rural logistics practitioners (X16) replaced the business volume of telecommunication services (X5) in third place.

It can be seen that the barrier factors are usually changing from year to year in each province and the order is constantly being adjusted, indicating that the development within the system is a dynamic process of change and that the importance of the indicators is not static; the two are a dynamically changing coupled system.

Table 6. Main obstacle factors and obstacle degree of digital economy and rural logistics index layer (%)

Year	Region	Liaoning			Jilin			Heilongjiang		
2013	Obstacles	X_5	X_8	X_{16}	X_{15}	X_{14}	X_5	X_{15}	X_{14}	X_5
	Obstacle degree	16.17	11.78	9.88	15.57	13.16	8.83	16.94	13.31	9.61
2014	Obstacles	X_5	X_8	X_{16}	X_{15}	X_{14}	X_5	X_{15}	X_{14}	X_5
	Obstacle degree	18.53	12.20	10.82	16.02	13.30	9.02	17.56	13.72	9.70
2015	Obstacles	X_5	X_{16}	X_7	X_{15}	X_{14}	X_5	X_{15}	X_{14}	X_5
	Obstacle degree	19.83	13.45	11.01	16.02	13.30	9.02	18.09	14.28	9.52
2016	Obstacles	X_5	X_{16}	X_8	X_{15}	X_{14}	X_5	X_{15}	X_{14}	X_5
	Obstacle degree	19.97	13.03	11.12	16.41	13.59	9.15	17.75	14.07	9.77
2017	Obstacles	X_5	X_{16}	X_8	X_{15}	X_{14}	X_5	X_{15}	X_{14}	X_5
	Obstacle degree	20.07	15.08	10.48	17.49	14.29	9.19	18.27	14.41	9.25
2018	Obstacles	X_{16}	X_5	X_6	X_{15}	X_{14}	X_8	X_{14}	X_{15}	X_{16}
	Obstacle degree	14.95	14.12	13.33	18.55	15.06	8.60	14.79	18.72	10.11
2019	Obstacles	X_{15}	X_{16}	X_6	X_{15}	X_{14}	X_6	X_{15}	X_{14}	X_6
	Obstacle degree	17.00	14.07	11.40	19.17	16.52	9.22	19.30	15.70	10.29
2020	Obstacles	X_{15}	X_{16}	X_{14}	X_{15}	X_{14}	X_6	X_{15}	X_{14}	X_6
	Obstacle degree	29.68	13.92	11.87	19.31	16.59	9.18	19.42	15.92	10.36
2021	Obstacles	X_{15}	X_5	X_{16}	X_{15}	X_{14}	X_5	X_{15}	X_{14}	X_5
	Obstacle degree	27.93	20.31	11.61	18.24	15.19	10.80	17.48	13.99	10.04

5 Conclusions

The article builds a digital economy and rural logistics evaluation index system, and analyzes it based on the panel data based on the three northeastern provinces from 2013 to 2021, and the research results of the article follow:

(1) At the level of development, the development progress of digital economy in the three northeastern provinces from 2013 to 2021 has changed from weaker than rural logistics to stronger than rural logistics, and the gap between the two has been changing and tends to narrow, with Liaoning's digital economy and The development level of both the digital economy and rural logistics in Liaoning province is in the first place.

(2) At the level of coordination of coupling, the digital economy and rural logistics in the three northeastern provinces are at an overall stage of integration. However, there is a large difference in the level of coordination between the three provinces, with Liaoning at the coordination stage, Jilin moving from the antagonism stage to the friction stage, and Heilongjiang remaining at the friction stage.

(3) At the barrier degree diagnosis level, the main barrier factors affecting the digital economy and rural logistics include total telecommunication business (X5), e-commerce sales (X8), number of people in the rural logistics industry (X16), express business revenue (X7), software business revenue (X6) and freight turnover (X15), but the coupled and coordinated development of the digital economy and rural logistics is a dynamic change process. The barrier factors are constantly changing and the order is constantly being adjusted from year to year in each province.

Based on the results of the study, the article makes the following recommendations: (1) Each region should comply with laws of development of the times, actively play a leading role in the digital economy, and accelerate the transformation and upgrading of rural logistics. Local governments should take the initiative to provide strong policy for the development of the digital economy and logistics-related industries. (2) Formulate and actively implement policies related to the development of the digital economy and rural logistics in the light of the actual situation in the region, so as to inject new momentum into the development of the digital economy and rural logistics, and take all measures to ensure the coordinated and balanced development of the digital economy and rural logistics. for example, by increasing school-enterprise cooperation, so as to provide a new force for social development. (3) Strengthen infrastructure construction and optimization of spatial layout for digital economy and rural logistics. With policy support, relevant enterprises need to strengthen the cultivation and introduction of specialized and diversified digital talents and logistics composite talents, and strengthen the use of advanced technology and advanced equipment to jointly facilitate the development of digital economy and rural logistics.

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