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Coordinated Development Relationship between Port Cluster and Its Hinterland Economic System Based on Improved Coupling Coordination Degree Model: Empirical Study from China’s Port Integration

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Abstract: In recent years, the port integration in China has been carried out vigorously, and has basically covered all coastal provinces from south to north and some areas along the Yangtze River. In order to quantify the practical effects of the port integration, this paper conducts research investigating whether or not the port integration would be able to realize the coordinated development between the port cluster and its hinterland economic system more smoothly. This paper carries out the research by building the improved coupling coordination degree model for evaluating the coupling coordination degree between the port cluster and its hinterland economic system, and further by applying the improved model to the empirical analysis of three port clusters with different integration patterns. The empirical results reveal that: (1) the port integration may lead to a “Painful Period” for the coordinated development relationship between the port cluster and its hinterland economic system in the short term, especially at the beginning of the integration, and the coupling coordination degree of the whole system would fall into a drop temporarily; (2) among different port clusters with different port integration purposes and patterns, there are evident differences in the change of the coupling coordination degree of the whole system at the beginning of the integration; and (3) in the long run, the port integration would be able to effectively improve the coupling coordination degree of the port cluster and its hinterland economic system, and thus the whole system can obtain a better relationship of coordinated development.

Keywords: port integration; port cluster; hinterland economy; improved coupling coordination model; coupling coordination degree; coordinated development relationship; panel data

1. Introduction

As important infrastructure, ports often act as the transportation hubs as well as the engines for boosting the regional economy; therefore, major countries all over the world attach great importance to the development of ports [1]. In China, the development of ports has entered the “fast lane” since the decentralization of port governance, and the “port bottleneck” problem which previously restricted China’s economic development, has thus been resolved [2]. However, it has also led to an extensive development pattern of blindly pursuing the expansion of port scale, which causes many problems such as overinvestment, the structural imbalance between demand and supply, the vicious competition for cargoes, and the ineffective utilization of coastline resources. Faced with these new challenges, the central government in China has realized that a new round of port development reform must inevitably be put into effect. Then, in December 2014, the Ministry of Transport promulgated an important document which clearly pointed out the necessity of promoting the integration of regional port resources. Since then, many coastal provinces and some inland provinces along the Yangtze River have begun to integrate their port resources.
With the acceleration of the integration process, up to now, a situation of “one province, one port” has formed, which is quite different from the previous situation of “one city, one port”.

Influenced by the reform of provincial port integration, the relationships among ports in the same province have thus changed from the previous type of mutual independence and even competition to the type of cooperation. Accordingly, the relationship, especially the economic relationship between the port cluster which is composed of ports in the same province (hereinafter referred to as “the port cluster”) and its hinterland, would also change. Moreover, due to the difference in the integration patterns among different provinces, the relationships between the port clusters and their hinterland economic system may also differ from each other. Some interesting questions subsequently arise: what influence will the port integration have on the relationship between the port cluster and its hinterland economic system? Will the port cluster fit in more with its hinterland economic system than before? Will the relationship between the port cluster and its hinterland economic system differ from each other with different integration patterns? Focusing on these questions, this paper hopes to contribute to quantifying the practical effects of the port integration, and providing theoretical reference for the formulation of development strategies for the integrated port clusters.

Due to the important role of China’s ports in the international transportation network, research into port integration in China has been a hot topic in recent years. The related research can be generally divided into two categories. The first category focuses on qualitative research on the motivation and path of China’s port integration. For example, Pan analyzed the integration of regional ports in China from the perspective of combined ports and summarized the experience of foreign combined ports in the system, property rights competitiveness, and port coordinated development. The paper also put forward a development model based on combined ports to promote the integration of regional ports in China [3]. Wang et al. summarized the development of port integration in China, including the relevant time path, spatial pattern, and dynamic change. The results show that legislative tools, spatial planning, coastline resources, and port competition would affect the integration of ports in China. In addition, they found that the integration of ports in China has grown rapidly since the 21st century, with various coastal provinces in China consolidating ports in different areas [4]. Wu and Yang took the whole process of port integration in Liaoning Province (a typical port cluster with fierce competition in China) as an example to explain the motivation, methods, and corresponding impacts of port integration [5].

