



# Research on the Coupling Mechanism of Intelligent Logistics and the Northeast Regional Economy—A Case Study of Liaoning province

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**Abstract.** This paper proposes an evaluation index system for intelligent logistics and regional economic growth in Liaoning Province, based on the "14th Five-Year Plan" for modern logistics development in China. It fully employs entropy weighting and a coupling coordination degree model to analyze the index system and identify factors and countermeasures for coordinated development. The study unveils that the degree of coordination between the smart logistics system and the regional economic system in Liaoning Province is gradually increasing and is currently in the primary coordinated development stage. The primary constraints on the coordinated development of smart logistics and the regional economy are the level of sophistication of the logistics industry and the industrial structure. These constraints can be addressed through increased investment in fostering the level of regional logistics technology, which will construct a more advanced logistics technology, thus strengthening the stability of the benign environment of economic growth. This will open up a new way for regional economic development, and fill the gap in the research of intelligent logistics in Northeast China, and effectively affect the coordinated development of both sides. A new economic development path has been established, thus enabling smart logistics and sustainable economic development.

**Keywords:** smart logistics; regional economy; northeast region; evaluation index system; coupled coordination degree model

## 1 Introduction

Liaoning Province, a key province in Northeast China with a strong foreign trade economy, has strengthened win-win cooperation with other countries under the Belt and Road Initiative. The integration of external resources and the operational efficiency of the modern logistics industry have been greatly improved. The "14th Five-Year Plan" includes the construction of a smart and green modernized logistics system. <sup>[1]</sup>Promoting coordinated development of smart logistics and regional economy is key to economic transformation in Liaoning and the Northeast region.

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In the study of regional smart logistics evaluation, scholars in related fields, such as Chen et al. <sup>[2]</sup>(2019), aimed to provide references for future regional logistics policies by analyzing indicators that contribute to regional economic growth using specific provinces as samples. Zhang et al. <sup>[3]</sup> (2021), on the other hand, analyzed the current situation of logistics development in 23 representative hub cities and proposed solutions to existing regional development problems. Lu et al. (2020) <sup>[4]</sup>explored the development mechanism between regional economy and logistics, constructed a system dynamics model for empirical research, and offered practical suggestions, using Henan Province as an example. Additionally, Ma et al. (2022) <sup>[5]</sup>conducted a diversified study on the development level of smart logistics, focusing on the economic environment and economic activities at the economic level, as well as the scale of development and logistics technology at the logistics level. It is concluded that the basic situation of smart logistics development in China's regional segments is unbalanced and exhibits significant differences. Furthermore, Fang and Hu (2023)<sup>[6]</sup>conducted a multi-level, multi-faceted analysis of the development of smart logistics in the Yangtze River Economic Belt, emphasizing the transformation of the logistics industry from traditional to smart to enhance the efficiency of economic development and promote high-quality, high-quantity, and high-speed regional economic development. In terms of strategic development research, Yang and Li (2023)<sup>[7]</sup>proposed developmental opinions for the regional logistics industry and the regional economy by exploring the relationship between the low-carbon logistics industry and the regional economy in Yunnan Province. Moreover, Wang et al. <sup>[8]</sup>(2019) defined intelligent logistics as a science and technology-intensive logistics industry that helps logistics enterprises upgrade and transform into scientifically intelligent entities. The development of a resource-sharing model that combines intelligence and manpower cooperation is identified as a new trend in intelligent logistics. Lastly, Liu (2023)<sup>[9]</sup>evaluated the traction mechanism of intelligent logistics on regional green economic development through various methods and proposed relevant countermeasures based on the analysis.

In summary, scholars have conducted extensive research on the coordination between regional logistics and economic development and adopted a variety of methods, laying a solid foundation for future research on intelligent logistics and coordination. Their application of modeling algorithms and empirical methods proved the feasibility and relevance of the study of coordinated development relations. However, the research on the synchronous development of intelligent logistics and regional economy in Northeast China is still lacking. Recognizing the importance of understanding the coordination between logistics and the regional economy in this important economic region, this study will also fill the gap in the study of smart logistics in the Northeast region

## **2 Research Data Sources and Research Methodology**

### **2.1 Sources of Research Data**

Currently, Liaoning Province, the sole coastal province in Northeast China, employs air, rail, waterway, and road transportation modes. Shenyang Airport District serves as

a pivotal hub for air and road transport, while Panjin City functions as a key transit and distribution center for land transportation. Dalian, being a maritime hub, exemplifies a comprehensive "sea, air, and land integration" development model. The most prominent indicators of smart logistics in regional economic advancement include the intelligence level of the logistics industry, the length of postal routes, and the extent of fiber optic cable infrastructure. The intelligence level of the logistics industry is gauged by e-commerce sales, facilitating an in-depth understanding of the regional smart logistics development level.

