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An Exploratory Analysis of Networked and Spatial Characteristics of International Natural Resource Trades (2000–2016)

Yujing Wang ¹, Fu Ren ^{1,2,3,4}, Ruoxin Zhu ⁵ and Qingyun Du ^{1,2,3,4,*}

¹ School of Resource and Environmental Sciences, Wuhan University, Wuhan 430079, China; afreeboat@whu.edu.cn (Y.W.); renfu@whu.edu.cn (F.R.)

² Key Laboratory of Geographic Information Systems, Ministry of Education, Wuhan University, Wuhan 430079, China

³ Key Laboratory of Digital Mapping and Land Information Application Engineering, National Administration of Surveying, Mapping and Geoinformation, Wuhan University, Wuhan 430079, China

⁴ Collaborative Innovation Center of Geospatial Technology, Wuhan University, Wuhan 430079, China

⁵ Chair of Cartography, Technical University of Munich, Munich 80333, Germany; ruoxin.zhu@tum.de

* Correspondence: qydu@whu.edu.cn

Received: 28 July 2020; Accepted: 18 September 2020; Published: 20 September 2020

Abstract: Natural resources, as the material basis of human life and production, play a crucial role in national economic and social development. It is essential to reveal the structural characteristics of global natural resource supply and demand, which has become one of the most critical factors affecting every country's policy strategy and economic development. However, mining the characteristics of international natural resource trades is a huge challenge because of the availability and quality of trade data. In this study, the international natural resource trade system is modeled as networks based on the available bilateral trade data from 2000 to 2016. Complex network methods and spatial analysis are utilized to explore the networked and spatial characteristics of different international natural resource trade networks (INRTNs). First, we quantitatively present the overall evolution trend of INRTNs by calculating several indicators of network features at the macrolevel. Then, as the intermediate-level characteristics of INRTNs, the core–periphery structures are explored by applying hierarchical clustering and a visual matrix heatmap. Finally, at the microlevel, the imbalance in direction is detected through the combination of node importance in a complex network with bivariate choropleth maps of spatial analysis. The empirical evidence from INRTNs of different product types in this paper will help governments and business administrations to perceive the complex natural resource trade environment, which can instruct policymakers to formulate effective import–export policies and ensure national resource security and sustainable development.

Keywords: core–periphery structure; international natural resource trades; node importance; spatial autocorrelation

1. Introduction

Natural resources, as the material basis of human life and production, play a crucial role in the development of national economic and social development [1]. Natural resources account for 20% of world trade and dominate the exports of many countries [2]. They are also crucial for importers who may have no domestic supply and for whom resources are an essential input to their economies. In particular, in the 21st century, the development of the industrial economy and modern manufacturing in the world is increasingly dependent on certain types of natural resources, such as coal, iron, and oil. Moreover, sustainable management and efficient utilization of natural resources is

vital to achieving the specific aims of the Sustainable Development Goals (SDGs) [3]. To sustain and promote rapid industrialization and economic growth, countries should exchange resource products with corresponding trade strategies to optimize the allocation of natural resources and maximize their profits.

However, because of the geographically uneven distribution between the supply and demand of most resources and the scarcity of specific resources, issues surrounding the international trade of natural resources have attracted worldwide attention and exerted profound influence [4–7]. International natural resource trades that involve many countries and various products have become increasingly interrelated and intricate, forming a complex geographical network system [8]. International natural resource trade networks (INRTNs) are complicated, dynamic, and affected by various factors, including socioeconomics, international politics, and geopolitics [9]. A detailed investigation of the import–export relation network of international natural resource trades is crucial to enable practical policymaking and ensure natural resource sustainability.

Most scholars apply complex network methods to quantitatively characterize INRTNs for various products and to explore the impact of crises and related measures on international natural resource trades [10–15]. Complex network theory is the methodological framework commonly used to detect the structure, functional characteristics, and even dynamic evolution of international trade networks. According to our review of the literature, various complex network methods have been used to analyze the international trade network. The scale-free property [16], clustering structure [17], and disassortative property [18] have been discussed in the study of trade networks. Node importance measures [19] and community detections [20–23] are also often used to explore the structural characteristics and evolutionary trends of trade networks. The above studies discuss the complex network features of many resource products in international trades that play an important role in finishing our research.

To date, a few studies on natural resource trade have focused on a limited number of countries and products [23–30], but a systematic exploration of global scope is lacking. For example, the research into trade networks has been confined to local areas and organizations, such as the Belt and Road trade network [29–34] and North American Free Trade Area (NAFTA) [35–37]. International trade issues of specific resources, namely, coal [38–40], oil [41,42], scrap metal [6], and natural gas [28], have been investigated in detail. Although most scholars have made considerable efforts to investigate international natural resource trades, less attention has been paid to the complete picture of the global flows of natural resources. Meanwhile, trade regionalization is still high in most industries, and geographical proximity still plays a role in conducting international trades [43].

