Article

Data-Driven Coordinated Development of the Digital Economy and Logistics Industry

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Abstract: With a renewed global scientific and technological revolution and industrial reform, the digital economy, with data resources as the key element, has rapidly developed. This study proposes a data-driven measurement and evaluation method to promote the coordinated development of the digital economy and logistics industry. An evaluation index system is constructed, which comprehensively considers the index dimensions that reflect the development level of the digital economy and logistics industry. A Z-score standardisation method is applied to data processing, to carry out dimensionless standardisation processing of the original index data. A collaborative degree model is constructed to evaluate the collaborative development level of the digital economy and logistics industry composite system. We demonstrate the implementation process of these models using data from Anhui province from 2013 to 2020. The results verify the feasibility of the research method and emphasise that the development level of the composite system of the digital economy and logistics industry in Anhui province shows a fluctuating growth trend, with variations between the types and degrees of collaboration policy; suggestions are made accordingly. This study provides theoretical and methodological support for the coordinated development of the regional digital economy and logistics industry.

1. Introduction

With a renewed global scientific and technological revolution and industrial reform, the digital economy, with data resources as the key element, has rapidly developed. In 2021, a new image of the global digital economy emerged, and, in 2020, the added value of the digital economy reached 32.6 trillion USD, and the proportion of the global digital economy's share of GDP was 43.7%, which was an increase of 2.5 percentage points compared to the preceding year [1]. In addition, industrial digitisation accounted for 84.4% of the digital economy and 36.8% of GDP. Therefore, it is an important part of the development of the digital economy. The digital economy promotes the innovation and reform of traditional industries [2]. As an important industry of the national economy, especially during the COVID-19 pandemic, digital technology enables the logistics industry to more efficiently meet supply and demand in all aspects of society and alleviate the impact that the pandemic has had on the economy and society. The logistics industry and digital economy interact with each other, facilitate the coordination of regional industries' development, and drive the continuous strengthening of the economy. Facing the challenges of economic recovery, higher requirements are proposed for the coordinated development of the digital economy and industry. Therefore, exploring the coordinated development and efficiency of the digital economy and logistics industry is of great significance and has become the focus of academic attention.

First, the digital economy, first proposed by Tapscott [3], is a network-based economy. It is the sum of new economic activities based on information technology [4,5], new business forms, new production methods [6], new commodity-circulation methods [7], and so on. Carlsson [8] states that the digital economy is a unique economic form and the product of the combination of information digitisation and the Internet, which is conducive to innovative product development and product services [9,10]. The development of the digital economy accelerates digital transformation in the logistics industry [11], which is conducive to the realisation of cost reductions, efficiency increases, and the sustainable development of the logistics industry [12]. The digital transformation of the logistics industry is conducive to improving the efficiency of each operations link in the logistics industry [13] and facilitates the logistics industry to improve the way supply is matched to demand [14]. The intelligent and digital development of the logistics industry is the embodiment of industrial digitisation and promotes the development of the digital economy [15].

Second, in research on the measurement index system of the digital economy and logistics industry, Haltiwanger [16] examined the topic from five aspects: ICT infrastructure, industrial structure, e-commerce, price behaviour, and labour characteristics. Mesenbourg [17] supported the measurement of infrastructure, e-commerce processes, and e-commerce transactions. Gan [18] found that a brand-new statistical system should be established to embody the digital economy and improve calculating it. Brynjolfsson et al. [19] found that the digital economy was integrated into social life and proposed an alternative indicator of GDP-B. Chen et al. [20] included the improvement of higher education levels and the number of patents issued in their measurement indicators. Strassner et al. [6] and Mc Kinsey [21] measured this topic from the perspective of input–output models. The US Bureau of Economic Analysis [22] measured the development scale from the perspective of infrastructure in the production, e-commerce, and digital-media industries. In addition, research institutions researched digital economy calculations [23–25].

Regarding the measurement of the development level of the logistics industry, scholars measured the efficiency of the logistics industry from the perspective of input–output systems. Schøyen et al. [26] regarded the number of yard machines, terminal areas, and quay lengths as input factors, and container throughput and twenty-foot-equivalent units per year per port as output factors. Nguyen (2018) and Tran [27] considered factors such as total assets and liabilities as input, and operating profit as output. Bajec and Tuljak-Suban [28] used transport capacity, employee quality, and educated employee variables as inputs and the average delivery cycle of each delivery and each driver's productivity as outputs.

Finally, the collaborative evaluation method of the logistics industry was researched. Both the digital economy and logistics industry are complex systems involving many factors, and the synergy degree model of composite systems was used to measure the level of mutual collaborative development between two or more systems [29,30]. In research on the coordination level of composite large-scale systems, we need to pay attention to the coordination level of relevant elements of each subsystem. The system-coordination level is affected by each constituent element. Currently, the synergy degree of the composite system is applied to measure and evaluate the collaborative development of the logistics industry and related fields. For example, studies evaluated the regional economy and logistics industry [31,32], manufacturing industry, and logistics industry [33], the coordinated development of agriculture and logistics industry [34], the container-system association [35], and the coordinated development of cross-border e-commerce and logistics [36]. However, there are few studies on the coordinated development of the digital economy and the logistics industry. With the rapid development of the global digital economy and the acceleration of the integration of the digital economy and traditional industries, in recent years scholars have researched the related development of the digital economy and industries [37], such as the digital economy and agriculture [38], manufacturing [39], and tourism [40]. The digital transformation of traditional industries has also accelerated; however, the coordinated development of the digital economy and logistics industry needs further research.

Research by domestic and foreign scholars on the digital economy and logistics industry provides an important reference for exploring the coordinated development of this field. However, there are still some limitations:

(1) Scholars studied the relationship between the digital economy and the development of the logistics industry. However, they focused on the impact of the digital economy on the digital transformation of the logistics industry. The synergy between the two systems needs further examination.

(2) The digital economy and logistics industry systems involve many factors, wide data sources, and inconsistent dimensions. Developing an accurate measurement and evaluation composite index system to promote the coordinated development of the digital economy and logistics industry is a difficult problem.