The total length of postal routes serves as a gauge of the infrastructure construction status within the regional industry, while the value of the fiber optic cable route length signifies the technical level of regional logistics production. The most representative indicators in the regional economy include the industrial structure and the Internet penetration rate. The characteristic index of industrial structure is expressed by the ratio of the output value of the tertiary industry to the output value of the secondary industry in Liaoning Province from 2006 to 2021. This demonstrates that the reform of industrial structure can enhance the fundamental environment for regional development. The acceleration of regional economic development towards an optimal state is facilitated by the index of scientific and technological development, which utilizes the Internet penetration rate to reflect economic progress. Assessing the strength of scientific and technological infrastructure construction through the Internet penetration rate broadens the scope for regional economic development. The data regarding logistics and the economy are derived from various sources, including the Liaoning Provincial Statistical Bulletin of National Economic and Social Development, the Liaoning Statistical Yearbook, and the Wind Database. To mitigate the impact of the COVID-19 pandemic, the study period spans from 2006 to 2021.

## **2.2 Construction of an Evaluation Indicator System**

This paper focuses on the data from Liaoning Province, China, spanning the years 2006 to 2021, and establishes an indicator system with smart logistics evaluation and regional economic assessment as its subsystems. The evaluation system for the smart logistics subsystem comprises five indicators across three dimensions: logistics infrastructure, logistics technology level, and logistics industry efficiency. The theoretical foundation of this paper is based on the research conducted by relevant scholars in the field of regional economies, while also addressing the practical requirements for a comprehensive evaluation of regional economies in Liaoning Province, as well as the evaluation standards set by scholars in other disciplines. Furthermore, it develops a comprehensive evaluation index system for regional economies, consisting of six indicators across three dimensions: smart economic development, economic development level, and economic development potential.

## 2.3 Modeling

### 2.3.1 Calculation of the Ordering Degree of the Ordinal Covariates.

The integrated ordered parameter of the smart logistics system and the regional economic system is denoted as  $u_i$ . The  $j$ -th index of the  $i$ -th ordered parameter is represented by  $u_{ij}$ , with a value of  $X_{ij}$  (where  $i=1, 2, \dots, m$ ). In order to address potential computational errors arising from differing quantification standards in the original data, we have adopted a method commonly employed in the field of logistics research. This method involves generating standardized data through the application of polarity standardization, with the calculation of  $u_{ij}$  as follows:

$$u_{ij} = \begin{cases} \frac{x_{ij}-b_{ij}}{a_{ij}-b_{ij}}, \\ \frac{a_{ij}-x_{ij}}{a_{ij}-b_{ij}}, \end{cases} \quad (1)$$

In this context of  $u_{ij} \in [0, 1]$ ,  $u_{ij}$  represents a value ranging between 0 and 1, inclusive. A lower value of  $u_{ij}$  indicates a closer proximity to unsatisfactory, while a higher value indicates a closer proximity to satisfactory. A value of 1 signifies optimal efficacy in the most satisfactory scenario. The correlation and distinction between the intelligent logistics system and the regional economic system are notably significant. This study utilizes the linear weighted sum method to compute the total efficacy of subsystems based on the hierarchy of covariates. The calculation formula is as follows:

$$u_i = \sum_{j=1}^n w_j u_{ij}, \sum_{j=1}^n w_j = 1 \quad (2)$$

where  $u_1$  represents the comprehensive evaluation index of the intelligent logistics system,  $u_2$  represents the comprehensive evaluation index of the regional economic system,  $u_{ij}$  signifies the comprehensive ordering degree efficacy value of the coupled system consisting of the intelligent logistics subsystem and the regional economic subsystem, and  $w_j$  denotes the weight value of the influence of the change in the order parameter on the entire coupled system.

The entropy value method, as a classic assignment method, ensures maximum data objectivity. This paper employs the entropy value method proposed by Zhu and Wei<sup>[10]</sup> to calculate the weight of each index. The specific calculations are as follows:

Calculation of the weight of each indicator:

$$f_{ij} = \frac{u_{ij}}{\sum_{i=1}^m u_{ij}} \quad (3)$$

Calculation of the information entropy:

$$e_j = -k \sum_{i=1}^m f_{ij} \ln f_{ij} \quad (4)$$

where  $k = 1/\ln m$  and  $m = 10$  in this paper. When  $f_{ij} = 0$ , then let  $\ln f_{ij} = 0$ .

