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Competition between Export Cities in China: Evolution and Influencing Factors

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Abstract: Based on the Export Similarity Index (ESI), this study examines the export competition pattern among Chinese cities in the global market from 2000 to 2017, analyzing the mechanism of competition using a panel Granger causality test and a gravity model. The study reports several findings, as follows: (1) The competition pattern among Chinese cities first increased and then decreased, and the ESI between most cities was low. (2) More provincial capitals in the central and western regions converged with the developed eastern regions in their export structures, and cities in the regions of Beijing-Tianjin-Hebei, Yangtze River Delta, and Pearl River Delta competed differently. (3) Using all cities in the sample, the results show a bidirectional causal relationship between a city's Gross Domestic Product (GDP) and the average export competitive pressure from other cities. However, results for the provincial capitals and three urban agglomerations indicated that GDP intensifies competition among cities. (4) The gravity model's regression results show that the larger the economic size and the smaller the distance between cities, the more obvious the competition between them. This study provides a new direction for the study of export trade from the perspective of urban scale.

Keywords: export trade; Export Similarity Index; network analysis; panel Granger causality test; gravity model

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1. Introduction

Export trade is an important driving force behind urban development in China [1]. Chinese cities at different stages of development and on different bases of development vary in the types and quality of goods they export to other countries, while also competing with each other [2]. For example, radio equipment made up 15.22% and 14.41% of the goods exported by Shenzhen and Dongguan, respectively, in 2017. Shenzhen and Dongguan are located in close proximity, and both have developed economies in the Pearl River Delta (PRD). As in their case, similar export structures often lead to fierce competition between cities.

In China, a country experiencing rapid urbanization and industrialization [3,4], the competition between export cities is also complex and changing. Analyzing this kind of competitive relationship will provide a scientific basis for the government to produce development plans and industrial layouts. In fact, under the tide of informatization and globalization, cities gradually became the "rational economic man" in a geographical space. To compete with other cities in the world trade market is a challenge that must be faced in the process of urban development. The analysis of this evolution process and the internal mechanisms of this competitive relationship will also help cities consider their own economic and geographic environments more scientifically when constructing export strategies.

So, what is the competitive pattern of export trade among Chinese cities? In some typical urban agglomeration areas, what are the characteristics of this competition? What are the underlying causes of this competitive pattern? We will focus on exploring these issues. The paper is structured as follows: Section 1.1 presents a critical review of the literature on competition between export countries and identifies the lack of research on export competition at the city level and the lack of a network analysis perspective. Section 1.2 describes the hypothesis and framework. Section 2 presents the methodology, data, and study area. Section 3 reports and discusses the results of the analysis, and Section 4 discusses the conclusions and the implications of the study findings.

1.1. Literature Review: Competition between Export Countries

Existing research on the competition between different regions in trade markets mainly focuses on countries. Some studies focus on European countries, especially on export competition among countries within the European Union [5,6]. There are also studies focusing on export competition between EU countries and other regions [7–9]. From the perspective of structural change, they discuss the development history of EU trade before and after the eastern expansion of the EU.

When scholars discuss export trade competition among European countries, they seldom analyze the economic and geographical factors that produce the competition relationship—in particular, whether factors such as economic size and stage of development affect the competitive pressure a country faces in the global market. However, the analysis of this problem has been well addressed in other research regions: some scholars have seriously and rigorously analyzed the dynamic mechanism of China's export trade competition with other countries. Both Dean et al. and Schott's analyses of the internal causes of the export competition between China and other countries show that the larger China's economic aggregate is, the more intense the trade competition between China and other countries will be [10,11]. In addition, the improvement in human capital and the government policies in the form of tax-favored high-tech zones also explain China's export structure evolution [12].

In fact, the export trade competition between China and other countries (regions) has become a popular topic in academic circles in the past decade. Studies have identified different competition relations between China and Latin American countries [13], China and OECD countries [14,15], and China and ASEAN countries [16] in different years. Most of these studies agree that China's rapid trade growth brought some challenges and pressures to other countries. These studies also reflect China's increasingly sophisticated export structure, which is closer to that of the developed world, as China's economy grows.

In the literature on the export trade competition among the countries mentioned above, Finger's Export Similarity Index (ESI) is a key index used to calculate the size of the competitive relationship between two countries [17]. The ESI can indicate the degree of convergence of the commodities of two regions in a certain market. The higher the ESI, the more intense the competitive relationship.

Extant studies on the competitive relationship of export trade using ESI mostly focus on relationships between countries, with little discussion of the competitive export trade relationship between cities. Additionally, competition is a kind of relationship, and relationships can "connect" different regions. These interlinked relationships will form a network. However, the existing research on competitive relationships of export trade rarely uses network analysis. Only a few studies used network analysis when analyzing the export competition between countries [18,19]. Taking Chinese cities as its research object, this paper discusses the evolution and mechanism of the competition between cities in the global export market from 2000 to 2017. By doing so, this paper not only expands the study of export competition relations at a city scale, but also makes a comparative analysis of the competition relations among cities in different urban agglomerations in China, with certain policy implications for the cities' foreign economic development.

1.2. Hypothesis and Framework: Competition between Export Cities

Based on the above discussion, we propose that there is a competitive relationship between Chinese cities in export trade and, furthermore, that this competitive relationship is different in different regions. To verify these hypotheses and further analyze the internal mechanism behind the competitive relationship, we adopt the following research framework (see Figure 1):

1. The ESI is used to represent the export competition between cities, and the evolution of the ESIs from all cities and regions is analyzed to form an overall understanding of the competitive relationships among cities.
2. The panel Granger causality test model is used to analyze the relationship between export competitive relationships and Gross Domestic Product (GDP).
3. The relationship between export competitive relationships and geographical distance is explored through scatter plot fitting.
4. The mechanism of the evolution of export competitive relationships between cities is explored by using the nonlinear least square (NLS) method, based on the gravity model.