(3) The composite system synergy model is widely used, which provides a reference framework for this study. However, it is challenging to scientifically and objectively measure and evaluate the collaborative developmental levels of the digital economy and logistics industry as well as to build a data-driven composite system synergy model that includes the development of the digital economy and logistics industry.

Accordingly, to compensate for these shortcomings, this study proposes a data-driven measurement and evaluation method for the coordinated development of the digital economy and logistics industry, by referring to the research methods and ideas of Bai et al. [29], Yang et al. [30], Fang et al. [35], Li et al. [41], and Liu et al. [42]. Furthermore, it proposes targeted policy suggestions according to the evaluation results, to provide decision support for relevant practitioners and decision makers to consider the coordinated development of the digital economy and logistics industry.

The study contributes to the literature by researching the coordinated development of the digital economy and logistics industry from the perspective of data drivers, which is expected to become a breakthrough system in related fields. This study constructs a "measurable and evaluable" composite evaluation index system, which is data-driven and examines the order-parameter indexes of the digital economy and logistics subsystems from the perspective of system theory and input and outputs, to reflect the development level of each subsystem more objectively and scientifically. Using the composite system synergy degree model for evaluation, the quantitative evaluation of the synergy of the composite system of the digital economy and logistics industry is realised, which is expected to enrich the research on the evaluation of the coordinated development of the logistics and related industries. The study's results have important practical application value for promoting the cross-integration and coordinated development of the digital economy and logistics industry. It identifies the subsystems or order-parameter factors that affect the coordinated development of the digital economy and logistics industry, using data to improve the level of their coordinated development and core competitiveness. Furthermore, it facilitates promoting the digital transformation and sustainable development of the logistics industry, by providing a decision-making framework for practitioners and scholars in the digital economy and logistics industry field.

This paper is organised as follows: Section 2 introduces the data-driven method process, including the data collection and processing, data model, and application of this model. Section 3 is a case study to measure and evaluate the coordinated development of the digital economy and logistics industry in Anhui province, China. Section 4 is the conclusion.

2. Method

2.1. Method and Process

Promoting the coordinated development of the digital economy and logistics industry is conducive to promoting the digital transformation of traditional industries and achieving more efficient development. It is one of the necessary elements that must be addressed to promote high-quality economic development. The coordinated and efficient development of these two systems urgently requires that their synergy be measured and evaluated

from the perspective of system theory and that relevant development countermeasures from the perspective of global optimisation are formulated. However, data from the complex system of the digital economy and logistics industry are multi-source and varied. Therefore, it is challenging to develop effective models to measure and evaluate whether the countermeasures and suggestions can effectively support the decision-making of local governments and relevant practitioners.

To meet this challenge and improve the coordinated development level of the composite system of the digital economy and logistics industry, this study constructs a data-driven measurement and evaluation method for this composite system. The data-collection process mainly collects relevant data that reflect the development level of the digital economy and the logistics industry. The original data are processed using Z-score, which is a standard and dimensionless method. Thereafter, data modelling is used to build the synergy model of the composite system of the digital economy and regional logistics industry. This study proposes countermeasures and suggestions to promote the coordinated development of the digital economy and logistics industry. The method flow is as follows in Figure 1.
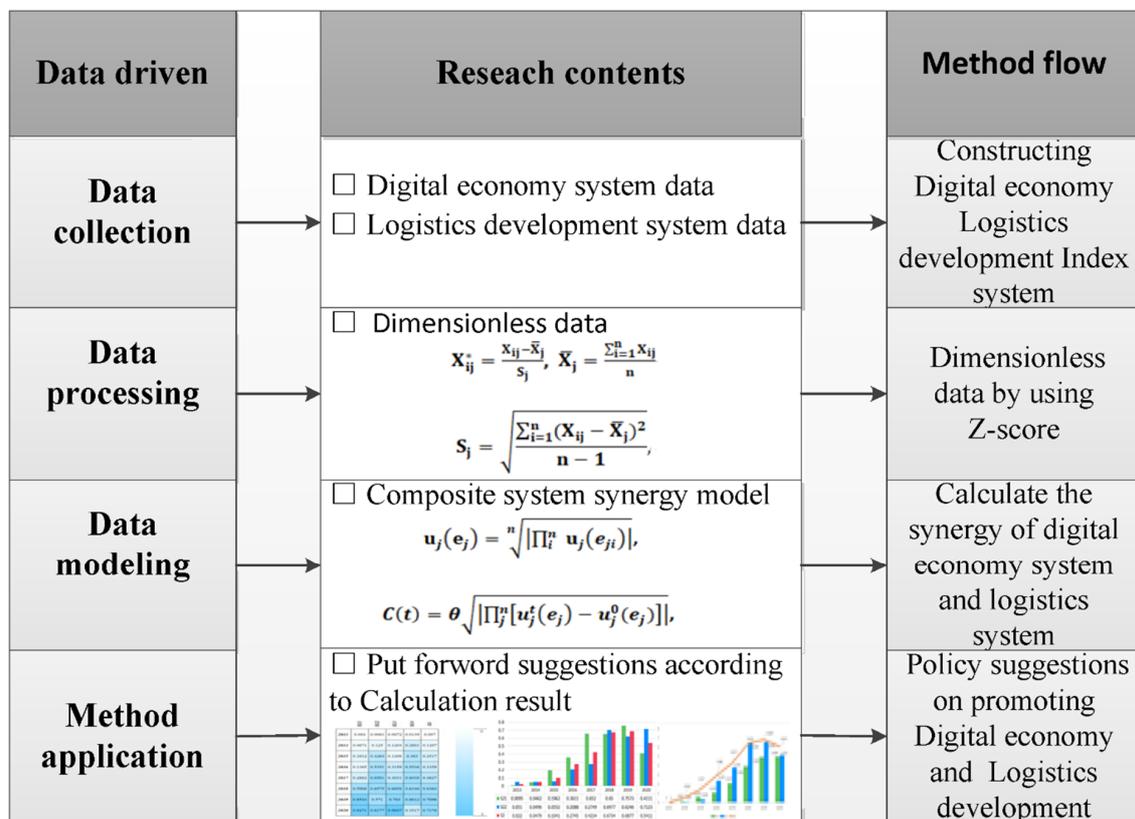

Figure 1. Method flow chart.