The second category of research focuses on the effect of port integration. For example, Zhao and Zhen assessed the performance of port integration in China by comparing the efficiency of port resource allocation and the utilization level of port coastline before and after the integration [6]. Dong et al. used game theory to quantitatively analyze the influence of regional port integration in multi-port areas [7]. Yang et al. analyzed the influence of port integration policies on total factor productivity (TFP) of ports with different cooperation attitudes [8]. However, there are few studies carrying out research from the perspective of the economic relationship between the port cluster and its hinterland; this paper hopes to fill this gap.

As for the literature on the topic of the coordinated relationship of port-related issues, two categories of research are mainly involved, including the research on the coordinated relationship among ports within the same port cluster and the research on the coordinated economic relationship between a specific port and its hinterland cities.

In terms of the research on the coordinated relationship among ports within the same port cluster, both qualitative and quantitative studies can be found. The qualitative research mainly focuses on analyzing the current situation of the coordinated relationship among ports, finding out the existing problems, and giving suggestions as well as future development direction. For example, Seebode and Joseph discussed the coordinated development of New York and New Jersey Port Cluster in the United States [9]. Jaja pointed out the necessity of integration within the port cluster in order to achieve the orderly division
of labor and the coordinated development [10]. Zhang analyzed the current situation of port integration in Fujian Province (China) and proposed measures to promote the coordinated development of its port cluster [11]. The quantitative research mainly measures the coordinated development level of port clusters by constructing the evaluation indicator system. For example, Lu and Wang established an evaluation indicator system for the coordinated development of port clusters based on the rough set theory and the coupling coordination theory, and analyzed the coordinated development level of ports within the three port clusters around the Bohai Sea [12]. Li measured the coupling coordination degree of port clusters in the middle reaches of the Yangtze River by constructing the coupling coordination evaluation model [13]. Kong and Liu proposed an evaluation indicator system considering the economy, the environment, and the society, and measured the coordinated development situation of nine ports in China based on the relaxation degree measurement model and the coupling coordination degree model [14].

For the research on the coordinated economic relationship between a specific port and its hinterland cities, the existing studies basically adopt quantitative research methods. For example, Liu analyzed the interactive development of port cities in the middle reaches of the Yangtze River and its hinterland economy, where there is an evident relationship of mutual influence between port and its hinterland economy [15]. Liu and Yin [16] and Park and Seo [17] used the econometric model [18] to demonstrate the impact of ports on the economic growth of hinterland cities; Ma et al., used the DID model to analyze the influence of port integration on urban economy [19]. Wang and Liu quantified the relationship between port function and urban function by introducing the concept of concentration index, and determined the degree of interdependence between port and its hinterland city [20]. Song and Geenhuizen estimated the output elasticity of port infrastructure through production function, and analyzed the relationship between port infrastructure investment and regional economy [21]. Cong et al., used a panel data regression model to test the degree of influence between port throughput and urban economy [22]. Many studies focused on the coordinated development relationship between a single port and its hinterland cities by using the coupling coordination degree model, such as Meng and Gao [23], Liu et al. [24], and Gong et al. [25]. Furthermore, the existing literature also studies the coordinated development relationship between a port cluster and its hinterland economy. For example, Wang et al. applied the structural equation model to screen the indicators from the initial indicator system and generated three categories of 26 indicators to study the coordination relationship between the port cluster and its hinterland economy [26].

However, for the above literatures, some shortcomings still exist. For example, even though there are studies considering the coupling coordination relationship between port cluster and its hinterland economy, the influence of port integration on the coupling coordination relationship between port cluster and its hinterland economy has not been considered. Moreover, many existing studies conduct research by using empirical analysis which only considers a specific port cluster without any comparison among different port clusters. In terms of the research methods, the existing literature mainly adopted the coupling coordination degree model [14,23–25], the econometric model [16,17,19], the panel data regression model [22], etc. to analyze the coordinated development relationship of different contents. Among the research methods used, the coupling coordination degree model is relatively more widely applied because of its easier process and more intuitive results. However, the coupling coordination degree model currently used has an obvious shortcoming. That is, it can only focus on the result at a certain time point without the ability to analyze the result in the time dimension continuously and dynamically.

