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Yuyan Li

School of Business of BSU, Minsk, Belarus

OPTIMISATION PATHS FOR DISTRIBUTION LOGISTICS UNDER DIGITAL RESILIENCE

This paper examines the development level of distribution logistics from the perspective of digital toughness and resilience, using data from 30 Chinese cities from 2016 to 2021. According to the findings, the digital resilience level of distribution logistics is critical to promoting high-quality economic development. As a result, emphasizing logistics industry development, strengthening inter-regional exchanges and cooperation, and balancing regional spatial differences can help promote the digital development of distribution logistics and long-term economic development.

Keywords: logistics, distribution logistics, digitalisation, digital resilience, China

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Юйянь Ли

Институт бизнеса БГУ, Минск, Беларусь

**ПУТИ ОПТИМИЗАЦИИ ЛОГИСТИКИ РАСПРЕДЕЛЕНИЯ
В УСЛОВИЯХ ЦИФРОВОЙ УСТОЙЧИВОСТИ**

В статье на основе данных по 30 городам Китая за период с 2016 по 2021 год рассматривается уровень развития распределительной логистики с точки зрения «цифровой жесткости» и «устойчивости». Согласно полученным результатам, уровень цифровой устойчивости распределительной логистики имеет решающее значение для обеспечения качественного экономического развития. Таким образом, акцент на развитии логистической отрасли, укрепление межрегиональных обменов и сотрудничества, а также сбалансированность региональных пространственных различий могут способствовать цифровому развитию логистики распределения и долгосрочному экономическому развитию.

Ключевые слова: логистика, логистика распределения, цифровизация, цифровая устойчивость, Китай

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Introduction

Digital resilience refers to the ability of each segment to withstand shocks, avoid ruptures, and maintain the stability of its own system by using digital capabilities in response to internal and external risks. In an era of digitally and intelligently driven development, distribution links need to enhance the resilience of the logistics industry with the help of digital technology, and digital resilience through data strategy helps to promote the digital transformation of distribution, thereby strengthening economic resilience [1]. In September 2023, the China Federation of Logistics and Purchasing (CFLP) emphasized the enhancement of the resilience of the logistics industry, especially during the «digital integration» systematic and multi-directional integration of the key period. So, it is also necessary to further improve the development mode of distribution digitalization and to clarify the ability of the logistics industry to cope with economic shocks, i. e., the resilience level of digital distribution plays a crucial role in the high-quality development of the industry and the economy [2].

The current distribution logistics research on digitalization focuses primarily on the level of development of digital logistics, digital innovation capacity, spatial differences in regional logistics, and supply chain resilience, among other things [3]. The research focus is primarily on individual cities or businesses, with fewer research samples and even fewer studies on digital resilience for distribution logistics. This paper sets out to investigate distribution logistics in the context of digital resilience, with an approach that includes induction, analysis, abstraction, and modelling. Using the panel data of 30 provinces in China from 2016–2021, the digital resilience of distribution logistics is measured by the entropy weight method, and the spatial relationship of the digital resilience of distribution logistics is analysed by using the Moran index and geo-detector model, so as to explore the optimisation path of the digitalisation of distribution logistics. As a result, accelerating distribution logistics digitization is the core structure to promote the modernization and transformation of the logistics industry, which has become an important way to grow the economy and support high-quality economic development and is also of great practical significance for Belarus.

Results and discussion

This paper takes the concept of digital resilience as a guideline and constructs an evaluation index system for the digital resilience of distribution logistics based on the characteristics and nature of distribution logistics (Table 1).

Table 1

Indicators for evaluating the level of digital resilience in distribution logistics

First-level indicators	Second-level indicators	Unit
Digital logistics basic input factor	Fixed asset investment in logistics industry	Million yuan
	Employees in logistics industry	People
	Ownership of logistics trucks	Volume
	Logistics industry transport informatisation	%
Digital logistics innovation factor	Logistic industry total output / digital input	%
	Number of logistics patent applications	Number
	Number of logistics digitisation research projects	Number
	Students in general tertiary institutions	Million
	Energy consumption of logistics industry	Million tonnes
	Total volume of railway and road freight transport	Million tonnes
	Output value of logistics industry / GDP	%
Digital logistics coordination structure	Fixed capital stock of logistics per capita	Million yuan / person
	Retail sales of logistics industry	Billion yuan
	Value added of logistics industry	Million yuan

Source: author's developed.