2.2. Data Collection and Index-System Construction

This study's goal is to analyse the collaborative relationship between the complex digital economy and logistics system. Therefore, the key is a rigorous and scientific evaluation index system. The digital economy, in the current era, is defined based on Tapscott's definition [3]. The digital economy is measured in accordance with the white paper on the global digital economy. In addition, we draw on the research results of existing scholars for the measurement of the digital economy and logistics industry [6,16–28]. According to the principles of objectivity, authenticity, availability, and scientificity of index selection, this study constructs an evaluation index system of the composite digital economy and logistics industry system, which includes two large and six small systems and 31 order-parameter indexes to study the coordinated development of various systems.

The evaluation indexes of the digital economy subsystem include the levels of digital infrastructure, digital scientific and technological innovation, industrial digitisation, and the development level of the digital industry [38–40]. Digital infrastructure has laid a good foundation for the digital economy to better integrate into the logistics industry. The development of digital industrialization drives the upgrading of industrial structure and develops towards digitalization. Digital scientific and technological innovation is the key to the development of digital economy and determines the driving force of the development of digital economy. Industrial digitalization can promote the application of digital technology in the logistics industry and improve the quality and efficiency of the logistics industry. Unlike other studies, such as the popularity of cellular phones at the level of digital infrastructure construction, this indicator can more comprehensively reflect the use level of mobile digital infrastructure. The proportion of income of the information transmission, software, and information technology services in GDP to the development level of the digital industry as well as increases in the proportion of output values of scientific research and technology services in GDP, at the level of digital scientific and technological innovation, are considered. This can more accurately reflect the level of economic development of the relevant subsystems. The evaluation indexes of logistics subsystem are considered from the perspective of inputs and outputs [26–28], including the logistics development basic input and scale output subsystems. Unlike other studies, this study concentrates more on the input and output indicators' effects on the whole logistics industry, rather than focusing on port logistics [43] or a specific logistics enterprise [44]. In the basic input subsystem of logistics development, the mileage input of roads, railways, and waterways, as well as the fixed assets and personnel input of the transportation industry, are comprehensively considered. In the logistics development-scale-output subsystem, it is mainly measured by the turnover of goods, the volume of freight, the output value of transportation industry and the total volume of post and telecommunications business [31–34]. This can better reflect the development level of the logistics industry. Through the above indicators, we can measure the collaborative development level of the composite system of the digital economy and logistics industry. The details of the indicators are presented in Table 1.

2.3. Data Source and Processing

2.3.1. Data Source

This study uses the data of Anhui province from 2013–2020 as statistical sample data. The original data are from China Statistical Yearbook, Anhui Statistical Yearbook, and China Internet Development Report. For 2020, data were missing for certain indicators, so the missing value processing method was adopted to complete them.

2.3.2. Data-Standardisation Method

The original index data are standardised to remove the unit limit and convert it to dimensionless index evaluation values, to facilitate the comparison and comprehensive evaluation of different indexes. Common data-standardisation methods include min max standardisation and Z-score standardisation. This study's dimensionless calculation steps are as follows:

$$X_{ij}^* = \frac{X_{ij} - \overline{X}_j}{S_j} \tag{1}$$

$$\overline{X}_j = \frac{\sum_{i=1}^n X_{ij}}{n} \tag{2}$$

$$S_j = \sqrt{\frac{\sum_{i=1}^n (X_{ij} - \overline{X}_j)^2}{n-1}} \tag{3}$$

where X_{ij}^* is standardised data, X_{ij}. is raw data, $\overline{X}_j$ is the average value of X_{ij}, and S_j is the standard deviation of X_{ij}.

Table 1. Index system of coordinated development of the digital economy and logistics industry.

		Primary Index	Order Parameter Index	Symbol	Direction
Collaborative development system of the digital economy and logistics industry	Digital economy development level system (S1)	Digital infrastructure level (S11)	Internet penetration (%)	e_{11}	+
			Total telecom services (RMB 100 mn)	e_{12}	+
			Cellular phone penetration (department/100 people)	e_{13}	+
			Number of domain names per capita (PCS)	e_{14}	+
			Number of pages per capita (PCS)	e_{15}	+
		Development level of digital industry (S12)	Proportion of software business income in GDP (%)	e_{16}	+
			Proportion of income from information transmission, software, and information technology services in GDP (%)	e_{17}	+
			Proportion of operating income of computer communication and other electronic equipment manufacturing industry in GDP (%)	e_{18}	+
			Investment in fixed assets of information service industry (RMB 100 mn)	e_{19}	+
			Number of employees in information transmission, software, and information technology services (10,000 people)	e_{110}	+
			Total profits of computer, communication and other electronic equipment manufacturing industry (RMB 100 mn)	e_{111}	+
		Digital technology innovation level (S13)	Employment in scientific research and technical services (10,000 people)	e_{112}	+
			Research and experimental development expenditure (RMB 100 mn)	e_{113}	+
			Total number of people with bachelor's degree or higher (people)	e_{114}	+
			Patent applications per 10,000 people (PCS/10,000 people)	e_{115}	+
			Proportion of output value of scientific research and technical services in GDP (%)	e_{116}	+
		Industrial digitisation level (S14)	Number of computers used by enterprises per 100 people (set)	e_{117}	+
			Number of websites per 100 enterprises (PCS)	e_{118}	+
			E-commerce sales (RMB 100 mn)	e_{119}	+
			Number of e-commerce enterprises (total number of e-commerce enterprises/enterprises)	e_{120}	+
			E-commerce purchase amount (RMB 100 mn)	e_{121}	+

Table 1. *Cont.*

		Primary Index	Order Parameter Index	Symbol	Direction
Collaborative development system of the digital economy and logistics industry	Logistics industry development level system (S2)	Basic investment in logistics development (S21)	Highway mileage (km)	e_{21}	+
			Railway mileage (km)	e_{22}	+
			Channel mileage (km)	e_{23}	+
			Investment in fixed assets of transportation, warehousing, and postal industry (RMB 100 mn)	e_{24}	+
			Employment in transportation, warehousing, and postal services (10,000 people)	e_{25}	+
			Total length of postal routes and rural delivery routes (10,000 km)	e_{26}	+
		Logistics development-scale output (S22)	Cargo turnover (100 million tonnes km)	e_{27}	+
			The volume of freight transport (10,000 tonnes)	e_{28}	+
			Output value of transportation, warehousing, and postal industry (RMB 100 mn)	e_{29}	+
			Total post and telecommunications business (RMB 10,000)	e_{210}	+