In order to quantify the actual effect of port integration especially from the perspective of the relationship between the port clusters and its hinterland economic system, this paper conducts research by developing an improved coupling coordination model and applying the improved model to the empirical analysis of three typical provinces which implemented the port integration at a relatively early time. The contribution of this paper lies
in two aspects. Firstly, compared with the currently used coupling coordination degree model, the model developed in this paper improves the performance by adding the ability to calculate the result in a continuous and dynamical way. Secondly, the empirical results demonstrate the impact of port integration on the relationship between the port clusters and its hinterland economy, which is rarely considered in the existing literature.

The remainder of this paper is organized as follows. In Section 2, the improved coupling coordination degree model as well as the evaluation method for analyzing the coordinated development relationship between the port cluster and its hinterland economy is proposed and described in detail. Then, in Section 3, an empirical analysis is conducted by applying the proposed model and method in three typical provincial port clusters that have implemented the port integration. Section 4 provides the conclusions and findings.

2. Methodology
2.1. Construction of Evaluation Indicator System

Construction of the evaluation indicator system is the first step to analyze the coordinated development relationship between the port cluster and its hinterland economy. In this paper, the frequency statistics and the expert consultation method are utilized to determine the coordinated evaluation indicator system. The indicator system is designed in Tables 1 and 2, in which the port cluster subsystem contains three factor layers including the infrastructure capacity, the freight scale, and the development potential, a total of 10 indicators, while the hinterland economic subsystem contains three factor layers including the economic scale, the economic potential, and the economic quality, a total of 11 indicators.

Table 1. The evaluation indicator system for port cluster subsystem.

| Subsystem                | Factor Layers          | Indicator Layers                   |
|--------------------------|------------------------|------------------------------------|
| Infrastructure capacity   | Number of berths       |                                     |
|                          | Berth length           |                                     |
|                          | Annual throughput capacity |                                 |
| Port cluster subsystem   | Freight scale          | Throughput of cargoes               |
|                          |                        | Throughput of containers            |
|                          |                        | Throughput of foreign trade         |
| Development potential    | Growth rate for cargo throughput |                      |
|                          |                        | Growth rate for container throughput |
|                          |                        | Growth rate for foreign trade throughput |
|                          |                        | Market concentration                |

Table 2. The evaluation indicator system for hinterland economic subsystem.

| Subsystem                  | Factor Layers                     | Indicator Layers                                                   |
|----------------------------|-----------------------------------|------------------------------------------------------------------|
| Hinterland economic subsystem | GDP                               | Investment of fixed assets                                       |
|                            | Economic scale                    | Gross product of industries                                       |
|                            |                                   | Total retail sales of consumer goods                              |
|                            |                                   | Total trade volume of import & export                              |
| Economic potential         | Growth rate of GDP                 | Growth rate of fixed-asset investment                              |
|                            |                                   | Growth rate of total retail sales of consumer goods               |
|                            |                                   | Growth rate of total import & export trade volume                 |
| Economic quality           | GDP per capita                     | Income per capita                                                  |
In the evaluation indicator system for port cluster subsystem, the market concentration is expressed by the concentration of port throughput:

\[ M = \sum (X_i / X)^2 \]  

(1)

where \( M \) represents the concentration degree of port throughput; \( X_i \) represents the throughput of each port in the port cluster; and \( X \) represents the total throughput of the port cluster.

Port market concentration is one of the important factors affecting the choice of port integration pattern [27], which indicates whether there are dominant ports in the port cluster. In the process of port integration, if there is an obvious leader port, the intervention of government policies is unnecessary. However, if no port has a clear advantage in market share, government intervention is necessary [28]. Market concentration affects the coupling coordination degree of the two subsystems by affecting the development potential of port cluster subsystem. In the case of high market concentration, the port integration can be completed quickly, and the integrated ports can better realize the coordinated development. In the case of low market concentration, the competition among ports is more intense, and the integration would also take more time, and it is more likely to appear the situation of “harmony of form but discord of spirit”.