Estimation of the coefficient of variation for indicator  $j$ :

$$v_j = 1 - e_{ij} \quad (5)$$

Estimation of the weight of the  $j$ th indicator:

$$w_j = \frac{v_j}{\sum_{j=1}^n v_j}, \sum_{j=1}^n w_j = 1 \tag{6}$$

**2.3.2 Coupledness Model.**

Coupling, originally a physical term, refers to the interaction between multiple systems or forms of motion. As a focal point for model skeleton planning, coupling aims to design various models of coupling degrees. This paper delves into the coupling and coordination degree between smart logistics and the regional economy using the coupling coordination degree model. The following data are designed to calculate this degree:

The degree of coupling (C), the coordination index (T), and the degree of coupling coordination (D), where  $C \in [0, 1]$ , are given by Equation (7).

$$C = \frac{m \sqrt{u_1 \cdot u_2 \cdots u_m}}{\prod(u_i + u_j)} \tag{7}$$

The coupling degree between smart logistics and regional economy can be directly calculated based on Equation (8) as follows:

$$C = \sqrt{\frac{u_1 \cdot u_2}{(u_1 + u_2) \cdot (u_1 + u_2)}} \tag{8}$$

When the value of C is 0, it represents the lower limit of the system coupling degree, indicating a lack of coordination between the smart logistics and regional economy systems. Conversely, when the value of C equals 1, it reflects the upper limit of the system coupling degree, signifying coordinated development in a positive and orderly direction for both systems.

**2.3.3 Coupled Coordination Degree Model.**

The degree of coupling between the smart logistics and regional economy systems can be calculated using the coupling coordination degree model. The specific steps are as follows:

$$T = hu_1 + gu_2, D = \sqrt{C \cdot T} \tag{9}$$

The coefficients h and g, to be determined, satisfy  $h+g=1$ . Since the values of h and g are not clearly defined in the academic field and they hold equal importance, we can set  $h=g=0.5$ . In this case, the D value represents the degree of coordination, where a larger D value indicates a greater degree of coordination between the smart logistics and regional economy systems. Therefore, the D value is based on the work of Sun et al.<sup>[11]</sup> for the division of coupling coordination degrees, with the D value being divided into 10 levels, as shown in Table 1.

**Table 1.** Coupling harmonization classification.

| Interval of D-values for coupling coordination | Level of coordination | Degree of coupling coordination        |
|--|-----------------------|--|
| [0.0~0.1)                                      | 1                     | Extreme disorder                       |
| [0.1~0.2)                                      | 2                     | Severe disorder                        |
| [0.2~0.3)                                      | 3                     | Moderate disorder                      |
| [0.3~0.4)                                      | 4                     | Mild disorder                          |
| [0.4~0.5)                                      | 5                     | On the verge of becoming dysfunctional |
| [0.5~0.6)                                      | 6                     | Sue for harmonization                  |
| [0.6~0.7)                                      | 7                     | Primary coordination                   |
| [0.7~0.8)                                      | 8                     | Intermediate level coordination        |
| [0.8~0.9)                                      | 9                     | Good coordination                      |
| [0.9 to 1.0]                                   | 10                    | Quality coordination                   |

This paper utilizes statistical data from Liaoning Province spanning from 2006 to 2021, calculates standardized data using Formula (1), and determines indicator weights by applying Formula (3) to Formula (6). The results are presented in Table 2.

**Table 2.** Evaluation index system of intelligent logistics and regional economic system in Liaoning province.

| Aggregate target                | Level 1 indicators                        | Secondary indicators                                       | Weights |
|---------------------------------|---|--|---------|
| Intelligent logistics subsystem | Status of logistics infrastructure        | X1: Total length of postal routes/km                       | 5.93%   |
|                                 |   | X2: Share of urban population/%                            | 0.33%   |
|                                 | Logistics technology level                | X3: Length of fiber optic cable line /km                   | 0.20%   |
|                                 |   | X4: Internet broadband access ports /10,000 ports          | 37.8%   |
|                                 |   | X5: Logistics Industry Intelligence Levels                 | 0.80%   |
|                                 | Scientific and technological developments | X6: Internet penetration/%                                 | 3.77%   |
|                                 |   | X7: Tertiary GDP/billion yuan                              | 12.44%  |
| Regional economic subsystems    | Level of economic development             | X8: Regional GDP/billion dollars                           | 7.13%   |
|                                 |   | X9: Consumption expenditure per inhabitant/billion dollars | 9.33%   |
|                                 | Economic development potential            | X10: Industrial structure                                  | 7.97%   |
|                                 |   | X11: Value added of tertiary industry/billion dollars      | 14.22%  |