2.4. Coordination Degree Model of the Composite System

Haken [45] first proposed synergy theory in 1964. The theory is based on factors such as system theory, cybernetics, and information theory and adopts the method of combining statistics and dynamics to establish the synergy model of a composite system by analogy for the phenomenon from disorder to order [45]. In the composite system, there are various contradictions and uncoordinated phenomena between subsystems and their order parameters, and between subsystems in the process of interaction. Only through continuous cooperation can we maintain the dynamic balance relationship between systems and achieve the effect that the overall function of the composite system is greater than the sum of local functions under the cooperation of subsystems. The digital economy and logistics industry can be regarded as two systems. Through their internal collaborative development, they jointly promote the digital collaborative development of the logistics industry and realise the result that the overall function is greater than the sum of the individual functions.

Therefore, there are two levels of system synergy in the composite system of the digital economy and logistics industry in this study: the first level is the coordinated development between the digital economy and logistics industry development systems, which constitutes the integrated development of the digital economy and logistics industry. The second level is the coordinated development of the internal subsystems of the digital economy and logistics industry. The two-tier system is progressive and operates in layers. This study proposes countermeasures and suggestions to promote the coordinated development of the composite system of the digital economy and logistics industry by studying the coordinated development within their subsystems.

Based on existing research results, the synergy degree model of the composite system is constructed by using the two subsystems as an example. The steps are as follows:

2.4.1. System Order Parameter Variable Order Degree

The composite system can be conceptualised as $S = \{S_1, S_2, \ldots, S_j\}$. In this study, the composite system is $S = \{S_1, S_2\}$, in which the digital economy system is S1 and the logistics system is S2, which is S_j, $j \in [1, 2]$. The digital economy system and logistics system are composed of relevant subsystems. The subsystems are $S_j = (S_{j1}, S_{j2}, \ldots, S_{jp})$, $p \in [1, 2, \ldots, n]$. The digital economy system is represented by $S_1 = (S_{11}, S_{12}, \ldots, S_{1p})$, and the logistics system is represented by $S_2 = (S_{21}, S_{22}, \ldots, S_{2p})$. The order-parameter variables that are set in each system, $e_{ji} = (e_{j1}, e_{j2}, e_{j3}, \ldots, e_{jn})$, $i \in [1, 2]$, $n > 1$, $\alpha_{ji} \leq e_{ji} \leq \beta_{ji}$, $i \in [1, n]$, α_{ji}, and β_{ji}, are the critical limits of order-parameter variables at the stable node of the system. α_{ji} and β_{ji} are expressed as 1.01 times the minimum and maximum values of the subsystem order-parameter variables within the study range, respectively. If the order-parameter variable has a positive effect on the development of the subsystem, the order-degree equation of the order-parameter variable is:

$$u_j(e_{ji}) = (e_{ji} - \alpha_{ji})/(\beta_{ji} - \alpha_{ji}), i \in [1, k] \tag{4}$$

If the order-parameter variable has a negative effect on the development of the subsystem, the order degree of the order-parameter variable is:

$$u_j(e_{ji}) = (\beta_{ji} - e_{ji})/(\beta_{ji} - \alpha_{ji}), i \in [k + 1, n] \tag{5}$$

According to Equation (5), the closer $u_j(e_{ji}) \in [0, 1]$ is to 1, the greater its contribution to the order degree of the subsystem. The closer it is to 0, the smaller its contribution to the order degree of the subsystem.

2.4.2. Subsystem Order Model

The order parameters, which affect the coordinated change of the system, are formed by the e_{ji} integration of the order-parameter components. The integration result is jointly determined by the order degree value and combination form of the order-parameter

components. In this study, the geometric average method with high recognition is adopted for integration, as shown in the following equation:

$$u_j(e_j) = \sqrt[n]{\left| \prod_i^n u_j(e_{ji}) \right|} \tag{6}$$

In Equation (6), $u_j(e_j)$ is the system order of the order-parameter variable e_j. According to Equation (6), $0 \leq u_j(e_j) \leq 1$. The magnitude of this value indicates the influence of e_j on system S_j, The greater the order degree of the system is, the greater the contribution of e_j to the order of system S_j, so the higher the order degree of the system, and vice versa.

In this study, the digital economy system S_1 is composed of four subsystems; therefore, the order degree of S_1 is:

$$u_1(s_1) = \sqrt[n]{\left| \prod_i^n u_1(s_{1i}) \right|} \tag{7}$$

The logistics system S_2 consists of two subsystems; therefore, the order degree of S_2 is:

$$u_2(s_2) = \sqrt[n]{\left| \prod_i^n u_2(s_{2i}) \right|} \tag{8}$$

2.4.3. Collaborative Degree Model of the Composite System

The degree of synergy can correctly reflect the degree of collaborative development among the subsystems in the composite system and the interaction and synergy between subsystems in the composite system. Based on an order degree model for subsystems, this study constructs a composite system synergy degree model to evaluate the level of coordinated development of the digital economy and logistics industry. In the two-system (S1, S2) model, $S_1(e_1)$ and $S_2(e_2)$ are the order degrees of the two subsystems calculated by the subsystem order degree model. This order degree changes dynamically with time in the research interval. Suppose that the initial time of subsystem development is 0, and the order degree of subsystem at time 0 is $u_j^0(e_j)$, j = 1, 2, ... , n, then with the dynamic development of the composite system, the order degree of subsystem is $u_j^t(e_j)$ at time *t*. Equation (9) is the synergy degree of the development of the digital economy and logistics industry, which is defined as $C(t)$; therefore, the synergy degree $C(t)$ of the composite system in the process of dynamic change with time is:

$$C(t) = \theta \sqrt{\left| \prod_j^n \left[u_j^t(e_j) - u_j^0(e_j) \right] \right|} \tag{9}$$

where $\theta = \dfrac{min\left[u_j^t(e_j) - u_j^0(e_j) \neq 0 \right]}{\left| min\left[u_j^t(e_j) - u_j^0(e_j) \neq 0 \right] \right|}$, $C(t) \in [-1, 1]$.