2.2. Determination of Indicator Weight

The weight determination method can usually be divided into two types, i.e., the difference-driven method and the function-driven method [29]. The two methods have their own advantages and disadvantages. That is, either the importance of indicators or the difference of indicator values is reflected. Among the weight determination methods, the entropy method is the most commonly used method. Therefore, this paper adopts the entropy method to determine the weight of indicators. The specific process is as follows:

2.2.1. Process the Original Data in a Standardized Way

In terms of the original data, due to the difference in the quantity units and the orders of magnitude, it is not feasible to calculate them directly. Therefore, it is necessary to conduct the standardized processing for the original data. Since the indicators selected in this paper are all positive, the following equation is adopted.

\[ x_{ij} = (a_{ij} - \min(a_{ij})) / (\max(a_{ij}) - \min(a_{ij})) \]  

(2)

where \( a_{ij} \) represents the initial value of indicator \( j \) for port cluster \( i \) and \( \min(a_{ij}) \) and \( \max(a_{ij}) \) represent the minimum and maximum value of indicator \( j \) for port cluster \( i \), respectively.

2.2.2. Determine the Weight of Each Indicator

See below:

\[ r_{ij} = x_{ij} / \sum_{i=1}^{m} x_{ij} (i = 1, 2, \ldots; j = 1, 2, \ldots; n) \]  

\[ e_j = -\frac{1}{\ln m} \sum_{i=1}^{m} r_{ij} \ln r_{ij} \]  

\[ w_j = (1 - e_j) / \sum_{j=1}^{n} (1 - e_j) \]  

(3)

(4)

(5)

where \( r_{ij} \) represents the proportion of indicator \( j \) for port cluster \( i \), \( e_j \) represents the entropy value of indicator \( j \), and \( w_j \) represents the weight of indicator \( j \).

2.2.3. Establishment of Improved Coupling Coordination Degree Model

Coupling is a basic concept in physics. Coupling refers to the phenomenon that two or more systems affect and interact with each other through various interactions. The coupling
degree describes the degree of correlation between systems or between elements within a system. The regular formula for measuring the coupling degree is:

\[ C = \left[ \prod_{i=1}^{n} U_i \left( \frac{1}{n} \sum_{i=1}^{n} U_i \right) \right]^{\frac{1}{n}} \] (6)

where \( n \) denotes the number of systems considered and \( U_i \) denotes the development level of system \( i \) which is valued between 0 and 1.

In this paper, the state of interaction between the port cluster system and the hinterland economic system is defined as the coupling coordination state. The coupling coordination mechanism between the two systems is reflected in their close relationship. On the one hand, the good development of the hinterland economy can provide support for the development of the port cluster, including sufficient investment and transportation demand. On the other hand, as the window of foreign trade in the hinterland, the good development of the port cluster can also provide employment opportunities and drive the development of the hinterland economy.

For the evaluation of the coordinated development relationship of port cluster and its hinterland economic system, the following coupling degree model is first established.

\[ C = 2 \sqrt{U_1 U_2} / (U_1 + U_2) \] (7)

\[ U_1 = \sum_{k=1}^{K} b_k \times y_k \quad U_2 = \sum_{s=1}^{S} d_s \times v_s \] (8)

where \( C \) represents the coupling degree function of port cluster and its hinterland economic system, \( U_1 \) and \( U_2 \) represent the development level of port cluster and its hinterland economic system respectively, \( b_k \) and \( d_s \) are the weights of indicators of the two subsystems, \( y_k \) and \( v_s \) are the standardized values of indicators of the two subsystems, and \( K \) and \( S \) are the number of indicators of the two subsystems.