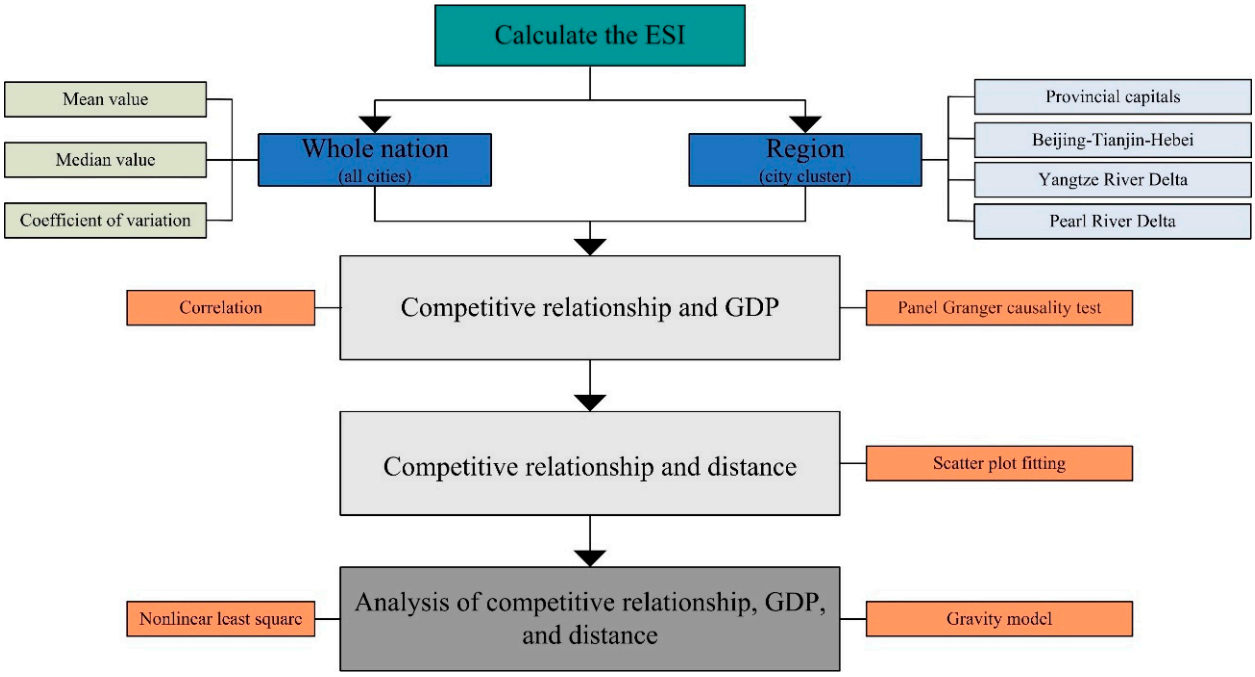


Figure 1. The research framework.

2. Materials and Methods

2.1. Methodology

2.1.1. ESI and Average Export Similarity Index (AESI)

Many scholars, especially those who focus on economic geography, adopted the ESI to reflect the similarity in exports between regions in studies related to international trade, industrial economies, and other multidisciplinary fields [17,20,21]. The formula is as follows:

$$ESI_{ijk} = 100 \times \sum_{l} \min\left(\frac{\exp^{l}{}_{ik}}{\exp_{ik}}, \frac{\exp^{l}{}_{jk}}{\exp_{jk}}\right), \quad (1)$$

where ESI_{ijk} is the similarity between city i and city j regarding the exports in market k, $\frac{\exp^{l}{}_{ik}}{\exp_{ik}}$ represents the ratio of the commodity l exported by city i to market k to the total exports of city i to market k, and $\frac{\exp^{l}{}_{jk}}{\exp_{jk}}$ represents the ratio of the commodity l exported by

city j to market k to the total exports of city j to market k. The value of ESI_{ijk} is between 0 and 100, and the closer it is to 100, the more similar the export products of city i and city j in market k are. In short, the higher ESI_{ijk} is, the more intense the export competition between city i and city j is; the lower ESI_{ijk} is, the less intense the export competition between city i and city j is. In this article, market k is the global market.

The ESI represents the relationship between two cities. To investigate the overall competition between each city with other cities in the global market, we introduce a new indicator, the AESI, which we calculate as:

$$AESI_i = \frac{\sum_j ESI_{ijk}}{269}. \tag{2}$$

This study's research object is 270 cities. Each city will have one ESI with every other city, which means each city will have 269 ESIs. The higher the $AESI_i$, the greater the competitive pressure city i faces from other cities in the global market.

2.1.2. Panel Unit Root Tests

Previous studies used panel unit root tests over normal time series unit root tests as they have superior power [22]. Based on previous studies [23–25], we adopted the Levin-Lin-Chu (LLC) test created by Levin et al. using Stata/MP 16.0 [26]. The formula is:

$$\Delta y_{i,t} = \delta y_{i,t-1} + q'_{i,t}\phi_i + \sum_{v=1}^{V} \varpi_{iv} y_{i,t-v} + \varepsilon_{i,t}, \tag{3}$$

where $y_{i,t}$ is the panel data, $i = 1, 2, \ldots, n$ is a unit of the cross-section, $t = 1, 2, \ldots, T$ is time, δ is the common autoregression coefficient, $q'_{i,t}\phi_i$ is the panel-specific mean, ϖ_{iv} is the coefficient, $v = 1, 2, \ldots, V$ is the lag order, and $\varepsilon_{i,t}$ is the error term.

2.1.3. Panel Cointegration Tests

While many panel cointegration techniques exist, such as those by Kao [27] and Pedroni [28], we utilized Westerlund's cointegration method to test the cointegrating relationships between the variables [29]. The formula is

$$\Delta y_{i,t} = \eta_i \prime d_t + \varpi_i (y_{i,t-1} - \zeta_i \prime x_{i,t-1}) + \sum_{v=1}^{V} \varpi_{iv} \Delta y_{i,t-v} + \sum_{v=0}^{V} \tau_{iv} \Delta x_{i,t-v} + \varepsilon_{i,t}, \tag{4}$$

where η'_i represents the trend effects, d_t represents the deterministic components, and ϖ_i is the error correction parameter. The remaining parameters have the same meanings as in Formula (3).

2.1.4. Panel Granger Causality Test

As an important means of causal analysis used by scholars in the field of econometrics, the Granger causality test is widely used in the study of many aspects of human and economic geography, such as urbanization [30] and international trade [31]. This model was first proposed by Granger [32]. Subsequently, Dumitrescu and Hurlin proposed a test based on panel data, which further promoted the application of this model in the field of econometrics [33]. Compared with the simple causal analysis of a time series, the panel Granger causality test provides an important method for researchers to examine the inherent nature of data in multiple dimensions. The formula is

$$y_{i,t} = \alpha_i + \sum_{v=1}^{V} \gamma_{iv} y_{i,t-v} + \sum_{v=1}^{V} \beta_{iv} x_{i,t-v} + \varepsilon_{i,t}, \tag{5}$$

where $x_{i,t}$ and $y_{i,t}$ are the independent and dependent variables, respectively, at the observation point i, t, V is the lag order, γ_{iv} and β_{iv} are coefficients, and $\varepsilon_{i,t}$ is the error term.

The panel Granger causality test assumes that the past value of x does not help predict the future value of y as the null hypothesis (H_0). If the result is the rejection of H_0, then x is said to be the Granger cause of y.

In the panel Granger causality analysis, the choice of the lag order is key. Thanks to the development of measurement methods on Stata/MP 16.0, we were able to determine the optimal lag order under three different criteria (Akaike's Information Criterion—AIC [34], Bayesian Information Criterion—BIC [35], and Hannan and Quinn's Information Criterion—HQIC [36]) by using the *xtgcause* command.

2.1.5. Gravity Model

As the core theory of classical physics, gravity models were gradually introduced to many disciplines including economics [37], transport geography [38], economic geography [39], and urban and regional planning [40–42] by humanities and social sciences scholars. The formula is

$$Q_{ij} = \theta \frac{s_i s_j}{d_{ij}^{\sigma}}, \quad (6)$$

where Q_{ij} is the strength of connection between regions i and j, which can be traffic flow, population flow, trade flow, and so on. In addition, Q_{ij} can represent relationships. s_i and s_j are the "qualities" of regions i and j, such as their GDP, GNP, and population. d_{ij} is the geographical distance between regions i and j, and θ and σ are parameters.