The positive or negative result mainly depends on whether the order degree of its constituent subsystems at time *t* is greater than that at time 0 of the initial test. The value depends on time *t*, and the order degree of its constituent subsystem is equivalent to the increase in the order degree of the subsystem at time 0. The greater the value of coordination degree $C(t)$ of the composite system, the higher the coordination degree between representative subsystems, and vice versa.

According to Equation (9), the degree of synergy depends not only on the improvement of the order degree of a system, but also on the common improvement of the order degree of each system. If only the order degree of individual systems increases rapidly, while the order degrees of other systems increase slowly, the synergy degree of the composite systems will be lower than that of each system. Therefore, the synergy degree of the composite

system requires the coordinated development of various systems. The greater the value of synergy between the digital economy system and logistics industry is, the higher the degree of synergy between them. In contrast, a lower degree of synergy between them indicates a need for further improvement. According to the literature [46,47], the degree of synergy between the digital economy and logistics industry is divided into categories, as shown in Table 2.

Table 2. Composite system synergy evaluation criteria.

Synergy Category	Synergy Degree	Subcategory	Index Comparison	Tertiary Category
Coordinated development	$0.8 < C(t)\,[3] \leq 1$	Advanced coordination	U1 [1] < U2 [2]	Digital economy lag
			U1 = U2	Balanced development
			U1 > U2	Logistics industry lag
Transformation and development	$0.6 < C(t) \leq 0.8$	Moderate coordination	U1 < U2	Digital economy lag
			U1 = U2	Balanced development
			U1 > U2	Logistics industry lag
	$0.4 < C(t) \leq 0.6$	Low coordination	U1 < U2	Digital economy lag
			U1 = U2	Balanced development
			U1 > U2	Logistics industry lag
Uncoordinated development	$0.2 < C(t) \leq 0.4$	Moderate imbalance	U1 < U2	Digital economy lag
			U1 = U2	Balanced development
			U1 > U2	Logistics industry lag
	$0.0 < C(t) \leq 0.2$	Severe imbalance	U1 < U2	Digital economy lag
			U1 = U2	Balanced development
			U1 > U2	Logistics industry lag

[1] U1: synergy degree of the digital economy system; [2] U2: synergy degree of the logistics industry system; [3] C(t): synergy degree of the composite system.

2.5. Data Application

Promoting the coordinated development of the digital economy and logistics industry is practically significant for improving the digital transformation and upgrading of the regional logistics industry as well as realising the coordinated and sustainable development of the digital economy and logistics industry. This is especially important because of the rapid development and the continuous integration and development of the digital economy and traditional industries. Due to the comprehensive consideration of the digital economy and logistics industry system, this study constructs a composite evaluation index system, which involves multiple pieces of data. Therefore, this study adopts the data-driven method to accurately measure and evaluate the collaborative development level of the composite system of the digital economy and logistics industry, proposes policy suggestions based on the quantitative evaluation results, and provides decision support for practitioners and managers in the regional digital economy and logistics industry. The specific application is shown in Figure 2.

The first step is to collect data and establish a list of database elements related to the development of the digital economy and logistics industry. According to the principles of data availability and scientificity, the index system is constructed from the development level of the digital economy and logistics industry. The Z-score method is used to deal with the data's lack of dimension.

The second step is to construct the synergy degree model as well as measure and evaluate the synergy degree of the complex digital economy and logistics system.

Third, according to the measurement results, the level of the collaborative development level of the digital economy and logistics industry composite system is analysed.
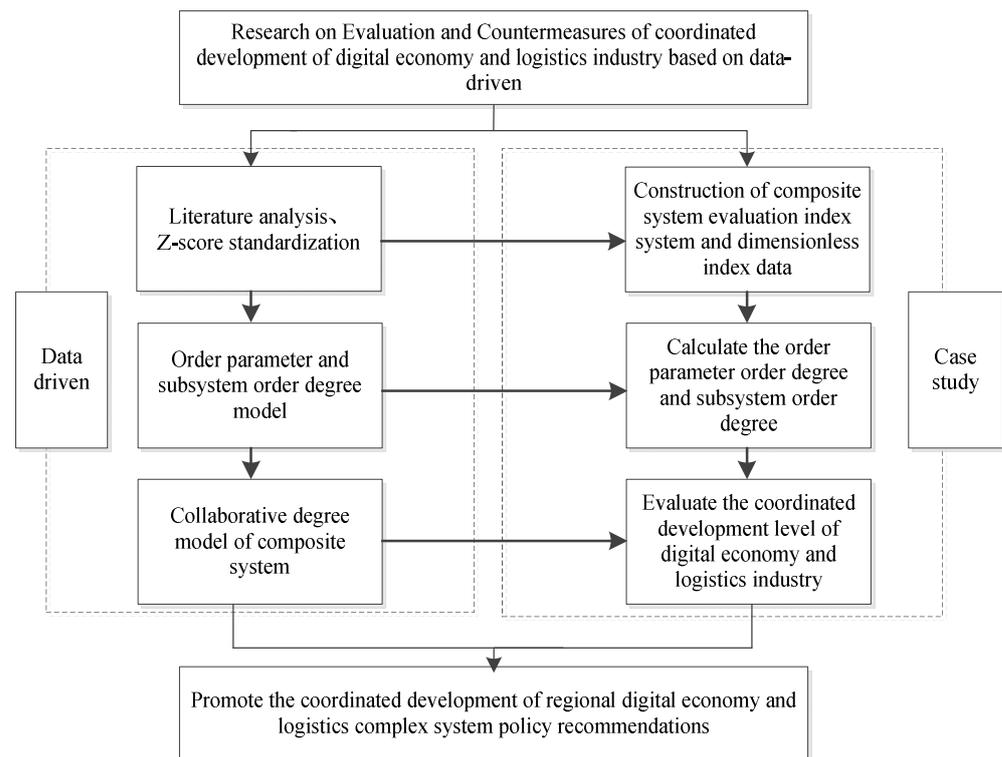
Figure 2. Data-application diagram.