The coupling degree model is able to measure the association degree between the two subsystems, but it has a significant shortcoming; that is, when the development level of both subsystems are low, the coupling degree may still reach a large value. In order to avoid this shortcoming, the coupling coordination degree is adopted to measure the degree of collaborative development between two subsystems, and thus the coupling coordination degree model is established.

\[ D = \sqrt{C \times T} \] (9)

\[ T = 0.5 \times U_1 + 0.5 \times U_2 \] (10)

where \( D \) represents the coupling coordination degree and \( T \) represents the comprehensive coordination degree between the port cluster and its hinterland economic system. The coupling coordination degree \( D \) is valued between zero and one. The value closer to 0 means a lower level of collaborative development of the two subsystems, while the value closer to 1 means a higher level of collaborative development.

The above-mentioned coupling coordination degree model is commonly utilized; however, an obvious shortcoming exists. That is, the model is only able to evaluate and compare the coupling coordination status of different research objects at a certain time point, or can only analyze the coupling coordination status of a research object at different time points. That is to say, the common coupling coordination degree model cannot compare and analyze the research objects both in space and time dimensions simultaneously, which may result in some important information unrevealed to a certain extent.

In view of the above shortcoming, this paper improves the existing coupling coordination degree model by increasing the time adjustment coefficient, and adopts the panel data to analyze the changes in coupling coordination status between the port cluster and its
In view of the above shortcoming, this paper improves the existing coupling coordination degree model and the common one is shown in Figure 1. The improved model is as follows:

\[ U'_{gr} = U_{gr} \times (1 - R_g)^{r_{\text{max}} - r} \]  \hspace{1cm} (11)

\[ f_{kr} = \frac{(Y_{kr} - Y_{k(r-1)})}{Y_{k(r-1)}}, R_1 = \frac{\sum_{k=1}^{r_{\text{max}}} \sum_{r=r_{\text{min}}}^{r_{\text{max}}} b_k f_{kr}}{r_{\text{max}} - r_{\text{min}}} \]  \hspace{1cm} (12)

\[ f_{sr} = \frac{(V_{sr} - V_{s(r-1)})}{V_{s(r-1)}}, R_1 = \frac{K \sum_{k=1}^{r_{\text{max}}} r_{\text{max}} - r_{\text{min}}}{r_{\text{max}} - r_{\text{min}}} \]  \hspace{1cm} (13)

where \( U_{gr} \) and \( U'_{gr} \) represent the development level of system \( g \) in year \( r \) without and with the time adjustment respectively, where \( g = 1 \) states the port cluster subsystem and \( g = 2 \) means the hinterland economic subsystem. System \( g \) in year \( r \) without and with the time adjustment respectively, where \( g = 1 \) states the port cluster subsystem and \( g = 2 \) represents the hinterland economic subsystem. \( R_g \) represents the time adjustment coefficient. \( Y_{kr} \) and \( V_{sr} \) represent the average of various indicators in year \( r \) for the port cluster subsystem and the hinterland economic subsystem. \( f_{kr} \) and \( f_{sr} \) represent the growth rate of various indicators in year \( r \) for the port cluster subsystem and the hinterland economic subsystem compared with the previous year.

Figure 1. The difference between the improved coupling and the common coupling coordination degree model. (a) Basic types of coupling coordination models. (b) Improved coupling coordination degree model.

In order to clearly distinguish the coordinated development level between the port cluster and its hinterland economic system, according to the relevant research [30–32],
the uniform distribution function method is adopted, and finally the coordinated development level between the two subsystems is divided into three stages and 10 types based on the coupling coordination values (as shown in Table 3).

Table 3. Classification criterion for identifying the coordinated development relationship.

| Stage                        | Range   | Coordination States          | Range  |
|------------------------------|---------|------------------------------|--------|
| Stage of disorder            | $D \in [0, 0.4]$ | Serious imbalance            | [0, 0.1] |
|                              |         | Severe disorders             | [0.1, 0.2] |
|                              |         | Moderate disorders           | [0.2, 0.3] |
|                              |         | Mild disorder                | [0.3, 0.4] |
| Stage of transition          | $D \in [0.4, 0.6]$ | On the verge of disorder     | [0.4, 0.5] |
|                              |         | Barely coordination          | [0.5, 0.6] |
|                              |         | Primary coordination         | [0.6, 0.7] |
| Stage of coordinated development | $D \in [0.6, 1]$ | Intermediate coordinate      | [0.7, 0.8] |
|                              |         | Good coordination            | [0.8, 0.9] |
|                              |         | Perfect coordination         | [0.9, 1] |