2.2. Data and Study Area

2.2.1. Data

The data (2000–2017) in this study were taken from two sources:

1. The export data of each city came from the customs database of China (service trade data are not included). According to the enterprise codes, the export situation of enterprises in the same cities were summarized and used as the original export data of those cities. In addition, the customs database includes a large span of data collection years, resulting in multiple versions (HS1996, HS2002, HS2007, HS2012, and HS2017). Although the differences between the versions are not significant from a macro viewpoint, each version has a certain degree of fine-tuning compared with its previous version, so they need to be recoded systematically. According to the comparison table of the commodity codes issued by the United Nations Trade Database (https://unstats.un.org/unsd/trade/classifications/correspondence-tables.asp (accessed on 1 June 2021)), we uniformly adjusted the 8-digit commodity codes of every year of the customs data to the HS1996 version with 6-digit codes, so that the export similarity between the different years could be comparatively measured. However, because of the large amount of data in the customs database, there were extremely large calculation tasks when determining the ESI between different cities in different years. Therefore, we used PyCharm to calculate the ESIs programmatically.
2. In addition to the data processing of the customs database, the GDP for each city in this study was taken from the cities' statistical yearbooks and the provincial statistical yearbooks. Data that were difficult to obtain for some regions and years were based on the National Economic and Social Development Statistical Bulletin and local yearbooks.

2.2.2. Study Area

After synthesizing the availability of all data, we selected 270 cities as the analysis objects (see Figure 2a). To analyze the export competition situation of all cities in the global market, it is necessary to consider the overall situation at a macro-scale as well as to analyze local aspects to explore the temporal and spatial evolution characteristics of the export similarities between cities in different regions. Therefore, we focus on the analysis of provincial capitals and China's three coastal urban agglomerations (see Figure 2b,c). The provincial capitals are the economic centers of the provinces, with high levels of

industrialization and strong export capacity. Beijing–Tianjin–Hebei (BTH), Yangtze River Delta (YRD), and PRD play a crucial role in China's export trade as the three most mature and economically active urban agglomerations in China.[1] In 2017, the export volume of these three urban agglomerations reached USD 1,598 billion, accounting for 70.60% of China's total export volume.

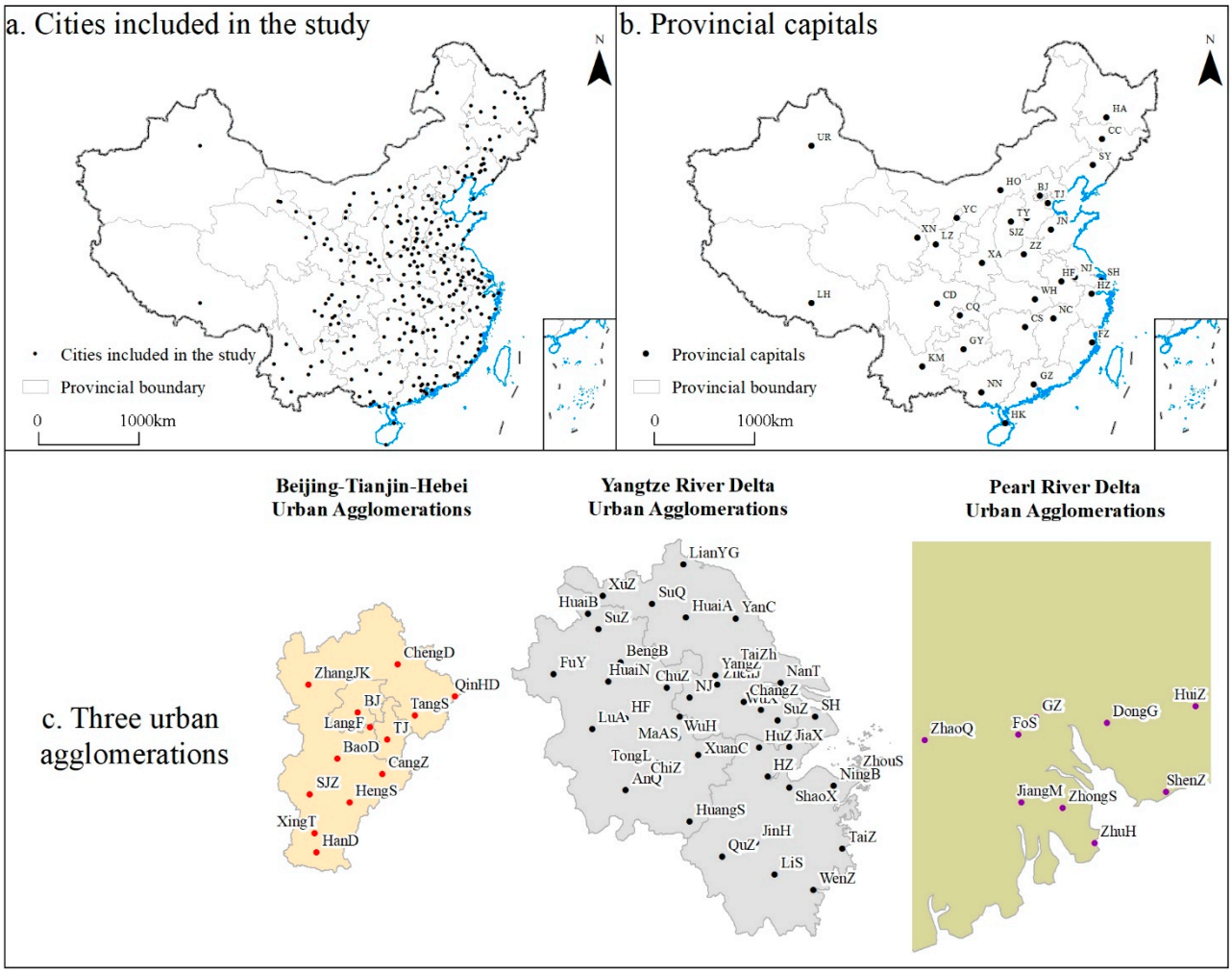


Figure 2. The study area.

3. Results and Discussion

3.1. Spatiotemporal Evolution of the ESI

3.1.1. Overall Analysis

Figure 3 shows that from the evolution characteristics of the mean and median[2] of the ESIs between all cities, there are roughly three time periods, as follows:

1. From 2000 to 2011, the similarities among Chinese cities' exports in the global market is relatively low. The mean values are always below six and the median also fluctuates at a low level. Especially between 2000 and 2008, these two indicators are in the low ranges of three to five and one to three, respectively.
2. From 2011 to 2014, the similarity of exports between cities in the global market increases significantly. Compared with 2011, the mean and median in 2014 increased by 82.94% and 112.65%, respectively, indicating that during this period, the competition between different cities increased significantly and the complementarity weakened.

3. From 2014 to 2017, the similarity of exports between cities in the global market declined. In 2017, the mean and median ESIs were 7.90 and 5.22, respectively, which are 22.47% and 24.24% lower than the 2014 peak.