The original indicator data of digital resilience evaluating for 30 provinces in China are obtained from the China Statistical Yearbook for 2016–2021, supplemented by local statistical yearbooks, and the missing individual data are made up by interpolation [3].

The specific research design is as follows, using the TOPSIS method to determine the digital logistics resilience indicator weights [4].

The level of digital resilience in distribution logistics is measured based on the weights of the indicators and the values after standardisation of the indicators:

$$S = \sum_{i=1}^n W_i x'_{ij}.$$

Statistical analysis is then combined with spatial analysis to analyze the spatial evolution patterns of distribution logistics and differences in numerical resilience.

$$\text{Moran's I} = \frac{\sum_{i=1}^n \sum_{j=1}^m w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{S^2 \sum_{i=1}^n \sum_{j=1}^m w_{ij}}$$

In the formula, n and m are 30, indicating 30 provinces, autonomous regions, and cities; x_i and x_j are the digital toughness values of distribution logistics in different regions in the study year; \bar{x} is the average value of digital toughness of distribution logistics in all years; S^2 is the sample variance; w_{ij} and is the spatial adjacency matrix constructed on the basis of all study regions.

In order to explore the spatial heterogeneity of the digital toughness of distribution logistics, this paper adopts the factor detector and the factor interaction detector in the geographic detector to analyze the main driving factors affecting the development of the digital toughness of distribution logistics [5]. Mainly through the assumption that the spatial distribution of the independent variables has similarity when they have an effect on the dependent variable, the q -value is used to judge the intensity of the factor effect and the interaction effect.

$$q = 1 - \frac{\sum_{h=1}^{30} (N_h \cdot \sigma_h^2)}{N \sigma^2}$$

Table 2 shows the development index of digital resilience in distribution logistics in 2016 and 2021, as well as the ranking. Overall, the top-ranked provinces of digital toughness of distribution logistics are concentrated in the eastern region with stable changes, followed by the central region, and the western region lags behind in the development level of digital toughness of distribution logistics, showing an overall distribution pattern of high in the east and low in the west [6].

Table 2

Development Index and Ranking of Distribution Logistics Digital Resilience 2016, 2021

Region	City	2016	Sort	2021	Sort	Region	City	2016	Sort	2021	Sort
East	Guangdong	0.453	1	0.690	1	West	Sichuan	0.142	11	0.220	8
	Jiangsu	0.389	2	0.468	2		Chongqing	0.136	14	0.190	13
	Shanghai	0.359	3	0.421	3		Shanxi	0.125	16	0.160	17
	Beijing	0.290	4	0.408	4		Guangxi	0.092	21	0.128	19
	Zhejiang	0.288	5	0.352	5		Yunnan	0.082	23	0.117	21
	Shandong	0.263	6	0.301	6		Xinjiang	0.093	20	0.112	22
	Fujian	0.176	7	0.253	7		Guizhou	0.070	27	0.106	24
	Tianjing	0.165	8	0.201	9		Ningxia	0.056	30	0.086	26
	Liaoning	0.154	10	0.167	15		Neimeng	0.072	26	0.084	28
	Hebei	0.123	17	0.147	18		Gansu	0.057	29	0.076	29
	Hainan	0.098	19	0.122	20		Qinghai	0.059	28	0.063	30
Central	Hubei	0.163	9	0.200	10	Central	Jiangxi	0.115	18	0.163	16
	Anhui	0.131	15	0.192	11		Shanxi	0.083	22	0.107	23
	Henan	0.139	13	0.191	12		Heilongjiang	0.082	24	0.087	25
	Hunan	0.140	12	0.180	14		Jilin	0.080	25	0.086	27

Source: author's developed on the basis of data obtained from the China Statistical Yearbook for 2016–2021 [3].