3. Empirical Study

In December 2014, the Ministry of Transport in China issued “The Opinions on Comprehensively Deepening the Reform of Transport”, which clearly pointed out that it was necessary to “straighten out the port management system, promote the integration of port resources, and promote the intensive and integrated development of regional ports”. In May 2016, the Ministry of Transport issued “The 13th Five-Year Development Plan for Water Transport”, which clearly pointed out to promote the integration of port resources so as to reduce resource waste and vicious competition among ports. In August 2017, the Ministry of Transport issued “About Learning from Experience of Zhejiang Notice to promote further the Reform of Regional Port Integration”, which pointed out that promoting the regional port integration is an important measure to solve the excess capacity and to build the international first-class ports. After the release of a series of important documents, coastal provinces in China began to actively promote the integration of port resources within the provincial area, and many achievements have been achieved so far.

Up to now, the port integration patterns adopted can be roughly divided into three types: the government-dominated pattern, the market-oriented pattern, and the government-dominated plus market-assisted pattern [27]. The difference among these three integration patterns can be explained as follows. The government-dominated pattern is mainly applied to integrate the port management departments of various cities into a cross-administrative port management department. However, the market-oriented pattern mainly relies on the measures such as merger, reorganization, and joint operation to realize the port integration. The government-dominated plus market-assisted pattern is relatively complicated, which integrates the port resources by restructuring the assets of port enterprises through market-oriented means under the dominance from the government.

In order to implement the empirical study, three representative provinces which have completed the port integration were selected, including Guangxi Province, Liaoning Province, and Zhejiang Province. Among them, Guangxi Province adopted the government-dominated pattern of port integration and integrated three ports in the provincial area (i.e., the Fangcheng Port, the Qinzhou Port, and the Beihai Port) as the Beibu Gulf Port Group. Liaoning Province introduced China Merchants Group during the integration process and established Liaoning Port Group based on the market-oriented pattern. Zhejiang Province followed the government-dominated plus market-assisted pattern in the process of port integration by adopting several relatively complicated measures. It first set up the provincial Ocean Port Development Committee as an institution which directly leads the integration and is responsible for the development of ports within the provincial area, and then abolished the former Ningbo Port Group and Zhoushan Port Group and established the Ningbo-Zhoushan Port Group through equity equivalent transfer. Later, based on the Ningbo-Zhoushan Port
Group, Zhejiang Port Group was established, which realized the integration of coastal ports in Zhejiang province.

According to the evaluation indicator system shown in Table 1, the data related with the port cluster and its hinterland economic system of three empirical provinces from 2004 to 2020 were collected. The data come from the Chinese Port Yearbook and Statistical Yearbook of the three provinces.

Based on the improved coupling coordination model established, the coupling coordination degree between the port cluster and its hinterland economic system for the three typical provinces was calculated, and the calculation results are shown in Figure 2.

3.1. Coupling Coordination Degree of the Two Subsystems for Guangxi Province

As can be seen from Figure 2a, the coupling coordination degree of the port cluster and its hinterland economic system in Guangxi province has been continuously rising since 2004, especially after the outbreak of the international financial crisis. In contrast to the other two provinces, the coupling coordination degree of the whole system in Guangxi Province has been increasing instead of decreasing. In 2009 Guangxi Port Cluster adopted the government-dominated pattern to carry out the port integration. Since then both the subsystem of port cluster and the subsystem of hinterland economy have been well developed, and the coupling coordination relationship of the whole system has also entered the stage of transition from the stage of disorder. Moreover, since the port integration enables Guangxi port cluster to better make use of port resources and to avoid the vicious competition among ports within the port cluster, the coupling coordination degree of the whole system still maintains a good growth trend after the domestic economy has entered the new normal, and in 2017 the whole system entered the stage of coordinated development.