From Equations (7) and (8), we calculated coupling degree C and coupling coordination degree D for the smart logistics and regional economic systems in Liaoning Province. Here,  $u_1$  and  $u_2$  represent the development levels of these two subsystems. When  $u_1 > u_2$ , it's a regional economic lag type, indicating that the economy constrains

smart logistics. When  $u_1 = u_2$ , it's a coordinated development type, reflecting mutual progress. When  $u_1 < u_2$ , it's a smart logistics lag type, indicating that logistics constraints the economy. The relationship between  $u_1$  and  $u_2$  is categorized into eight types, as shown in Table 3.

**Table 3.** Indicators of the coupling level between smart logistics and regional economy in Liaoning Province.

| Particular year | C     | T     | D     | U1                   | U2                  | Comparison of $u_1$ and $u_2$ | Degree of coordination                 |
|-----------------|-------|-------|-------|----------------------|---------------------|-------------------------------|--|
| 2006            | 1     | 0.01  | 0.1   | 0.01                 | 0.01                | $u_1 = u_2$                   | Severe disorder                        |
| 2007            | 0.933 | 0.065 | 0.246 | 0.030717032000226976 | 0.07654208512679654 | $u_1 < u_2$                   | Moderate disorder                      |
| 2008            | 0.976 | 0.143 | 0.373 | 0.10129374180751902  | 0.16374070968552124 | $u_1 < u_2$                   | Mild disorder                          |
| 2009            | 0.984 | 0.21  | 0.454 | 0.16294314671596113  | 0.2369409857129124  | $u_1 < u_2$                   | On the verge of becoming dysfunctional |
| 2010            | 0.998 | 0.344 | 0.586 | 0.3636908776255632   | 0.32142912261073553 | $u_1 > u_2$                   | Sue for harmonization                  |
| 2011            | 0.525 | 0.262 | 0.371 | 0.02653485710500691  | 0.4463011126090485  | $u_1 < u_2$                   | Mild disorder                          |
| 2012            | 0.995 | 0.613 | 0.781 | 0.682316567335277    | 0.5606326458937659  | $u_1 > u_2$                   | Intermediate level coordination        |
| 2013            | 1     | 0.668 | 0.817 | 0.6850305020600661   | 0.6604194017730096  | $u_1 > u_2$                   | Good coordination                      |
| 2014            | 0.995 | 0.844 | 0.917 | 0.9439773278079603   | 0.7756850507605778  | $u_1 > u_2$                   | Quality coordination                   |
| 2015            | 1     | 0.847 | 0.92  | 0.8677555831985432   | 0.8424707894101114  | $u_1 > u_2$                   | Quality coordination                   |
| 2016            | 0.999 | 0.835 | 0.913 | 0.8923396623031341   | 0.8011601847599849  | $u_1 > u_2$                   | Quality coordination                   |
| 2017            | 0.997 | 0.915 | 0.955 | 0.99                 | 0.8601538173296003  | $u_1 > u_2$                   | Quality coordination                   |
| 2018            | 0.994 | 0.858 | 0.924 | 0.7651655975674347   | 0.9473638504405932  | $u_1 < u_2$                   | Quality coordination                   |
| 2019            | 0.999 | 0.915 | 0.956 | 0.9649081210673817   | 0.8900510157269348  | $u_1 > u_2$                   | Quality coordination                   |
| 2020            | 0.992 | 0.841 | 0.913 | 0.7285998629809312   | 0.9455974211165165  | $u_1 < u_2$                   | Quality coordination                   |
| 2021            | 0.97  | 0.816 | 0.89  | 0.6067530032083881   | 0.99                | $u_1 < u_2$                   | Good coordination                      |

### 3 Results and Analysis

#### 3.1 Analysis of the Comprehensive Development Level of Intelligent Logistics and Regional Economy in Liaoning Province

When considering Figure 1 and Table 3 together, the coordinated development of smart logistics and the regional economy was evident in 2006. However, from 2007 to 2009, smart logistics experienced a three-year lag. In 2010, the regional economy constrained the development of smart logistics, resulting in this lag. Subsequently, in 2011, while the regional economy continued to grow rapidly, smart logistics once again fell behind.