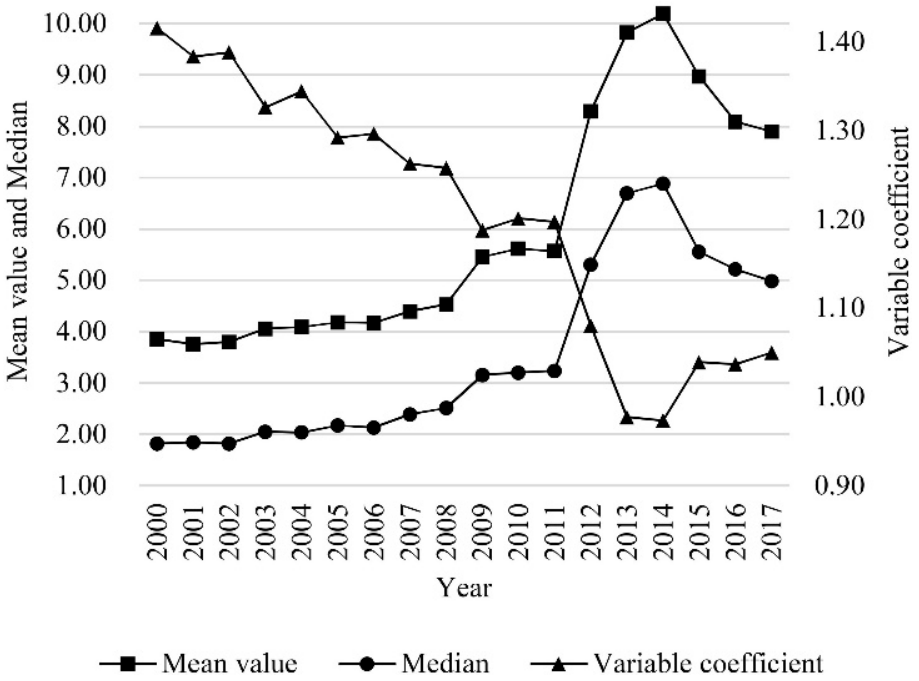


Figure 3. The mean, median, and variable coefficient of the ESIs between each pair of cities from 2000 to 2017.

ESI showed significant growth from 2011 to 2014 because some cities showed significant growth in export volume during this period. For example, in 2011–2012, the export trade of Changzhi, Bijie, and other cities showed significant growth, and the increase in the number of export commodities caused competition between these cities and other cities to become fiercer. In 2012, the exports of Changzhi increased by 1722.33% compared with that of 2011[3], while the exports of Bijie in 2012 increased by 1651.48% compared with 2011[4]. Similarly, the decline between 2014 and 2017 was due to a significant decline in exports in some cities. For example, the export volume of Jinchang and Yinchuan decreased by 79%[5] and 29.42%[6], respectively, from 2014 to 2015. The sharp drop in exports means that the variety and quantity of goods will shrink, and competition with other cities will ease. The changes in ESI reflect that China's urban export trade has experienced a period of adjustment. When some cities expand exports and participate in market competition, they fail to produce sustained economic benefits, so they reduce export scale, withdraw from competition, and choose a more suitable development model for themselves.

However, the coefficient of variation remains above one in most years, except 2013 and 2014, which also reflects the huge difference in the ESIs between cities. China's hundreds of cities vary widely from one another in resource endowments and geographical advantages as well as in export structures. There are "city pairs" with similar export structures and fierce competition, and there are "city pairs" with different export structures and gentle competition.

3.1.2. Regional Analysis

Evolution of the ESI Network Structure among the Provincial Capitals

Figure 4 shows the ESI network between the provincial capitals in 2000, 2005, 2011, and 2017. The edge connecting the nodes is the ESI between two cities. Over time, the ESIs between the provincial capitals generally rose. Specifically, the average ESIs among

the provincial capitals in 2000 was 14.54, and in 2005, 2011, and 2017, the values were 13.44, 15.49, and 16.65, respectively. This change shows that the level of competition among the export products of the provincial capitals in the global market increased and their complementarity weakened during this period.

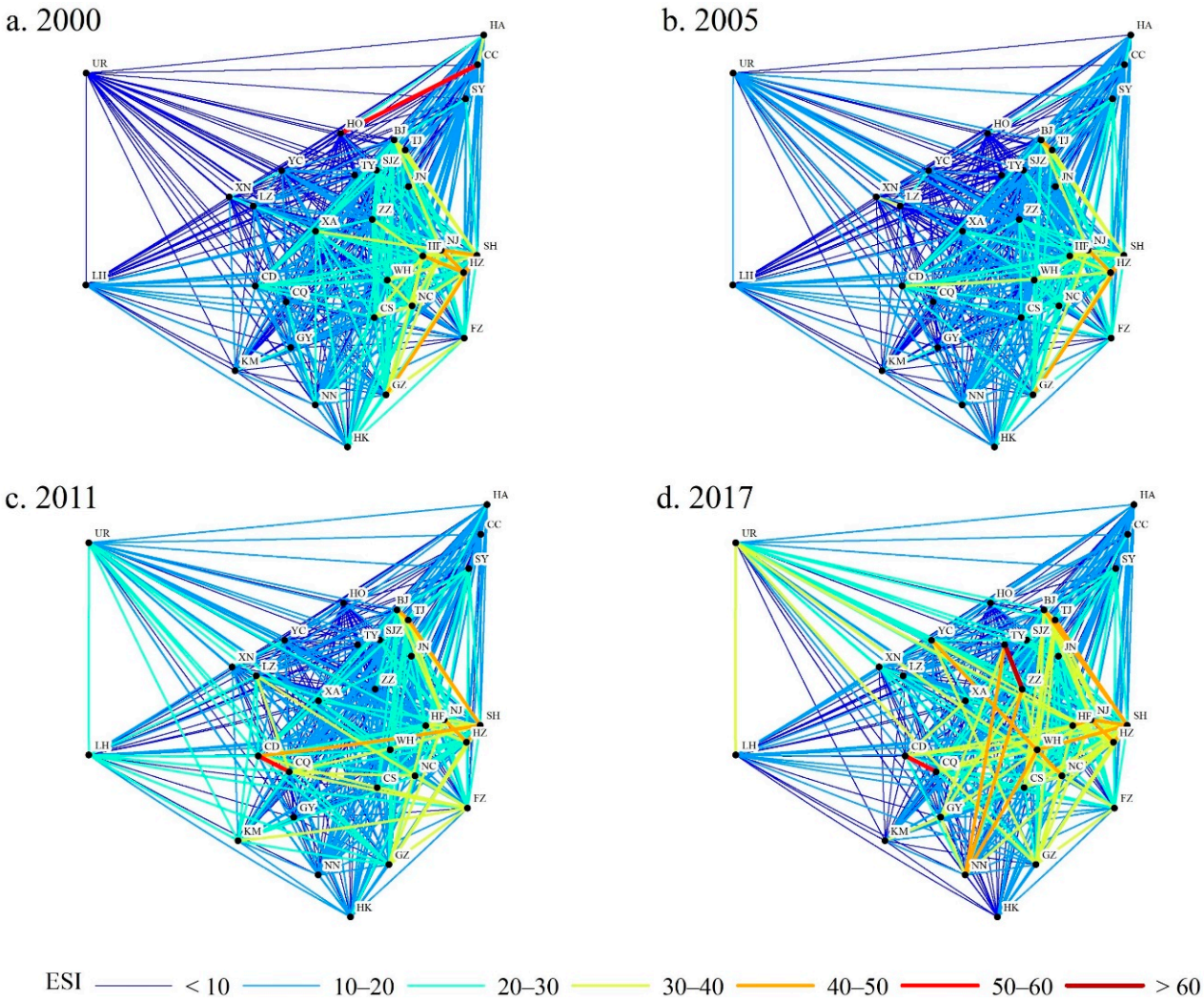


Figure 4. The ESI network between provincial capitals in 2000, 2005, 2011, and 2017.

From a spatial perspective, we see high ESIs between provincial capitals in the southeast coastal area from an early date, gradually spreading to the central and western regions. For example, the ESI of Chengdu (Western China) and Shanghai (Eastern China) was 21.17 in 2000 and increased to 33.36 in 2017. Figure 4 shows that the bright yellow high-value areas were still concentrated in the eastern region in 2000. However, by 2017, the high-value connections had expanded to the mid-west.