Therefore, this study is designed to utilize the complex network method and spatial analysis to explore the networked and spatial characteristics of different INRTNs and investigate changes in the trade pattern of various natural resource products from the network and geospatial perspectives. First, we quantitatively present the overall evolution trend of INRTNs by calculating several indicators of network features at the macrolevel. Then, as the intermediate-level characteristics of INRTNs, core–periphery structures are explored by applying hierarchical clustering and a visual matrix heatmap. Finally, at the microlevel, the spatial–temporal variation, the directional imbalance of node importance, is detected through the combination of node importance in a complex network with a bivariate choropleth map of spatial analysis.

This paper uses the international trade networks of multiple types of natural resource products to empirically probe the network dynamic evolution and spatial pattern changes of the natural resource trade network. The main contributions of this study are as follows. (1) A systematic exploration of global scope for various natural resource product trades from 2000 to 2016 is performed. We identify the unified trade patterns and distinctive characteristics of different resources using data analysis and visualization. (2) We use a combination of complex network theory and spatial analysis to detect networked and spatial characteristics. On the basis of node importance, we discuss the spatial distribution of the directional imbalance of node importance. The remainder of the article is organized as follows. Data and methods are described in detail in Section 2. Section 3 analyzes the results in

terms of the dynamic evolution of network features, dynamic evolution of the core–periphery structure, and spatial–temporal variation of node importance. Section 4 discusses the results and some of their implications. Finally, Section 5 presents the conclusions of the study.

2. Data and Methods

2.1. Data Description

To explore the evolution trends of international natural resource markets and trade behaviors, we collected bilateral trade data for more than 200 countries and territories from the Chatham House Resource Trade Database (CHRTD, <https://resourcetrade.earth/data>). The database reorganizes UN trade data into a natural resource hierarchy. The data include the monetary values and masses of trades for different types of natural resources and resource products by year, including agricultural products, fertilizer, forestry products, fossil fuels, metals and other minerals, and pearls and gemstones. In this study, we used the monetary value (1000 USD) as the unit of measurement. The data examined in this paper are from 2000 to 2016, and each country is represented by its international ISO country code. In the database, there are some uncertain data due to a lack of statistics or other reasons. These uncertain data have no exact location and refer to unknown regions. In this study, we took the unknown regions (Area, n.e.s.; other Asia, n.e.s.; Oceania, n.e.s.; Bunkers; other Africa, n.e.s.; free zones; etc.) as separate network nodes for the calculation and analysis of indicators and methods used in this paper. The detailed information of the unknown regions is provided in Appendix B.

2.2. Network Construction

To explore and understand the spatial–temporal variation characteristics and evolution trends of different natural resource trades, we generated a series of natural resource trade networks. According to different trade product types, we constructed six kinds of natural resource trade networks, including agricultural product networks (AGRI), fertilizer networks (FERT), forestry product networks (FORE), fossil fuel networks (FOSS), metal and mineral networks (META), and pearl and gemstone networks (PEAR). According to the annual trade data, we constructed network snapshots of each product from 2000 to 2016. Each network was directed and weighted and was constructed as $N_p^t = (V_t, E_t, W_t)$ by using nodes to represent countries and edges to denote the trade relationships between countries. p represents the trade product type, namely, AGRI, FERT, FORE, FOSS, META, and PEAR. t is the timestamp and ranges from 2000 to 2016. V_t is the set of countries and represents the nodes in the networks. $E_t = \{e_{ij}; i, j \in V_t\}$ is the edge set, where e_{ij} indicates the trade relationships from country i to country j with direction and weight. $W_t = \{w_{ij}\}$ is the matrix of weights, and w_{ij} represents the trade connection weight, which is the normalized export value of trade products exported from country i to country j . The normalized function is:

$$w_{ij} = \frac{\log_{10}(x_{ij})}{\log_{10}(x_{max})}, x_{ij} > 0 \quad (1)$$

x_{max} is the maximum export value, and x_{ij} is the export value from country i to country j . Because of the choice of data standardization methods, there is no general rule to follow. This standardized method was chosen based on the characteristics of currency and the principle of simplicity. The weights that represent the normalized export value have no dimension, so they range within approximately (0, 1). Thus, a series of natural resource trade networks with multiple product types and multiple timestamps were constructed. As shown in Figure 1, the links between countries represent the trade connections, and the colors of the links indicate the weights of trade connections in INRTNs. The red links are high weight and the blue links are low weight. In Figure 1, we can observe that the density of the trade connections increases. This means that the number of trade connections increases, which is also reflected in Table 1. The number of trade connections in the six trade networks all increased in

2016 compared with 2000. The international natural resource trade networks are bound to develop and change with the development and globalization of the world. However, different resource networks will certainly evolve and change quite diversely.