During the period from 2012 to 2017, smart logistics development outpaced regional economic growth in Liaoning, driven by advancements in mobile networks, leading to a lag in regional economic development. From 2018 to 2021, smart logistics continued to lag behind, with some fluctuations occurring in 2019. Since 2020, regional economic growth has caught up with smart logistics, but the gap between the two systems continues to widen. This indicates that Liaoning has achieved rapid growth in smart logistics, which has had a positive impact on regional economic development. However, further exploration of the potential for smart logistics and regional economic development is necessary.

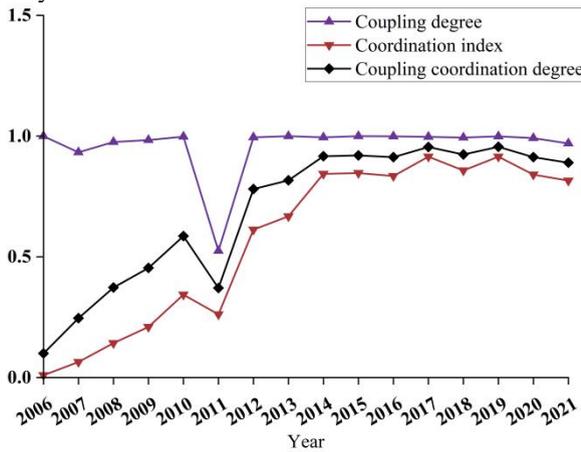


Fig. 1. Degree of coupling and coordination between smart logistics and regional economic comprehensive development level in Liaoning province.

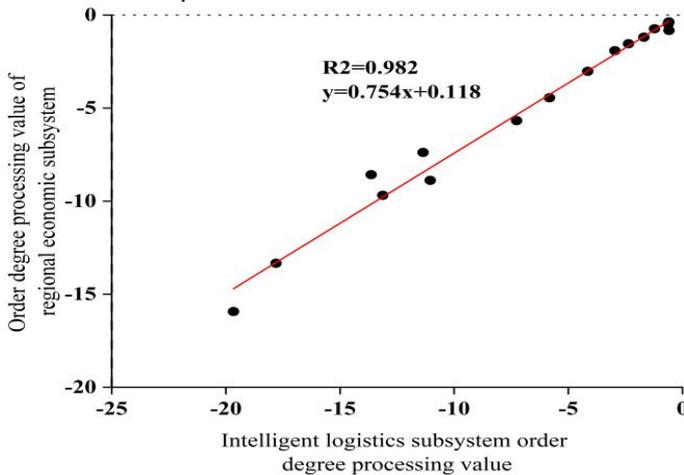
The evaluation value of smart logistics in Liaoning Province increased from 18077.57 in 2006 to 32512.35 in 2021, demonstrating an enhanced level of smart logistics and significant development advantages.

During the 12th Five-Year Plan (2011-2015), new development concepts like Digital+ and Wisdom Efficiency revolutionized the logistics sector in Liaoning Province. This transformation was aligned with transportation adjustments and industrial upgrades. The province prioritized the establishment of regional internet infrastructure, power grids, and other smart infrastructure, fostering technological innovation and advancements in smart logistics.

Characterized by a 'steady rise and slow growth,' the comprehensive evaluation value of Liaoning Province increased from 4,261.76 in 2006 to 14,568.67 in 2021, trailing the growth of intelligent logistics. The province's steady economic improvement can be attributed to its unique geographic conditions, situated in China's border area, which facilitates the expansion of foreign trade and industrialization. In 2019, the province actively implemented national plans, focusing on strengthening frontier consciousness and promoting foreign exchanges. However, Liaoning's economic growth is hindered by its extremely cold climate, which affects transportation and reduces the cost-effectiveness of new energy transportation. Additionally, its transportation infrastructure lags behind that of central and southern China. There is still much to be done in terms of improving investment returns, recovery speed, and attractiveness to foreign investment.

### 3.2 Analysis of the Coupling and Coordination Degree Between Intelligent Logistics and Regional Economy in Liaoning Province

Between 2006 and 2021, the coupling and coordination between the intelligent logistics system and the regional economic system evolved through three stages: serious dissonance (2006-2008), mild dissonance with progress (still unbalanced), and intermediate coordination (gradually restoring balance). By 2013, the system achieved better balance and coordination, with stable functions and operations. Correlation analysis between smart logistics and regional economic system orderliness revealed a robust relationship, as evidenced by a strong Pearson correlation coefficient of 0.754 and a high R-squared value of 0.966, indicating a significant linear fit. This underscores the pivotal role of smart logistics in propelling regional economic development, as shown in Figure 2 for a detailed depiction.