3. Case Study

Using the research methods that were presented in Section 2, this study analyses the development of the digital economy and logistics in Anhui province in the Yangtze River Delta.

3.1. Background

While accelerating the rapid development of the digital economy, we should be able to coordinate this development with regional industries to promote the high-quality development of the regional economy. Anhui province is in the hinterland of the Yangtze River Delta. The development of the digital economy and logistics industry plays a vital role in the Yangtze River Delta and affects the high-quality development of the regional economy. Therefore, measuring and coordinating the development level of these systems are of great significance to realise the coordinated and sustainable development of the digital economy and logistics industry in Anhui province.

3.2. Results

3.2.1. Results of Order Degree of Digital Economy and Logistics System in Anhui Province

In this study, Z-score is used for the dimensionless standardisation of the original data. The standardised index values are substituted into Equations (4)–(6) to obtain the order parameter: index order degree. This parameter is then substituted into Equations (7) and (8) to calculate the order degree of each subsystem of the digital economy and logistics industry, respectively. Thereafter, the order degree of the two systems is obtained through further iteration, as shown in Figures 3 and 4. The four subsystems of the digital economy development system (Figure 3) show that the order degree of digital infrastructure (S11), digital industry development level (S12), and digital scientific and technological innovation level (S13) increased from 2013–2020, and the contribution to the order degree of the system increased yearly. In addition, the order degree (S1) of the digital economy development level increased yearly.

	S11	S12	S13	S14	S1
2013	0.004	0.0061	0.0072	0.0139	0.007
2014	0.0671	0.125	0.1204	0.2801	0.1297
2015	0.1612	0.4264	0.1208	0.483	0.2517
2016	0.1365	0.5351	0.3159	0.5516	0.3359
2017	0.2862	0.6581	0.4031	0.6038	0.4627
2018	0.5906	0.6575	0.6658	0.6346	0.6364
2019	0.8543	0.571	0.763	0.6812	0.7096
2020	0.9271	0.8177	0.9947	0.3517	0.7176

Figure 3. Evolution of order degree of digital economy system and its subsystems.

In 2019 and 2020, the order of the digital infrastructure construction level reached 0.8543 and 0.9271, respectively. The order degree of digital scientific and technological innovation reached 0.9947. It is closely related to the increase in the national investment in the development of the digital economy—especially from infrastructure construction and scientific and technological innovation. The order of the digital industry development in 2019 was lower than that in 2018, which is due to the impact of COVID-19. The order degree of industrial digitisation level (S14) increased yearly from 2013–2019. However, in 2020, the order degree was lower than in 2019. Tracing the order-parameter-component index of the original data shows that the impact on the order degree of the industrial digitisation level in 2020 is due to a decrease in the number of websites per 100 enterprises and the number of e-commerce enterprises from 2019. In the post-pandemic era, most small and medium-sized enterprises struggled to survive and declared bankruptcy. Figure 3 shows that the order of the digital industry development level (S12) and industrial digital level (S14) increased rapidly from 2013–2016 and steadily increased at a slow pace from 2016–2019. The level of digital scientific and technological innovation (S13) increased rapidly after 2017. Up to and including 2017, the contribution of the digital industry development (S12) and industrial digitisation levels (S14) to the order degree of the digital economy system was higher than that of the other two subsystems. The greater contribution of the order degree of the scientific and technological innovation subsystem in 2018 stems from China's efforts to increase the development of scientific and technological innovation.

In addition, the order degree of the logistics system in Anhui province was measured from two subsystems: basic input and development-scale output.

As shown in Figure 4, from 2013–2019, the order degree of logistics' basic investment-level subsystem showed a yearly increasing trend and, by 2019, the order degree had reached 0.7573. In 2020, the order degree of the subsystem was lower than in 2019. Traced to the order degree-parameter component, it showed that employment in the transportation industry decreased by 12.23%, which directly caused the order degree of the logistics development level system in 2020 to be lower than it was in 2019. However, the order degree of the logistics development level system for 2013–2019 showed an increasing trend. From the perspective of the logistics development scale output subsystem, the overall order level showed an increasing trend. However, 2019 was affected by the pandemic, so the freight volume was lower than in 2018, resulting in a decrease in the order degree. In 2020, the order degree reached a maximum of 0.7123. It is expected to continue to achieve this steady progress.

	2013	2014	2015	2016	2017	2018	2019	2020
■ S21	0.0095	0.0462	0.1962	0.3611	0.652	0.65	0.7573	0.4111
■ S22	0.051	0.0496	0.0552	0.2088	0.2749	0.6977	0.6246	0.7123
■ S2	0.022	0.0479	0.1041	0.2745	0.4234	0.6734	0.6877	0.5411
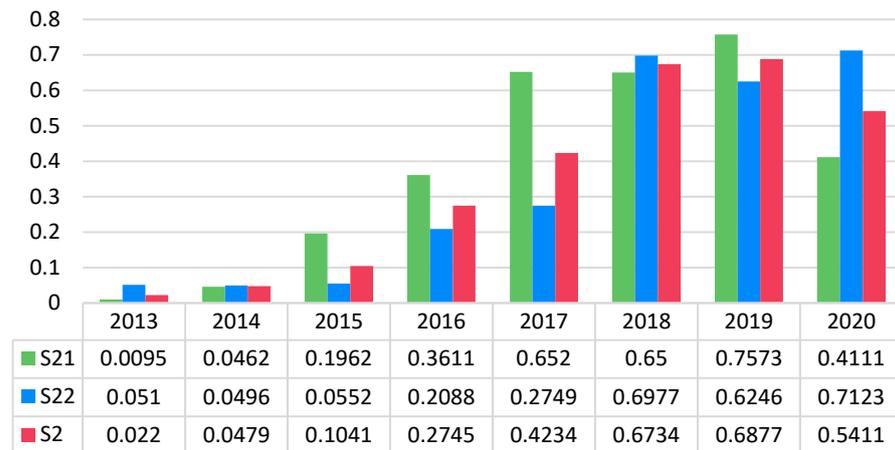
Figure 4. Changes of logistics subsystem and system order.