Figure 1. The overview of the international natural resource trade networks in 2000 and 2016.

Table 1. The number of trade connections.

Product Types	The Number of Trade Connections	
	2000	2016
AGRI	16,278	19,233
FERT	3801	5537
FORE	7449	8994
FOSS	7509	10,072
META	11,025	13,297
PEAR	3215	3993

2.3. Indicators of Network Feature

In complex network theory, there are diverse indicators to measure the characteristics of the network [44]. In this study, we used the clustering coefficient, degree correlation (assortativity), network density, reciprocity coefficient, and transitivity to measure the different facets of international natural resource trade networks and observe dynamic evolution trends.

2.3.1. Average Clustering Coefficient and Transitivity

The clustering coefficient is defined to measure the degree to which nodes tend to cluster together in a network. This indicator has two versions. The global version is used to quantitatively measure the overall clustering degree of the networks (often called transitivity) [45], whereas the local coefficient indicates the cohesiveness of a single node. The local clustering coefficient of a node is given as [46]:

$$c_i = \frac{\sum_h \sum_j (a_{ij} + a_{ji})(a_{jh} + a_{hj})(a_{hi} + a_{ih})}{2[k_i(k_i - 1) - 2k_i^{\leftrightarrow}]} \quad (2)$$

where k_i is the degree of node v_i and $k_i^{\leftrightarrow} = \sum_{i \neq j} a_{ij}a_{ji}$. $a_{ij} = 1$ if and only if an edge connects nodes v_i and v_j ; otherwise, $a_{ij} = 0$. The average clustering coefficient is defined as [44,47]

$$C = \frac{1}{n} \sum_i c_i \quad (3)$$

where n is the number of nodes in the network. The average clustering coefficient measures the overall level of clustering in a network as an alternative to the global clustering coefficient.

Transitivity (global clustering coefficient) is based on triplets of nodes and is defined as the number of closed triplets over the total number of triplets (both open and closed). Transitivity is defined as [45]

$$T = \frac{3 \times \text{number of triangles}}{\text{number of all triplets}} \quad (4)$$

Transitivity measures have been developed to measure the frequency or relative frequency of transitive triples in networks [40]. It is worth noting that the transitivity places more weight on the high-degree nodes, while the average clustering coefficient places more weight on the low-degree nodes.

These two indicators are a measure of how close the neighborhood of a node in a network is. A country has multiple trade partners, and there are trade relations among trade partners, so different trade groups are formed. A high clustering coefficient indicates good connectivity between neighbors (trade partners) around the node (a country). In this study, we apply these two indicators to explore the dynamic evolution of the clustering ability of international natural resource trade networks.

2.3.2. Assortative Mixing

Assortative mixing refers to the preference of nodes that tend to link other nodes that are similar (or dissimilar) to them in some aspects [48]. In general, the degree (number of direct neighbors) of the nodes shows assortative mixing. The degree assortativity is defined as follows [49]:

$$r = \frac{M^{-1} \sum_i j_i k_i - \left[M^{-1} \sum_i \frac{1}{2} (j_i + k_i) \right]^2}{M^{-1} \sum_i \frac{1}{2} (j_i^2 + k_i^2) - \left[M^{-1} \sum_i \frac{1}{2} (j_i + k_i) \right]^2} \quad (5)$$

where M denotes the total number of edges and j_i and k_i are the in-degree and out-degree of the vertices that the i th edge leads into and out of, respectively. The value of assortative mixing lies between -1 and 1 . When the value is close to 1 , the network presents obvious assortativity, which means that the nodes prefer to connect with other nodes with similar degrees. Countries with more trade partners prefer to construct trade relations with other countries with more trade partners. Conversely, when the value is close to -1 , the network presents obvious disassortativity, which means that the nodes prefer to connect with other nodes with different degrees. Countries with fewer trade partners tend to develop trade relations with countries with more trade partners.

As a pervasive phenomenon in many real networks, the measure of assortative mixing in the international natural resource trade networks can help us to consider the structure and function of networks and understand the dynamic changes of many trade behaviors.