**Fig. 2.** Linear fit between the orderliness of the smart logistics subsystem and the orderliness of the regional economic subsystem in Liaoning Province.

### 3.3 Analysis of Influencing Factors Constraining the Coordinated Development of Coupling

To foster the integration of smart logistics and the regional economy, identifying limiting factors is crucial.

Figure 1 showcases that Liaoning's regional economy lagged behind smart logistics from 2006-2021, forming a regional economic lag type. Figure 3 reveals that while the orderliness of smart logistics modules generally increased, the growth of logistics infrastructure and technology level was unsatisfactory.

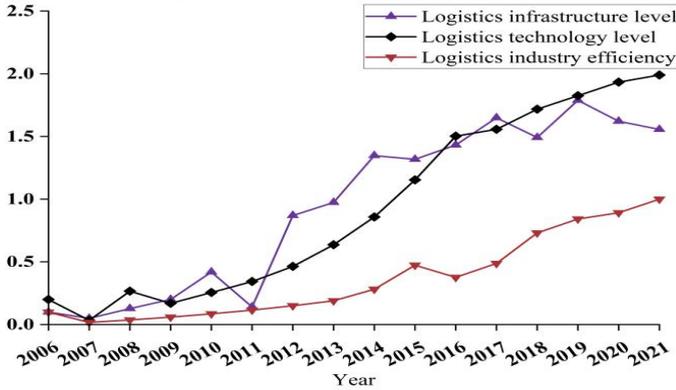


Fig. 3. Orderliness of each module of the smart logistics subsystem.

Before 2011, the development of all three modules was limited. After 2012, the logistics infrastructure module witnessed significant progress, whereas the logistics technology and efficiency modules lagged. This suggests that the logistics technology level and efficiency modules impede the development of smart logistics. The coherence of each module's specific indicators is illustrated in Figures 4 and 5.

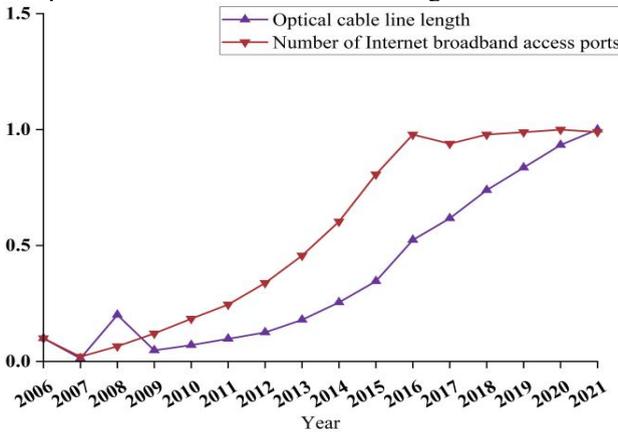
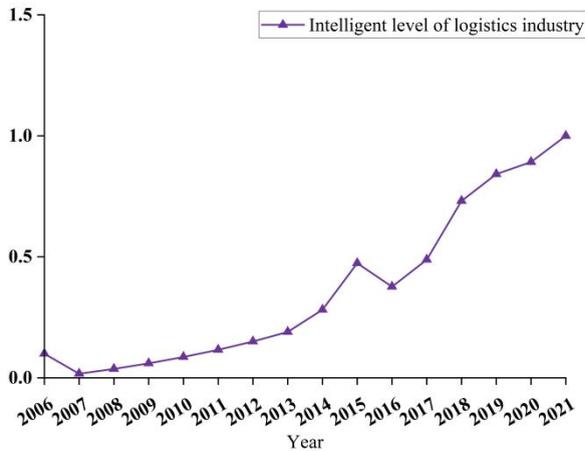


Fig. 4. Orderliness of the indicators of the logistics technology level module.