The three major regions in China are used to analyze the trend of the digital resilience development level of distribution logistics in 2016–2021, and the changes in the resilience level in China are compared

and analyzed. It can be seen that the digital resilience of distribution logistics in the eastern region has the greatest change, and the trend of the national resilience development level and the change of the resilience development level of the central and western provinces is basically the same, and the eastern region contributes more to the improvement of the national resilience development level, which is mainly related to the eastern region's favourable geographic conditions, developed economy, and obvious industry-driven effect.

The evolution of the digital resilience spatial structure of distribution logistics is verified by the global Moran index. The Moran index varies between $[-1, 1]$. Through the study of the Moran index of the development level of digital resilience of distribution logistics in 2016–2021, it was found that the Moran index is positive in the study period, indicating that the digital resilience of distribution logistics in this period shows a spatial clustering trend in space and there is a positive spatial correlation, and the decline of the Moran index as of 2021 indicates that the spatial correlation is weakened, which is related to the regional development in different periods. Policies are closely related to economic development, but they all passed the 1 % significance test with a z-value greater than 2.58 (Table 3).

Table 3

The Moran Index of Digital Resilience in Distribution Logistics 2016–2021

Year	Moran's I	Expected value (I)	Standard deviation	Z-value	Probability
2016	0.383	-0.034	0.118	3.540	0
2017	0.397	-0.034	0.118	3.665	0
2018	0.390	-0.034	0.117	3.622	0
2019	0.361	-0.034	0.115	3.446	0
2020	0.352	-0.034	0.114	3.401	0
2021	0.346	-0.034	0.113	3.358	0

Source: author's developed.

To summarize existing studies and analyze the extent to which each factor influences changes in digital resilience in distribution logistics (Table 4).

Table 4

Spatial influences on digital resilience in distribution logistics

Code	Impact Factor	Factor Explanation
X1	Policy support	Fiscal expenditure on distribution sector
X2	Urban Development	Urbanisation rate (urban population / regional resident population)
X3	Environmental level	Completed investment in environmental pollution control
X4	Employees	Employees in the distribution and logistics industry
X5	Regional Development Potential	GDP per capita
X6	Regional Consumption Potential	Consumption potential per capita

Source: author's developed.

As shown in Table 4, policy support affects the construction of digital logistics infrastructure and related industry norms; the development of regional urbanization is closely related to economic development, the economy has an important role in the digital development of distribution logistics; the level of the environment on behalf of the prospects for the development of the logistics industry, as well as social responsibility, etc.; the impact of the distribution logistics practitioners on the development of the logistics industry throughout the whole process, and all aspects are inseparable from these practitioners; the regional development potential. Development potential, regional GDP can reflect the potential for regional development, economic strength of a better foundation of the region can improve the digital development of distribution logistics efficiency and resilience; regional consumption potential, the existence of the consumer market is the basis for the development of the logistics industry.

The effect values of the six impact factors were detected by the geodetector factor drive. The q -values of the selected impact factors in 2016 and 2021 both pass the test of significance of 1 %, indicating that the impact of the impact factors on the level of digital resilience of distribution logistics is both significant and correlated. In 2016, regional consumption potential was the key factor influencing the digital development of distribution logistics, followed by distribution logistics practitioners and regional development potential, and the level of regional economic development played a basic supportive role in the digital development of distribution logistics. Digital development has a basic support role.

In 2021, the strongest influence on the digital development of distribution logistics is the level of the environment; the regional consumption potential role value becomes second; the regional development potential still maintains third place; at the beginning and end of the period, policy support and the level of urban development have an impact on the development of the digital resilience of distribution logistics. Regional consumption potential and development potential for the development of digital logistics continue to provide impetus for the development of digital logistics over time. As development changes, the digital development of distribution logistics has become an object of concern. The factor interaction detector is able to explore the impact of the interaction between the various influencing factors on the digital development of distribution logistics based on the detection of influencing factor interactions on the development of digital resilience in distribution logistics in 2016 and 2021.

In 2016, regional consumption potential X6 had the strongest interaction with other factors (Table 5).