2.3.3. Network Density

Network density is defined as the proportion of the number of actualized edges to the number of possible edges in a network with n nodes [50]. The density for the directed network is

$$d = \frac{m}{n(n-1)} \quad (6)$$

where n is the number of nodes and m is the number of edges in the network. Network density is used to evaluate the overall tightness among countries in the trade networks. The value ranges from 0 to 1 . The closer the value is to 1 , the denser the network is and the more cohesive the countries in the trade network are. It is well known that material or information can flow more easily in dense networks than in sparse networks. The countries in a trade network with greater density are closer to each other. Greater density represents more abundant and stronger economic interactions from trade behaviors.

Monitoring the dynamic change in the network density in the international natural resource trade networks can help to find the evolution trend of network tightness and economic interaction.

2.3.4. Reciprocity Coefficient

The reciprocity coefficient is a quantitative measure of the likelihood that a node in a directed network is mutually linked. Garlascheil and Loffredo [51] defined reciprocity as the correlation coefficient between the entries of the adjacency matrix of a directed network:

$$\rho = \frac{\sum_{i \neq j} (a_{ij} - \bar{a})(a_{ji} - \bar{a})}{\sum_{i \neq j} (a_{ij} - \bar{a})^2} \quad (7)$$

where the average value $\bar{a} = \frac{\sum_{i \neq j} a_{ij}}{N(N-1)}$, $a_{ij} = 1$ if there is a link from i to j , and $a_{ij} = 0$ if not.

As the proportion of the two-way trade relationship between the two countries, the reciprocity coefficient is an important measure of INRTNs [52,53]. It measures countries' participation in the international trading system. The reciprocity measure in INRTNs is crucial to understanding the dramatic effects of network structure on the dynamical process.

2.4. The Core-periphery Structure Analysis Based on Hierarchical Clustering and Visual Matrix Heatmaps

The core-periphery structure is a mesoscale structure that has been detected in many real complex systems, especially in the world trade system [54]. In contrast to the community structure, the core-periphery structure refers to the grouping of core nodes and peripheral nodes in a network, where the nodes within the core are densely interconnected and those in the periphery are sparsely interconnected [55,56]. It divides countries into core countries, strong semiperiphery countries, weak semiperiphery countries, and peripheral countries. Meanwhile, the nodes in a core are also reasonably well-connected to those in the periphery. The core-periphery structure may have practical implications for understanding the robustness, efficiency, and uneven development of the global natural resource trades [57].

The core countries are industrialized capitalist countries specializing in the development of capital-intensive and high-tech industries on which semiperiphery countries and periphery countries depend. Core countries control and benefit from the global market and play an important role in developing world trade [58]. Periphery countries exist on the outer edges of the global trade market and are less developed than the semiperiphery and core countries. Periphery countries are always engaged in cheap labor-intensive industries or rough processing of raw materials and offer cheap, raw material and labor to core countries. The semiperipheral countries, as the intermediary between the core countries and the periphery countries, benefit from it. The core countries import raw materials and rough-processed products from peripheral countries and transform them into expensive high-tech products. Ultimately, these high-tech products are exported to the core, semiperipheral, and peripheral countries to obtain more added value. As a result, there are more trades between core countries and much fewer trades between periphery countries. The core countries dominate world trade in two aspects: on the one hand, the core countries are more involved in the world trade relationship than the periphery countries; on the other hand, because the products of the core countries have higher added value, the value of the exports of the core countries is higher than the value of the imports. In different INRTNs, the positions of individual countries and the mode of trades between countries are not the same or fixed. Exploring the diverse characteristics of different INRTNs is helpful to comprehensively analyze the global trade market, understand the complex trade mechanism, and discover the potential trade implications.

Therefore, we analyzed the core-periphery structures for different INRTNs by using hierarchical clustering and a visual matrix heatmap. The core-periphery structure in this study was evaluated through hierarchical clustering to analyze the trade structure according to the structural equivalence of

the complex network. Nodes with identical rows and columns in the adjacency matrix are structurally equivalent nodes. Specifically, structural equivalence is based on whether the row and column properties of nodes are similar or not. It can be quantified to calculate the dissimilarity of two nodes. Then, the hierarchical clustering algorithm can be used to aggregate the structurally equivalent nodes.