3.2. Coupling Coordination Degree of the Two Subsystems for Zhejiang Province

In contrast to the trend of the coupling coordination degree of Guangxi Province, the coupling coordination degree of the whole system in Zhejiang Province started from a high point, but experienced two declines from 2004 to 2020. The first decline occurred during the international financial crisis. As the port cluster and the hinterland economy of Zhejiang Province were highly dependent on foreign trade, the huge impact of the international financial crisis on the import and export trade led to a significant decline in the coupling coordination degree of the whole system from 2008 to 2009, and the whole system stepped back to the stage of disorder from the stage of transition. The second decline occurred in the new normal economic period, due to the reduced contribution of the port cluster subsystem at the early period of the integration, together with the mild economic growth. However, the “Painful Period” of port integration did not last too long since the port cluster in Zhejiang Province enjoys a relatively high development level, and in 2018 the whole system entered the stage of coordinated development.

3.3. Coupling Coordination Degree of the Two Subsystems for Liaoning Province

The original development level of the port cluster and its hinterland economic system in Liaoning province is higher than that in Guangxi Province but slightly lower than that in Zhejiang Province. However, due to the fierce port competition in Liaoning province and the relatively late integration, the coupling coordination degree of the whole system has declined for two long periods and was still in the stage of transition in 2018. The two declines in the coupling coordination degree of the whole system occurred respectively in the period of international financial crisis and the period of new economic normal. However, in contrast to the situation in Zhejiang Province, Liaoning Province introduced China Merchants Group in 2017 and adopted the market-oriented pattern for port integration. On one hand, this pattern improved the situation of overcapacity; on the other hand, through the introduction of the external market, it has added new vitality to the port shipping market in Liaoning Province. Therefore, the contribution of the port cluster subsystem has not decreased, and the “Painful Period” brought by the port integration has passed smoothly.
In order to implement the empirical study, three representative provinces which have completed the port integration were selected, including Guangxi Province, Liaoning Province, and Zhejiang Province. Among them, Guangxi Province adopted the government-dominated pattern of port integration and integrated three ports in the provincial area (i.e., the Fangcheng Port, the Qinzhou Port, and the Beihai Port) as the Beibu Gulf Port Group. Liaoning Province introduced China Merchants Group during the integration process and established Liaoning Port Group based on the market-oriented pattern. Zhejiang Province followed the government-dominated plus market-assisted pattern in the process of port integration by adopting several relatively complicated measures. It first set up the provincial Ocean Port Development Committee as an institution which directly leads the integration and is responsible for the development of ports within the provincial area, and then abolished the former Ningbo Port Group and Zhoushan Port Group and established the Ningbo-Zhoushan Port Group through equity equivalent transfer. Later, based on the Ningbo-Zhoushan Port Group, Zhejiang Port Group was established, which realized the integration of coastal ports in Zhejiang province.

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Based on the improved coupling coordination model established, the coupling coordination degree between the port cluster and its hinterland economic system for the three typical provinces was calculated, and the calculation results are shown in Figure 2.

**Figure 2.** Coupling coordination degree of port cluster and its hinterland economic system in three provinces.

(a) Results of economic coupling and coordination between port cluster and hinterland in Guangxi Province

(b) Results of economic coupling and coordination between port cluster and hinterland in Zhejiang Province

(c) Results of economic coupling and coordination between port cluster and hinterland in Liaoning Province

(d) Comparison of economic coupling and coordination results between port cluster and hinterland in three provinces.

Figure 2. Coupling coordination degree of port cluster and its hinterland economic system in three provinces.
4. Discussion

It can be seen from the results of the three provinces that, although the port integration may lead to a decline in the coupling coordination degree of the system in the short term, in the long run, the port integration will lead to a coordinated development of higher quality for the whole system. For example, the coupling coordination degree of the whole system in Guangxi Province increased greatly after the port integration. The whole system of Zhejiang Province ended the transitional period lasting more than ten years and entered the stage of coordinated development since the port integration. For Liaoning Province, the coupling coordination degree of the whole system ended the downward trend after the port integration.