The ESI Network Structure Evolution among the BTH, YRD, and PRD

The urban agglomerations have certain differences. We found that the changes between cities in the PRD was not obvious from 2000 to 2017. In 2017, the average ESI among nine cities in the PRD was 36.90, a decrease of 1.91% when compared with 2000. Conversely, the average ESI among cities in the YRD increased by 78.17% between 2000 and 2017; the average ESI among cities in the BTH increased by 49.94% between 2000 and 2017. Therefore, the export competitive relationship of cities in the YRD and BTH significantly increased when compared with the PRD.

Moreover, a comparison of the three urban agglomerations shows that the cities in the PRD had the most prominent competitive relationship in the global market. Taking Dongguan and Shenzhen as examples, their ESI in 2000 was 63.14, while the average ESI of all cities in that year was only 3.86 (see Figure 3). In contrast, the competition between cities in the BTH is not obvious. Most city-pairs in the BTH have ESIs below 20 (see Figure 5). Because of the large number of city-pairs in YRD, there are many high (orange and red lines) and many low (blue lines) ESI values (see Figure 5).

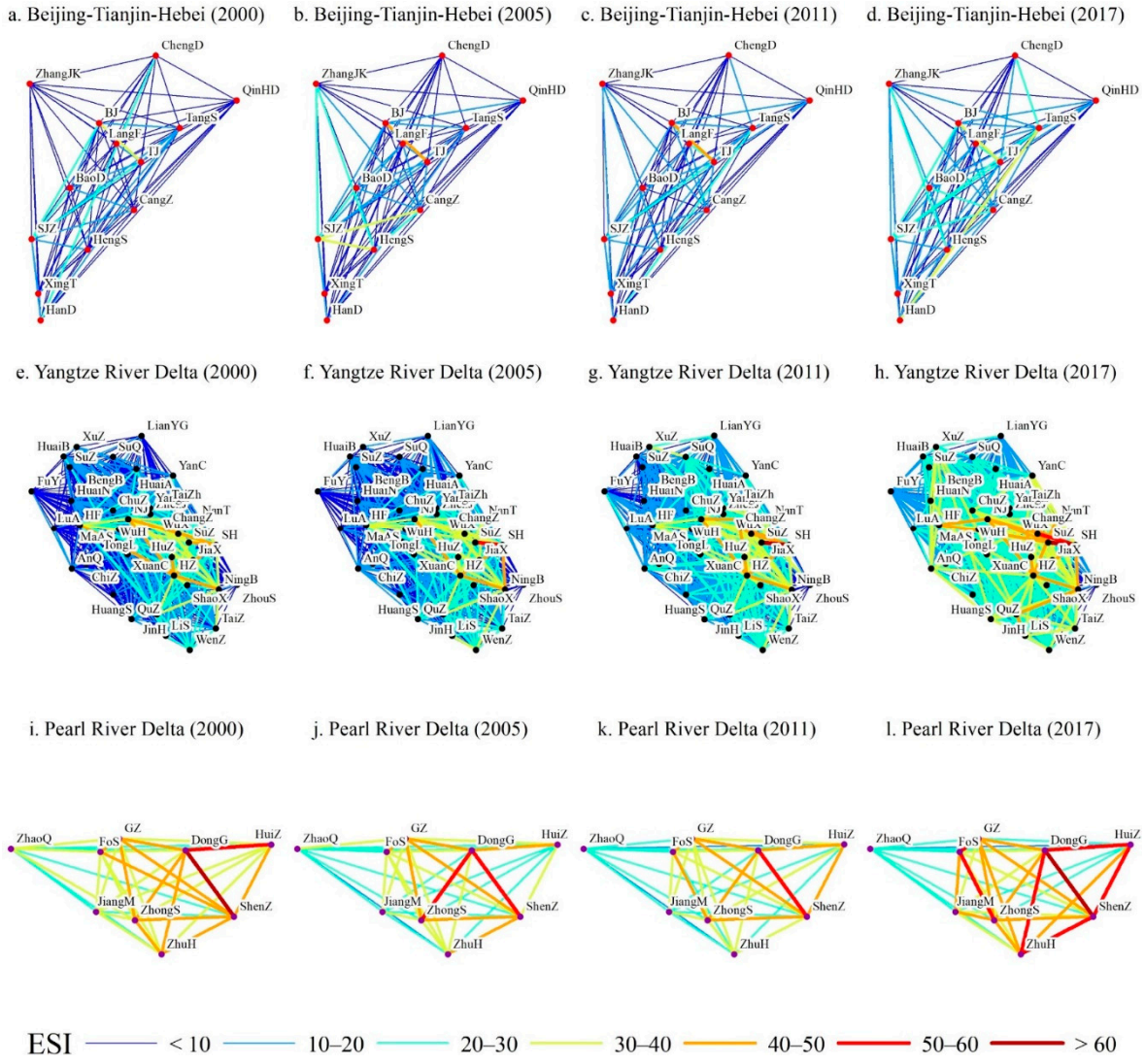


Figure 5. The ESI network of the three urban agglomerations. (Each dot represents a city. The redder and wider the line between cities, the fiercer the export competition between the two cities.)

3.2. The Relationship between AESI and GDP

Although previous studies on export competition between countries found that the competition relationship would strengthen with the growth of economic aggregate [10,11], they did not confirm whether there is a relationship between urban economic aggregate (represented by GDP) and the export competition pressure cities face.

3.2.1. Correlation between AESI and GDP

We analyzed the correlation between the GDP and AESI of each city from 2000 to 2017 to obtain the correlation coefficient (*cc*) of each city. We arranged the *cc*s in ascending order to form a scatter plot and draw a bit-order fitting curve (see Figure 6). For most cities, the

correlation between the GDP and AESI is strong (*cc* accounts for a high proportion of over 0.5). Interestingly, more economically developed cities have a higher *cc*. For example, there are 11 cities with *cc*s above 0.95; among which, seven are developed cities in China's east coast areas.