3.2.2. Results of the Degree of Synergy of the Composite System of the Digital Economy and Logistics Industry in Anhui Province

The base period was set as 2013. Thereafter, the order degree of each subsystem was substituted into Equation (9), and the synergy degree of each subsystem and composite system was calculated. The results are shown in Figure 5.
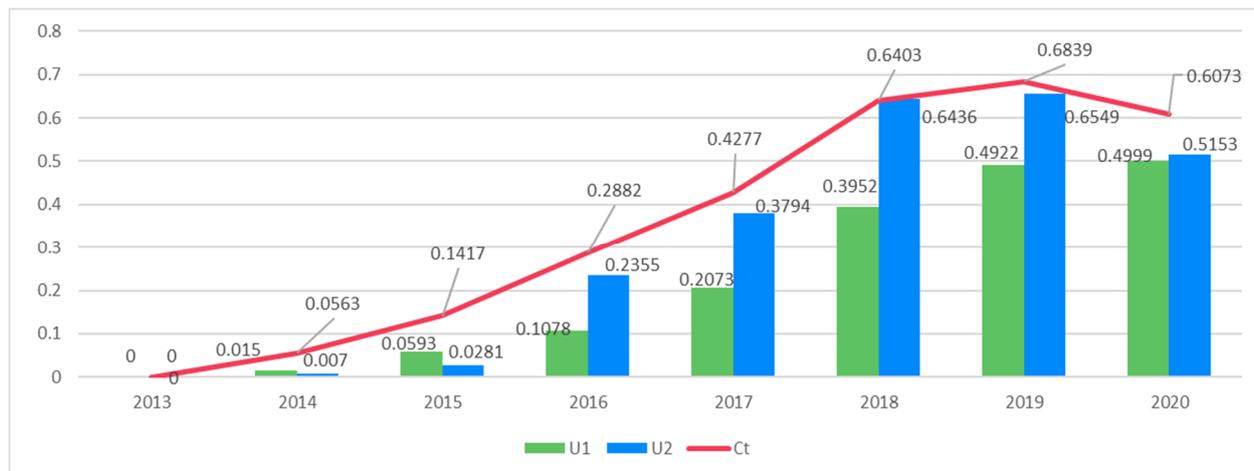
Figure 5. System synergy degree and composite system synergy degree of digital economy and logistics industry.

Accordingly, the synergy degree of the Anhui digital economy development system, logistics development system, and their composite system were obtained. Figure 5 shows that the synergy level of the complex digital economy and logistics system in the Anhui province increased yearly from 2013–2019, decreasing slightly in 2020 compared to 2019. The synergy degree of the composite system is related to the internal synergy degree of the two subsystems. The coordinated development of the logistics industry in 2020 was lower than in 2019, which was most likely caused by the impact of the pandemic at the end of 2019.

The synergy degree of the complex digital economy and logistics system in Anhui province was 0.0563 in 2014 and 0.1417 in 2015. Table 2 shows that the synergy level of the complex system belongs to the level of severe imbalance, and the synergy degree of the digital economy system is greater than that of the logistics system (U1 > U2), which indicates that it is at the logistics industry lag level. In 2016, the synergy degree of the composite system was 0.2882, and Table 2 shows that the synergy level of the composite system is at the level of modern imbalance. Furthermore, the synergy degree of the digital

economy system is lower than that of the logistics system (U1 < U2), which indicates that it is at the level of digital economy lag. In 2017, the synergy degree of the composite system was 0.4277, which places it at the low coordination level. In addition, the synergy degree of the digital economy system is lower than that of the logistics system (U1 < U2), which places it at the digital economy lag level. With the development of the social economy, the role of the logistics industry has become increasingly prominent. The Chinese government has also begun to introduce various policies to promote the development of the logistics industry, and the level of coordinated development of logistics industry has gradually increased. Although the digital economy was still developing at the time, the level of coordinated development still lagged behind. From 2018–2020, the synergy degrees of the composite system reached 0.6403, 0.6839, and 0.6073, respectively, which is at the level of modern coordination. In addition, the synergy degree of the digital economy system is lower than that of logistics system (U1 < U2), which is at the level of digital economy lag. During this period, both the synergy degrees of the composite system and each subsystem were higher than they were before 2017. Globally, various policies to promote the industrialisation of digital economy and transformation and development of traditional industries, were implemented successively and actively promoted. However, the synergy level of overall development must be further improved.

3.3. Policy Recommendations

The coordinated development of the digital economy and logistics industry is of great and practical significance to the high-quality development of China and its national economy. According to the measurement and evaluation of the coordinated development of the complex digital economy and logistics system in Anhui province from 2013–2020, the level of coordinated development of the complex digital economy and logistics system continued to increase. However, the overall synergy still requires further improvement, and the internal synergy of each subsystem is low. The synergy levels of the digital economy and logistics composite system in Anhui province were within the category of modern coordination and digital economy lag in 2020. Accordingly, this study proposes the following countermeasures.

First, strive to improve the level of coordinated development within subsystems of the digital economy and logistics industry in Anhui province. The synergy degree model of the composite system, Equation (9), shows that if the composite system can achieve a combined effect that is larger than the sum of the two individual effects, then it will not rely on a specific subsystem, and the development synergy degree of any subsystem will affect the highly integrated development of the composite system [30]. The synergy degree of the digital economy system in Anhui province was 0.4999 in 2020, which indicates that there were low levels of coordination. The synergy degree of the logistics system in Anhui province was 0.6549 in 2019, which indicates that there was moderate coordination, which could be further improved. Anhui province should take advantage of the complementarity advantages and disadvantages and promote the internal coordinated development of various systems of the digital economy and logistics industry to lay a solid foundation for the highly integrated development of the two systems.