**Fig. 5.** Orderliness of each indicator of the module of the level of intelligence of the logistics industry.

The development of infrastructure has attracted attention from both the public and the government. Improving internet broadband access points effectively signifies the digitalization of logistics and community-level services, ensuring efficient, accurate, and reliable logistics operations, thereby supporting the increase in e-commerce orders. However, the growth of fiber optic cable lines lags behind that of broadband access, indicating an area for improvement in the logistics industry for long-term development. Figure 5 illustrates clear trends in the length of fiber optic cable lines and the number of internet broadband access points, which are aligned. Since 2009, the length of fiber optic cables has shown an upward trend, reflecting the connection between Liaoning's strategy for intellectualization and regional infrastructure construction. Internet broadband access points exhibited steady growth from 2007 to 2016 but slowed from 2017 to 2021, with a slight downward trend due to declining demand for domestic fiber optic cables as the construction of 4G networks approached completion. To promote coordinated development between smart logistics and the regional economy, it is crucial to analyze limiting factors.

As can be seen from Figure 6, the modular order degree of the economic development situation from 2006-2021 shows an overall growth trend, with a certain degree of fluctuation. There was a substantial upward trend in 2007-2008, but it then fell back to the original development state in 2008-2009. Subsequently, the economic development of Liaoning Province in 2020 showed a smaller increase, but the overall trend remained positive. This is closely related to the efforts of the Liaoning Provincial Government to promote the enhancement of the region's high-quality development level and to continuously integrate new development concepts into regional construction. These efforts are closely linked to the completion of all aspects of regional construction. This is closely linked to the Liaoning provincial government's efforts to promote the improvement of the region's high-quality development level by continuously integrating new development concepts into all aspects of regional construction and achieving national development goals. As analyzed in Figure 6, the development degree of the

economic development potential module is significantly lower than the other two segments, and the development speed of this module has slowed down since 2016, and even shows a downward trend in the development process of 2020-2021. In the environment of benign economic development, the economic development potential module has not yet reached the ideal degree of regional economic development and has become a development shortfall.

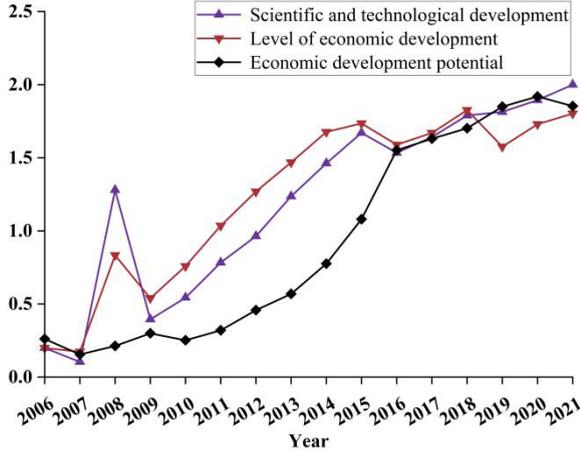


Fig. 6. Orderliness of the modules of the regional economic subsystems.

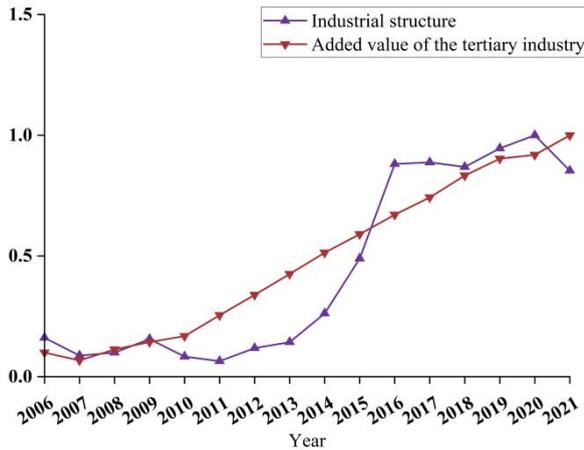


Fig. 7. Orderliness of indicators in the economic development potential module.

As analyzed in Figure 7, the added value of the tertiary industry continues to advance, indicating that the tertiary industry of Liaoning Province has been in a state of development over the past sixteen years. The added value of the tertiary industry in Liaoning Province has been increasing year by year, which highly coincides with the province's efforts to implement the comprehensive construction of a moderately prosperous society. During the "13th Five-Year Plan" and "14th Five-Year Plan" pe-

riods, the regional economic development of Liaoning Province has progressed steadily, improving the people's sense of well-being and integrating reform and opening-up into all aspects of life. The human and material resources invested in earlier-stage infrastructure construction have gradually yielded returns. From Figure 7, it can be observed that the degree of orderliness of the industrial structure has experienced violent fluctuations, with a downtrend in 2006-2011. This is primarily due to the relatively small output value of the tertiary industry during this period, leading to slow development speed. From 2012 to 2016, the industrial structure underwent an innovative transformation, creating a favorable human and social environment and fostering a new atmosphere to drive local regional economic development and stimulate growth in total social retail sales. From 2017 to 2019, there were continued fluctuations, but the overall trend indicated an upward trajectory. However, the impact of the COVID-19 pandemic in 2020 led to a contraction in the development of the industrial structure in 2020-2021. Analysis of regional economic constraints indicates the need to rationally optimize the regional industrial structure, plan the proportion of the tertiary industry among other industries, and accelerate the reform of the industrial structure. This is key for Liaoning province to mobilize joint efforts and break through the challenges.