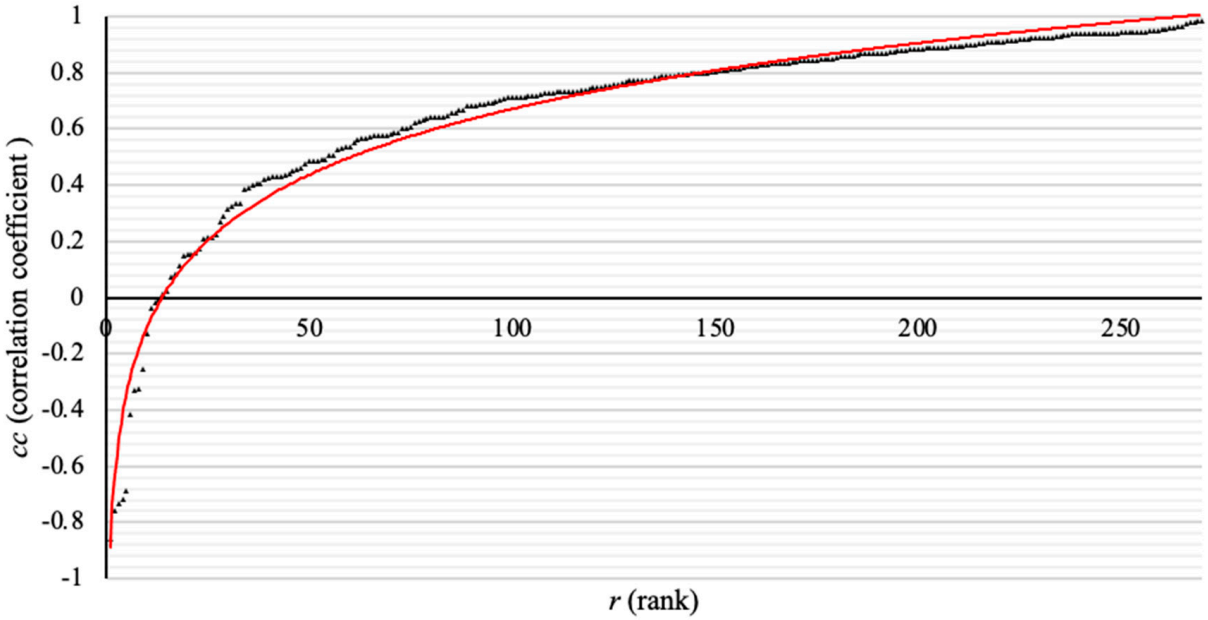


Figure 6. The correlation coefficient of the AESI and GDP on the fitting curve in ascending order.

3.2.2. Causal Analysis of AESI and GDP

The existence of a correlation between these two indicators only points to the fact that the average competitive pressure that a city faces from other cities is related to its GDP. However, whether there is a causal relationship between the two variables needs further analysis. The panel Granger causality test provides a good method to address this issue.

All Cities

The panel unit root test results show that the AESI and GDP passed the unit root test after the first difference. However, they did not pass the panel cointegration test. Therefore, a second difference was performed. Subsequently, they passed the cointegration test after passing the unit root test. Therefore, the panel Granger causality test could be performed. Table 1 shows that the GDP and AESI demonstrate a two-way causal relationship for all cities.

Table 1. The results of panel Granger causality test for all cities, provincial capitals, and three urban agglomerations.

Region	Criterion	Statistics	Optimal Lag Length	H_A: GDP Is not the Granger Cause of AESI	Optimal Lag Length	H_B: AESI Is Not the Granger Cause of GDP
all cities	AIC	W-bar	3	13.3684	3	6.5296
		Z-bar		69.5531 ***		23.6775 ***
		Z-bar Tilde		21.1994 ***		4.8518 ***
	BIC	W-bar	3	13.3684	1	1.56622
		Z-bar		69.5531 ***		6.5323 ***
		Z-bar Tilde		21.1994 ***		2.9908 ***
	HQIC	W-bar	3	13.3684	3	6.5296
		Z-bar		69.5531 ***		23.6775 ***
		Z-bar Tilde		21.1994 ***		4.8518 ***
provincial capitals	AIC	W-bar	3	10.0982	3	6.4667
		Z-bar		16.1344 ***		7.8799 ***
		Z-bar Tilde		5.8643 ***		2.2536 **
	BIC	W-bar	3	10.0982	1	1.3879
		Z-bar		16.1344 ***		1.5272
		Z-bar Tilde		5.8643 ***		0.5946
	HQIC	W-bar	3	10.0982	3	6.4667
		Z-bar		16.1344 ***		7.8799 ***
		Z-bar Tilde		5.8643 ***		2.2536 **
BTH	AIC	W-bar	3	6.2438	3	3.3452
		Z-bar		4.7747 ***		0.5081
		Z-bar Tilde		0.9147		−0.6057
	BIC	W-bar	3	6.2438	1	1.1876
		Z-bar		4.7747 ***		0.4783
		Z-bar Tilde		0.9147		−0.0225
	HQIC	W-bar	3	6.2438	3	3.3452
		Z-bar		4.7747 ***		0.5081
		Z-bar Tilde		0.9147		−0.6057
YRD	AIC	W-bar	3	15.7630	3	7.7811
		Z-bar		32.9539 ***		12.3446 ***
		Z-bar Tilde		13.0591 **		4.0444 ***
	BIC	W-bar	3	15.7630	3	7.7811
		Z-bar		32.9539 ***		12.3446 ***
		Z-bar Tilde		13.0591 **		4.0444 ***
	HQIC	W-bar	3	15.7630	3	7.7811
		Z-bar		32.9539 ***		12.3446 ***
		Z-bar Tilde		13.0591 **		4.0444 ***
PRD	AIC	W-bar	3	4.0850	2	2.3188
		Z-bar		1.3288		0.4782
		Z-bar Tilde		−0.1811		−0.2197
	BIC	W-bar	1	1.2150	1	0.5300
		Z-bar		0.4560		−0.9970
		Z-bar Tilde		0.0225		−1.0100
	HQIC	W-bar	3	4.0850	2	2.3188
		Z-bar		1.3288		0.4782
		Z-bar Tilde		−0.1811		−0.2197

Note: ** $p < 0.05$; *** $p < 0.01$. W-bar = average Wald statistic; Z-bar = standardized average Wald statistic ($\overline{Z}$); Z-bar tilde = standardized average statistic ($\tilde{Z}$).

Regional Analysis

The provincial capital GDP and AESI passed the panel unit root test after the first difference. Next, they passed the panel cointegration test ($p < 0.1$). Subsequently, in the panel Granger causality test, when the criterion is BIC, the Z-bar and Z-bar tilde did not reject H_B (see Table 1). Therefore, at the provincial capital level, the Granger causality test results of the panel provide some support for the hypothesis that GDP is the Granger cause of the AESI. In BTH, the panel Granger causality test results show that H_A is not strongly rejected (under the three criteria, only the *p*-value of the Z-bar met the requirements) and H_B is not rejected at all (under the three criteria, the Z-bar and Z-bar tilde are not significant). So, relatively speaking, the causal analysis results for BTH were also more in favor of the hypothesis that GDP is the Granger cause of the AESI. The Granger causality test results show that, in the YRD, there was a two-way causality between city GDP and AESI. Table 1 shows that the null hypothesis is strongly rejected under both criteria. In PRD, the empirical results do not reject either H_A or H_B. Therefore, for the PRD cities, there is no proven causal relationship between the economic aggregate and the competitive pressure that each city faced from other cities. One possible reason is that the growth of PRD export volume and the degree of convergence of commodity structure are more influenced by foreign investment (as global capital radiates to PRD through Hong Kong), rather than mainly due to the spillover effect brought by the growth of economic aggregate. In 2017, the export volume of foreign-invested enterprises in PRD accounted for 46.85% of the total export volume of PRD, while the value of BTH was only 33.87%. The values for YRD and National were also lower than that for PRD, accounting for 45.82% and 43.19%, respectively. On the other hand, the foreign investment entering PRD, mainly in the manufacturing industry, can indeed generate relatively large export volumes. In 2017, the ratio of PRD's foreign-invested enterprises' exports to the amount of foreign capital utilized was 12.68, whereas the ratios in BTH and YRD were only 1.03 and 5.28. Simultaneously, AESI has no impact on GDP in PRD, because the competitive relationship between exports of cities in PRD is not generated by the gradual expansion of local enterprises, but directly caused by foreign capital, with obvious homogeneity at the beginning. Therefore, this competitive relationship has no strong economic impetus. This phenomenon shows that the export development modes of PRD, BTH, and YRD are different.