The reasons for the positive impact of port integration on the coupling coordination relationship of port cluster and its hinterland economic system can be explained as follows. Firstly, after the port integration, the internal resources of the port cluster subsystem would be more effectively utilized, the vicious competition would be reduced, and the competitiveness of the whole port cluster would thus be enhanced when competing with other port clusters. Secondly, after the port integration, the ports in the same cluster would develop differently according to the types of cargoes in the hinterland, and thus the scope of the hinterland would be expanded in terms of advantageous types of cargoes, and the development of the local economy would thus be promoted. Thirdly, due to the direct economic growth in the hinterland, the local investment in the port distribution system would increase. Since the improvement of the port distribution system would increase the port service quality, then the competitiveness of the port cluster has been further enhanced. Therefore, a virtuous circle of coordinated development would have been formed between the port cluster and the hinterland economic system.

Although in the long term the port integration would make the port cluster and its hinterland economic system obtain a higher quality of coordinated development relationship, in the short term the impact of port integration on the port cluster and its hinterland economic system of the three provinces has some differences. Firstly, with the difference in the purposes of port integration, the effects on the coupling coordination degree of the whole system in the initial stage of integration would be different. For example, the purpose of port integration in Guangxi Province is to expand the production capacity to meet the growing demand. The contribution of the port cluster subsystem has increased significantly after integration, and the hinterland economic subsystem is also in a period of high-speed growth. Therefore, after port integration, the coupling coordination degree of port cluster and its hinterland economic system in Guangxi Province has increased by leaps and bounds. Comparatively, the purpose of port integration in Zhejiang Province is to curb the disorderly expansion of ports and resolve the overcapacity problem. Therefore, the contribution of port cluster subsystem in Zhejiang Province decreased after the integration, and thus the coupling coordination degree between port cluster and its hinterland economic system in Zhejiang Province has decreased. Secondly, with the difference in the patterns of port integration, the effects on the coupling coordination degree of the whole system in the early stage of integration would also differs. For example, the integration in Liaoning Province dominated by the external market has not seen the same decline in the coupling coordination degree as Zhejiang Province, because the introduction of the external market can not only stimulate the vitality of the port shipping market, but also bring new economic growth to the hinterland.

The coupling coordination degree model proposed in this paper can comprehensively consider the coordinated development level between the port cluster system and the hinterland economic system under the background of port integration, and overcome the problem that previous studies only measured the coordinated development level of a single port and its hinterland economic system. The direction of further research in the future would focus on comparing the impact of port integration strategy in a province on the coordinated development level of port cluster and hinterland economic system in surrounding provinces that do not implement the strategy.
5. Conclusions

The port integration at the provincial level is a “major event” that has occurred frequently in China’s coastal and inland provinces in recent years. In order to quantify the actual effect of port integration, this paper conducted research from the perspective of the relationship between port cluster and hinterland economic system. The evaluation system of the coordinated development relationship of port cluster and its hinterland economy was constructed, and the improved coupling coordination model was established. Three representative provinces with different integration patterns were selected in the empirical study, and based on the panel data from 2004 to 2020, the coordinated development relationship between port cluster and its hinterland economic system under different integration patterns was analyzed continuously and dynamically.

The results indicate that, in the short term, the port integration may lead to a “Painful Period” in the coordinated development relationship of the whole system, especially in the early stage of integration, which may lead to a temporary decline in the coupling coordination degree of the whole system. Moreover, the results also reveal that the different integration purposes and integration patterns will have a differential impact on the change of the coupling coordination degree of the whole system in the early stage of integration, but in the long term, the port integration can effectively improve the coupling coordination degree of port cluster and its hinterland economic system, and make the whole system obtain a higher quality coordinated development state. The results shed light on the phenomenon that the coordinated relationship between the integrated port cluster and its hinterland economic system would undergo a short period of deterioration and instability, which has practical relevance for the port cluster beginning to implement the port integration. Additionally, the results also have implications in terms of the choice of integration patterns for the port clusters which have not yet or only just begun to experience integration, but hesitate over the relationship with its hinterland economy. Moreover, the method proposed in this paper contributes to providing a new quantitative analysis tool for evaluating the effect of port integration.

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