Table 5

Results of spatial influence factors of digital toughness of distribution logistics in 2016

Factor	X1	X2	X3	X4	X5	X6
X1	0.335	Ne	Ne	Ne	Ne	Ne
X2	0.753	0.319	NE	NE	NE	NE
X3	0.996	0.996	0.349	BE	BE	BE
X4	0.884	0.926	0.889	0.522	BE	BE
X5	0.998	0.997	0.742	0.891	0.482	BE
X6	0.966	0.989	0.898	0.964	0.929	0.618

Source: author's developed.

The strongest influence on the development of distribution logistics digitalization, and the strength of the interaction of each factor in this period was higher than the value of the independent effect of each influencing factor. The two-by-two interaction of the influencing factors on the development of distribution logistics digitalization produces non-linear enhancement and two-factor enhancement effects, indicating that the digitalization of distribution logistics is the result of the joint action of multiple factors, and the intensity of the role of policy support and regional development period is the greatest, with an explanatory intensity of more than 99 %, followed by the level of urban development and the potential for regional development, indicating that the interaction of the potential for regional development is the strongest in the period, and in the interaction with the other factors, role Maximum.

In 2021, the factor interaction changes, this period is still non-linear enhancement and two-factor enhancement on the digital development of distribution logistics, but this period of two-factor enhancement to strengthen the role of the two-factor enhancement, non-linear enhancement effect is weakened, and still two-factor interaction values are greater than the value of the independent role of each factor (Table 6).

Table 6

Results of spatial influence factors of digital toughness of distribution logistics in 2021

Factor	X1	X2	X3	X4	X5	X6
X1	0.533	BE	BE	BE	BE	BE
X2	0.773	0.295	NE	NE	NE	NE

Ending of the table 6

Factor	X1	X2	X3	X4	X5	X6
X3	0.935	0.985	0.637	BE	BE	BE
X4	0.814	0.929	0.986	0.467	BE	BE
X5	0.953	0.998	0.830	0.864	0.555	BE
X6	0.848	0.989	0.943	0.852	0.993	0.628

Source: author's developed.

Environmental level interacts with policy support and urban development in the same way, and the value of urban development potential and policy support is still the largest, indicating that under the goal of digital development, the support of the government and the basis of regional economic development are the basis and key influences on the development of the digital resilience of distribution logistics.

Conclusions

Therefore, the following conclusions are drawn. The digital toughness of distribution logistics in 2016–2021 from time to time shows a trend of continuous improvement, through the ranking of the eastern region of the provinces more stable and unchanged, the central region and part of the western region of the provinces in the gradual improvement of the state of the western region more provinces are in the low level of development stage, regional differences are obvious. From the point of view of spatial change, the digital toughness of distribution logistics there is an obvious spatial positive correlation effect, and the local spatial agglomeration effect is significant, low-low agglomeration area gradually to the high-high agglomeration area to leapfrog, polarization phenomenon is weakened.

Based on the above conclusions, the following recommendations are proposed for the digital resilience enhancement of distribution logistics:

First, according to the development of digital resilience in distribution logistics, the state needs to further target the development of the logistics industry, increase investment in education, cultivate basic talents, improve the development of digital logistics, improve the conversion rate of scientific research results, apply them to the logistics industry, enhance the potential of digital development of distribution logistics, and retain talents.

Second, according to the development of the digital resilience of distribution logistics factors, we need to improve the level of infrastructure development of the digital development of distribution logistics in various regions, increase government policy support for the transport industry and environmental governance, strengthen artificial intelligence, Internet of Things construction, improve the efficiency of information communication in the logistics industry and the level of development [7].

Third, from the point of view of the impact factor, the current regional development potential and consumption potential is still a key factor affecting the digital development of distribution logistics, so we need to improve the level of regional economic development, pay attention to the consumption demand and development needs of different regions, combined with the development of the supply side, to promote the orderly development of supply and demand synergies, which in turn promotes the enhancement of the digital resilience level of regional distribution logistics.

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Information about the author

Li Yuyan – PhD student, School of Business of BSU,
e-mail: iamyanplus@gmail.com

Информация об авторе

Ли Юйянь – аспирантка, Институт бизнеса БГУ,
e-mail: iamyanplus@gmail.com

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