3.2.3. Relationship between ESI and Distance

Prior to the gravity model analysis, the following question needed to be confirmed: Is the ESI somehow related to distance?

All Cities

Figure 7 shows the scatter diagram formed by the ESI and the linear distance (D) of each city pair, indicating a certain degree of power law decline in the shape of the fitting curve. Regarding overall trends (see Figure 7a–d), as the distance between cities increased, the ESI decreased.

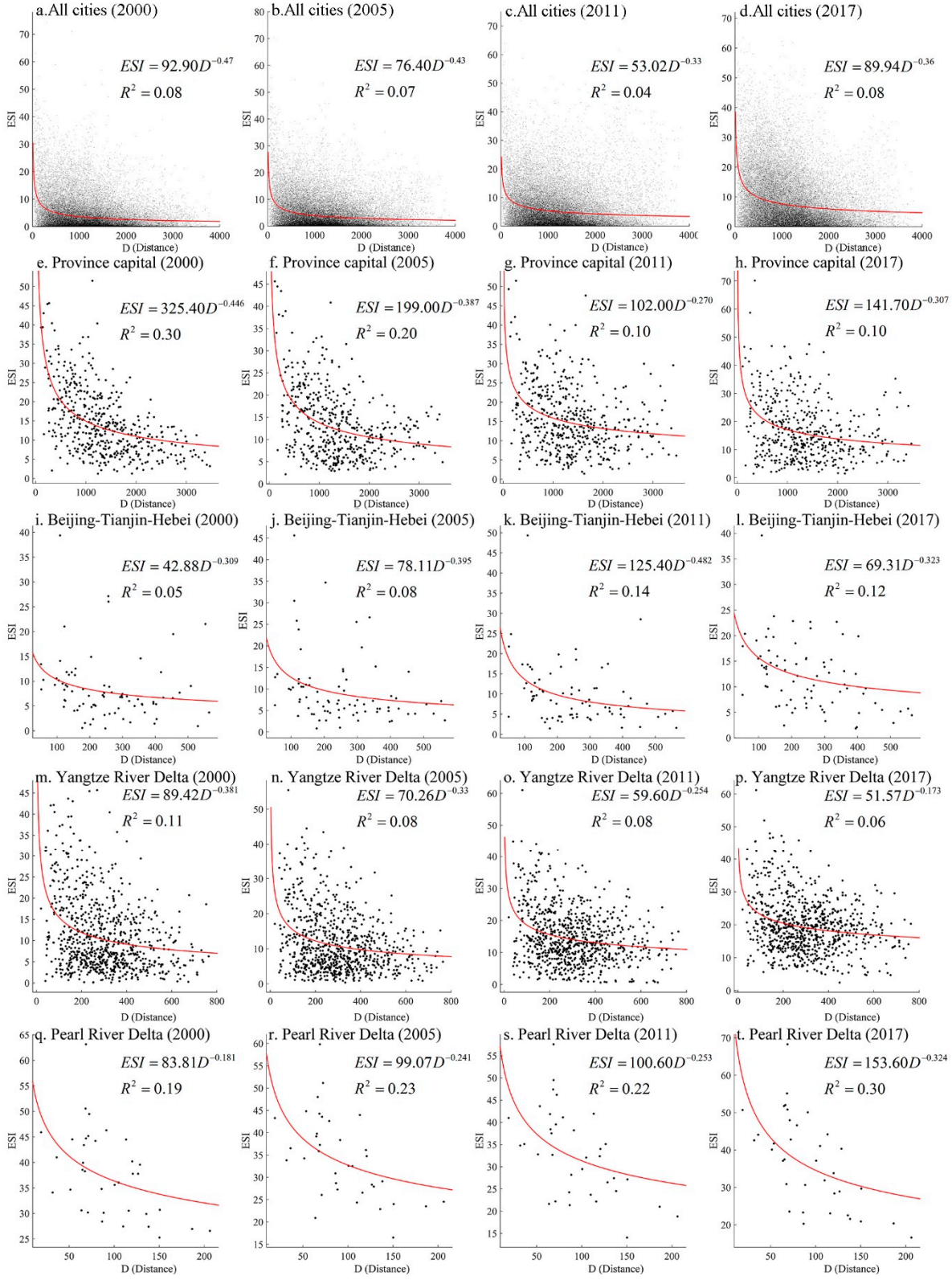


Figure 7. The scatter diagrams and fitting curves of the ESI and distance between cities.

Regional Analysis

The fitting relationship between the ESI and the distance between provincial capitals and within urban agglomerations also roughly meets the power law decreasing trend. From the time evolution of the power index, the trend of the ESI decreasing with the

increasing distance within the PRD intensified. In 2000, the absolute power exponent of the fitted curve of the ESI and the distance between the cities within the PRD was 0.181 (see Figure 7q). However, by 2017, the absolute value of the exponent increased to 0.324 (see Figure 7t). Therefore, the closer the cities were within the PRD, the higher the ESI, and the more competitive they were in the global market. Simultaneously, this trend of higher competition between closer cities became more pronounced over time. Conversely, in both the provincial capitals and YRD cities, the power index decreased from a relatively high value in 2000 to a relatively low value in 2017. The provincial capitals decreased from 0.446 to 0.307 (see Figure 7e,h) and the YRD decreased from 0.381 to 0.173 (see Figure 7m,p). For the provincial capitals and the YRD cities, the distance restriction effect of the export competition between cities weakened.

However, no matter how the exponent changes, there is no doubt that closer distance leads to higher ESI as a general trend. The finding, from the perspective of export competition, reaffirms the first law of geography: everything is related to everything else, but near things are more related than distant things [43].

3.2.4. Gravity Model: Relation between the ESI, GDP, and Distance

As we show, the ESI between cities is closely related to GDP and the geographical distance between cities:

1. The GDP is the Granger cause of the export competitive pressure that cities face.
2. The greater the distance between two cities, the less the competition between them.

For a deeper analysis of the comprehensive impact of GDP and distance on ESI, we propose the following model based on the gravity model: $ESI_{ijk} = [\theta \cdot (GDP_i\ GDP_j)^{\varphi}]/d_{ij}^{\sigma}$. ESI_{ijk} is the ESI of cities i and j in the global market (market k), representing the competition between them. GDP_i and GDP_j represent the economic aggregates of cities i and j, respectively. θ, φ, and σ are parameters. We should note that because the ESI has no directionality ($ESI_{ijk} = ESI_{jik}$), we modeled the product of GDP_i and GDP_j as a whole. In general, the empirical analysis of a gravity model should first be converted into a linear logarithmic expression. Because $ESI_{ijk} = 0$, the logarithm cannot be formed. Therefore, a nonlinear least squares estimation (NLS) was performed and the 0 value was incorporated into the analysis.

At the level of all cities, the NLS estimates for all data show that, regardless of θ, φ, and σ, they are all $p < 0.01$. At the regional level, φ and σ differ significantly among the provincial capitals, BTH cities, and the cities of the PRD. For the PRD particularly, the values of φ and σ vary greatly (see Table 2, Column 6). This result reflects that GDP plays a much smaller role than the distance between cities in influencing the competition relationship between cities in PRD. As the above causality test has confirmed, in PRD, there is no significant causal relationship between the economic aggregate of a city and the competitive pressure faced by the city. However, YRD is different, as φ (0.1911) is slightly less than σ (0.2122). Compared with BTH and PRD, competition between cities in YRD is thus more closely affected by GDP and distance.