Second, it is necessary to promote the highly integrated development of the digital economy and logistics industry in Anhui province. The global digital economy development report [6] points out that both digital industrialisation and industrial digitisation should be promoted to enable the transformation and upgrading of traditional industries. Therefore, the digital transformation and development of the circulation industry should be increased to promote the highly integrated development of the digital economy and the logistics industry. From 2013–2020, the composite synergy degree of the digital economy and logistics industry in Anhui province was 0.6839, so the synergy level of the composite system indicated a level of modern coordination. In addition, the synergy degree of the digital economy system was less than that of the logistics industry system (U1 < U2), which indicated a level of digital economy lag. Therefore, it is necessary to strengthen the

development of the digital economy. The synergy level of the digital economy subsystem stagnated in 2019 and 2020. Figure 3 shows that it is due to the low order of industrial digitisation. Furthermore, it is necessary to correctly grasp the trend and legal stipulations of the digital economy to promote the development of the logistics industry, strive to realise the coordinated development of the digital economy and logistics industry, and promote the integrated development of the industry to reach a new stage. In 2020, the synergy degree of the composite system of the digital economy and logistics industry was 0.6073, which was lower than in 2019. Figure 4 shows that the synergy level of the digital economy subsystem was mostly unchanged, mainly due to the decline in the synergy level of the logistics system. The reason is that the contribution of the order degree of the input subsystem of the logistics system (0.4111) was less than that of the output scale (0.7123). Therefore, it is necessary to accelerate the digital transformation and development of the logistics industry in Anhui province and improve the order contribution degree of the input subsystem.

Third, Anhui province should actively implement relevant policies. The relevant ministries, commissions, and local governments at all levels involved in Anhui province should comply with the development trend of the digital economy, deepen the reform of government functions, and amend or improve the relevant systems and mechanisms. They should actively promote the reform of the circulation system, accelerate the flow of various innovative elements, improve the standards and systems of the modern logistics industry, increase investment in the logistics industry, and adhere to the digital reform of the logistics industry. Furthermore, they should implement relevant policies and requirements to effectively improve the policy system, to promote the coordinated development of the digital economy and logistics industry. This will improve the competitiveness of the relevant industries and promote high-quality economic development.

3.4. Discussion

Compared to other studies [36–38], this study has the following advantages. First, from the perspective of synergy, system, and input–output theories, a more comprehensive evaluation index system of the composite system of the digital economy and logistics industry was constructed. The index system includes four subsystems: digital infrastructure, digital industry, industrial digitisation, and digital scientific and technological innovation, which reflect the collaborative development level of the digital economy. In addition, it uses the basic input and the scale output of logistics development, which reflect the collaborative development level of the logistics industry. It provides a measurement reference for the coordinated development of the digital economy and logistics industry, which is more systematic and scientific. The establishment of the composite index system provides a basis for the research on the coordinated development of the digital economy and logistics industry. Second, the data-driven method used in the composite system synergy degree model systematically and comprehensively considers the development of the digital economy and logistics industry and, more objectively, measures and evaluates the collaborative development level of the digital economy and logistics industry. The quantitative evaluation of the coordinated development of the composite system of the digital economy and logistics industry is realized. This model will facilitate scientific decision-making. Finally, to achieve high-quality economic development, considering the coordinated development of the two basic and leading industries of the digital economy and logistics industry, this study proposes targeted countermeasures and suggestions to promote the highly integrated and coordinated development of the logistics industry and digital economy.

Based on our results and conclusions, we provide the following three management insights. First, we should promote the coordinated development of the digital economy and logistics industry from the perspective of system theory and overall optimisation. We cannot rely on a subsystem to improve the development of the whole system. We should

give full play to the mutual support of the two subsystems and effectively promote the digital transformation and sustainable development of the logistics industry.

Second, with the development of the economy, society, and science and technology, the establishment of a data-driven measurement and evaluation method for the coordinated development of the composite system of the digital economy and logistics industry can give full play to the advantages of various subsystems. These include highlighting regional and professional advantages, realising complementary strengths and weaknesses, and coordinating development to more effectively serve the decision-making of local governments and related local enterprises' management.

Third, the coordinated development of the digital economy and logistics industry is very important to promote high-quality economic development. Governments and relevant departments need to cooperate to jointly promote the integrated development of the two areas. Realising the highly integrated and coordinated development of the digital economy and logistics industry remains a field worthy of in-depth research.

4. Conclusions

With the acceleration of the development of the global digital economy, all regions must pay more attention to the collaborative development of industrial digitisation and promote the integration of the digital economy and related industries [38–42]. The logistics industry is one of the important industries of the national economy. The coordinated development of the combined logistics industry and digital economy is conducive to the accurate matching of supply and demand of logistics industry. It is also conducive to promoting industrial digitalization, promoting the development of digital economy, and then boosting high-quality economic development. This study proposed a data-driven method to analyse and evaluate the coordinated development level of the regional digital economy and logistics industry. The innovations are as follows.

(1) This study constructed a measurement index of the composite system of the digital economy and logistics industry. The index system is fully considered from the perspective of system theory and inputs and outputs, which includes four subsystem indexes that reflect the synergy level of the digital economy and an input–output index system that reflects the synergy level of the logistics industry. It provides a measurement reference for the coordinated development of the digital economy and logistics industry, which is more objective and scientific.

(2) This study established a composite data-driven synergy model for the digital economy and logistics industry. The quantitative evaluation of the coordinated development of the composite system of the digital economy and logistics industry is realized, and the evaluation process is more objective, so the evaluation results are more credible. This model is helpful to find the rules of the coordinated development of logistics industry and digital economy and provides support for promoting their coordinated and stable development.

(3) The case study shows that this method is effective and feasible. Through empirical analysis, we can accurately propose targeted countermeasures and suggestions for the measurement and evaluation of the coordinated development of the composite system of the digital economy and logistics industry, to provide a scientific basis for policy makers' and practitioners' decision-making. This will play a positive role in promoting the coordinated development of the regional digital economy and logistics industry, make an important contribution to industrial digitalization, and boost the high-quality development of the regional economy.

However, the coordinated development of the digital economy and logistics industry is a complex engineering system, and this study also has some deficiencies. In social development, the composite system of the digital economy and logistics industry is affected by more factors, so the index system of the composite system needs to be further improved by future research. Furthermore, studies can explore the impact mechanism of the digital economy on the coordinated development of the logistics industry, to systematically clarify

the factors restricting the coordinated development of the two systems. In addition, they can propose more effective ways to facilitate the highly integrated development of the digital economy and logistics industry, to promote the high-quality development of the economy.

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