## **4 Conclusions**

### **4.1 Research Summary**

The relationship between the intelligent logistics system and the regional economy in Liaoning is found to be highly significant, according to Pearson's analysis. Despite advancements made under the "Digital+" initiative, the optimal level of integration has not yet been achieved. Over a span of 16 years, smart logistics in Liaoning has experienced accelerated growth driven by investments and innovations, highlighting the necessity for increased support to boost regional economic development. The convergence of logistics technology and economic potential plays a crucial role in system advancement, yet challenges persist in maximizing their effectiveness. It is imperative to enhance these aspects to promote system synergy, elevate the quality of smart logistics, and drive economic development in Northeast China.

### **4.2 Proposals for Smart Logistics and the Northeast Economy**

#### **4.2.1 Strengthening the Intelligent Logistics Infrastructure Construction in Liaoning Province.**

Intelligent logistics infrastructure effectively utilizes the storage space in fixed regional logistics and promotes the intelligent allocation and integration of logistics and urban transportation resources. This approach reduces logistics capital investment, modernizes urban logistics systems, and promotes the adoption of smart technologies. Given the critical role of urban logistics systems in cities, it is critical to prioritize the development of logistics infrastructure. Therefore, promoting the construction of key transportation infrastructure in Liaoning Province is an inevitable requirement for achieving high-quality development. According to national policy changes, infra-

structure construction should be centered on the "Belt and Road" pilot zone in Liaoning, focusing on optimizing resource allocation and economic intensification. Strengthening the construction of comprehensive transport network is an inevitable requirement for building an efficient, stable and safe logistics network, which will ultimately enhance the logistics competitiveness of Liaoning and promote regional economic development. By deepening logistics reform and speeding up infrastructure construction, Liaoning's untapped potential can be released. Take Liaoning Province as the representative, improve the construction of smart logistics infrastructure in the whole northeast region, and lay a solid foundation for the development of smart logistics in the Northeast region.

#### **4.2.2 Promoting the Introduction of Smart Logistics Technology into the Regional Economy.**

Logistics enterprises in Northeast China should be customized according to the specific needs of their environment, and should adopt advanced intelligent logistics technology suitable for regional economic development. In addition, the Northeast region should promote cooperation among logistics enterprises, institutions of higher learning and professional research institutions focusing on logistics, and establish an intelligent logistics system integrating practical application, personnel training and scientific research. Through joint research, we can promote the transformation of results, technological innovation and the application of intelligent logistics technology, thus promoting the progress of a new generation of information technology. The technology has the potential to promote the digital transformation and intelligent upgrading of the Northeast industry and promote industrial innovation and development. Referring to the current situation in Liaoning Province, despite the progress made in smart logistics, there is still a gap between its progress and regional economic development, which indicates that insufficient investment is hindering regional economic growth. Therefore, increased investment in smart logistics is essential to drive its development in the new era. Ultimately, it is crucial to integrate the concept of smart logistics into regional economic development plans, recognizing its critical role as a key driver and supporter of regional economic growth.

#### **4.2.3 Industrial Structure Transformation by Combining Intelligent Logistics.**

For Northeast China, establishing a national logistics hub city will elevate its position within domestic and international logistics networks, optimizing resource utilization, reducing costs, and enhancing efficiency. This initiative will stimulate job creation and economic growth, driving high-quality economic development. Intelligent logistics plays a pivotal role in this transformation, facilitating real-time information sharing, efficient resource allocation, and intelligent process monitoring. These capabilities boost operational efficiency and service quality, fostering innovation and high-quality supply chain management. The traditional logistics industry is undergoing profound changes in the era of intelligent exploration. Outmoded management approaches are inadequate, necessitating specialization, collaboration, and intensive transformation within the industry. This transformation entails upgrading technology

and management practices, transitioning from mere transportation and warehousing services to offering integrated solutions, and optimizing supply chain management.

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