Table 2. The gravity model results.

Statistics	All Cities	Regional Level			
		ProvinceCapital	BTH	YRD	PRD
θ	0.0073 ***	1.5555 ***	0.1749 ***	0.0904 ***	29.226 ***
	(0.0002)	(0.1905)	(0.0623)	(0.0071)	(5.7968)
φ	0.2630 ***	0.1161 ***	0.1718 ***	0.1911 ***	0.0343 ***
	(0.0007)	(0.0029)	(0.0088)	(0.0020)	(0.0051)
σ	0.2556 ***	0.2296 ***	0.3298 ***	0.2112 ***	0.2224 ***
	(0.0014)	(0.0079)	(0.0264)	(0.0057)	(0.0170)
R^2	0.53	0.81	0.76	0.84	0.95

Note: The standard error is in parentheses. *** $p < 0.01$.

It is necessary to further explain the effect of GDP on the competitive pressures faced by urban exports. Economic growth in a city means that enterprises in the city accumulate more wealth and tend to invest in high-tech and high-value-added industries to gain higher profits [44,45], especially in the production of export commodities, such as high-tech products. In fact, the expansion of economic scale can indeed promote the export of high-tech products [46]. At the same time, economic growth will also expand the variety of export products [47]. As most cities expand their export products with economic growth, the proportion of overlap between them increases and competition between them becomes increasingly fierce.

At the international level, something similar is playing out. In the early stage, developed countries transfer part of their low-end production links and technologies to neigh-boring less developed countries. At this time, because the backward countries and developed countries are in different links of the value chain, they are more complementary to each other in the world trade market. But as the economies of poor countries grow, they have a stronger incentive to upgrade their industrial structures for higher profits. Thus began the challenge of the poor to the developed in the global market. Recent trade frictions between China and the US are a case in point [48].

4. Conclusions

In this study, the Export Similarity Index is used to measure the competitive relationship of Chinese cities in the global market, expanding the discussion of cities in the study of export trade competition. Based on the econometric model, the mechanism of competition is discussed. The main conclusions are as follows:

1. From a national perspective, the intensity of the competition among cities in the global market first increased and then decreased from 2000 to 2017. Competition relationship change reflects the evolution and development of Chinese cities regarding industry and economic structure. Cities in different regions have different competition relationships in export trade, indicating that the export structure and basic characteristics of cities are related to their geographical location. Provincial capitals, as regional economic centers, have high levels of industrialization and urbanization and their industrial layout and export structure are relatively close. PRD, as the pioneer area of China's reform and opening up, had its economy grow dramatically, accompanied by the introduction of foreign capital and the development of local industrialization [49,50]. Therefore, local foreign trade processing products in the PRD tend to be similar in category and the competition between them in the global market is more significant than for BTH and YRD.
2. The GDP of each city was highly correlated with the AESI. Overall, the economic growth of cities and the pressure of export competition from other cities was related via cause and effect. However, at the regional level, the empirical results were more likely to support the GDP as the Granger cause of the AESI; that is, a city's economic growth will intensify the export competition pressure that it faces. Confirmation of such a causal relationship lays a foundation for the use of the gravity model in this study.
3. The evolution of the urban export structure in China is related to geographical proximity, to some extent. The ESI shows a trend of decreasing with increasing geographical distance. The proximity of a geographical location means there are similar development conditions [51], a higher possibility of economic factor spillover, a higher probability of export product convergence, and a more evident competitive relationship in the market.
4. The relationships among the ESI, the GDP, and geographical distance can be incorporated well into the gravity model. If the economic aggregate of the two cities is larger and the geographical distance is smaller, then the export similarity of the two cities will be higher, and the competition in the global market will be more obvious. However, the impact of GDP and distance on ESI varies in different regions. For

example, in BTH, the influence of distance on the competition between cities is more obvious than that of YRD and PRD. The success of empirical research using the gravity model reflects two basic characteristics of Chinese cities in developing export trading. First, economic growth provides the capital, technology, and human resources for increasing the variety of export products and upgrading the export structure. However, the path and direction of the export trade development tend to converge, resulting in an increased ESI and progressively fierce competition for global markets. Second, the ESI has obvious geographical proximity characteristics. This rule makes a high ESI more likely to occur in cities that are geographically adjacent, and competition in the global market is more obvious.

With the increasing integration of urban agglomerations in China, the export competition caused by economic growth and geographical proximity intensifies, which requires reasonable regulation by the government and enterprises. Different cities should have different functions in the region [52,53] and export different products. If there is too much production and export of the same or similar products, adjacent regions become prone to excessive competition and internal friction, resulting in diseconomies of scale. China's urbanization process and economic development stage are different from those in the early stage of reform and opening up, which requires more detailed and efficient regional coordination and management.

There is competition between cities for exports not only in China, but also in countries around the world. The cities of Incheon and Busan in South Korea, for example, compete with each other for exports [54]. On the other hand, the closer the distance between regions is, the more likely technology spillovers will occur, bringing about industrial structure convergence and higher export similarity. In the United States, the eastern states of Ohio and Indiana are close to each other, and their leading export products are transportation equipment (Wikipedia). There has long been competition between these regions. Therefore, the results of this paper are enlightening for not only the development of export trade in Chinese cities but also the development of export trade in cities/states in other large trading countries.

There are still some deficiencies in this paper. First, the factors that affect the competition of export trade between cities include not only GDP and distance, but also innovation cooperation between cities and the policies of central and local governments for the external economic development of cities. We will include further, more comprehensive factors in the future. Second, the data need to be updated further, as in recent years, Sino–US trade frictions and the COVID-19 pandemic have greatly affected the exports of Chinese cities. We will collect and sort updated data to improve our research. In addition, there is a lot of room to expand the scope of the research on competition in urban export trade. In the future, we will discuss in depth the influence of urban export trade competition on urban development and whether and how it affects the structure of urban export commodities.

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Notes

[1] The BTH urban agglomerations include the cities of Beijing and Tianjin as well as Hebei Province, with a total of 13 cities. According to the "*Outline of the Regional Integration Development Plan of the Yangtze River Delta*" (http://www.gov.cn/zhengce/2019-12/01/content_5457442.htm (accessed on 14 March 2021)), the YRD urban agglomerations include Jiangsu Province, Zhejiang Province, Anhui Province, and the city of Shanghai. Because of a data defect, Bozhou City in Anhui Province is not included in the analysis. With reference to the latest plan for the Guangdong–Hong Kong–Macao Greater Bay Area (http://www.gov.cn/zhengce/2019-02/18/content_5366593.htm#1 (accessed on 15 March 2021)) released in recent years, this study takes the cities of Guangzhou, Shenzhen, Zhuhai, Foshan, Huizhou, Dongguan, Zhongshan, Jiangmen, and Zhaoqing as the PRD urban agglomerations.

[2] Because there are 270 cities in total, the ESI has 269 + 268 + . . . + 1 = 36,315 values. The mean is the average of 36,315 ESIs; the median is the median value of 36,315 ESIs.

[3] Data source: Statistical Yearbook of Changzhi City.

[4] Data source: China Regional Economic Statistics Yearbook.

[5] Data source: Statistical Bulletin of Jinchang National Economic and Social Development.

[6] Data source: Yinchuan Yearbook.

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