The nodes located at the core have the most shared network neighbors. The dissimilarity between nodes is calculated according to the network structure and determined by the number of shared neighbors. The dissimilarity functions are defined as

$$\text{dis}(v_i, v_j)^{\text{out}} = \sqrt{\sum_{k=1}^n (a_{i \rightarrow k} - a_{j \rightarrow k})^2} \quad (8)$$

$$\text{dis}(v_i, v_j)^{\text{in}} = \sqrt{\sum_{k=1}^n (a_{k \rightarrow i} - a_{k \rightarrow j})^2} \quad (9)$$

$$\text{dis}(v_i, v_j) = \frac{\text{dis}(v_i, v_j)^{\text{out}} + \text{dis}(v_i, v_j)^{\text{in}}}{2} \quad (10)$$

$a_{i \rightarrow k} = 1$ if there is a link from i to k , and $a_{i \rightarrow k} = 0$ if not. To account for the export and import dissimilarity simultaneously, we used the mean value to balance the difference between these two values. The volume of trade is not taken into account in the dissimilarity measurement of nodes because the difference in the volume of trade is large; if it is considered, it greatly increases the complexity, and the conditions are too harsh.

The hierarchical clustering approach uses Ward's method to compute the distance between clusters in the clustering process. Ward's method is based on variance analysis. The sum of the squares of the deviation is the objective function that merges the cluster in the clustering process. The two clusters that have the smallest increase in the sum of the squares of the deviations are merged until all clusters are in one cluster. Compared with other methods, this approach can establish the influence of each element in the class without being affected by extreme values. The sum of squares of deviation gives the degree of difference among the samples in the cluster, and its value reflects whether the division of the given cluster is appropriate.

The adjacency matrix is one of the ways to organize and store complex network data, which can completely represent the structural relationships of the nodes and edges [59]. A visual matrix heatmap is used to visualize the network after determining the clusters of countries. The layout of countries in the matrix is arranged in order of cluster types, with the same order in rows and columns to effectively display the trade network structure and directly reflect the trade relationships between different classifications of countries. Meanwhile, the classification of countries is visualized on the map. The combination of the visual matrix heatmap and the map will more comprehensively display the characteristics of the core-periphery structure in cyberspace and geographic space.

2.5. Spatial Pattern Detection of Node Importance

Measuring the node importance in the network is a way to uncover the specific role played by such microscopic elements as individual nodes. The more important the node is, the more influence it has on the various functions of the network. It is well known that identifying key nodes of networks is of great significance because many mechanisms, such as spreading, cascading, and synchronizing, are highly affected by key nodes. Identifying the important nodes or measuring the importance of the nodes in INRTNs can help to find and understand the trade pattern to guide decision-makers in making decisions about national development and international trades.

The spatial pattern of node importance refers to the aggregation characteristics of node importance in terms of spatial distribution. In a directed network, the node importance differs in two directions.

This section analyzes the spatial pattern of node importance based on the directional imbalance of node importance.

2.5.1. Node Importance Indicators in the Complex Network

There are many methods to measure node importance in complex networks [60,61]. Degree centrality (DC) and strength centrality (SC) are frequently used methods.

DC is the simplest method and emphasizes the number of direct connections that a node has. The degree of node v_i , denoted as k_i , is defined as the number of directly connected neighbors of v_i . $k_i = \sum_j a_{ij}$, where $A = \{a_{ij}\}$ is the adjacency matrix and $a_{ij} = 1$ if V_i and V_j are connected and 0 otherwise. The normalized degree centrality is defined as

$$DC(i) = \frac{k_i}{n-1} \quad (11)$$

where n is the number of nodes and $n-1$ is the largest possible degree. In a directed network, the direction of every link should be considered. The out-degree of node V_i is defined as $k_i^{out} = \sum_j a_{i \rightarrow j}$ (the number of links from V_i to other nodes), and the in-degree of node V_i is defined as $k_i^{in} = \sum_j a_{i \leftarrow j}$ (the number of nodes having a directed link pointing to V_i). Thus, the out-degree centrality and the in-degree centrality are defined as

$$DC(i^{out}) = \frac{k_i^{out}}{n-1} \quad (12)$$

$$DC(i^{in}) = \frac{k_i^{in}}{n-1} \quad (13)$$

DC can measure the importance of nodes to some extent, but nodes with the same degree may not play the same important role. Strength centrality (SC), the expansion of DC in the weighted network, integrates information about both its connectivity and the weights of its associated links [60]. In an undirected network, the strength of node v_i is defined as the summation of the weights of the links associated with v_i , namely,

$$s_i = \sum_{j=1}^n w_{ij} \quad (14)$$

By normalizing the node strength, the strength centrality is defined as

$$SC(i) = \frac{s_i}{\sum_{j=1}^n s_j} \quad (15)$$

For directed networks, the in-strength and out-strength are defined as

$$SC(i^{in}) = \frac{s_i^{in}}{\sum_{j=1}^n s_j^{in}}, s_i^{in} = \sum_{j=1}^n w_{i \leftarrow j} \quad (16)$$

$$SC(i^{out}) = \frac{s_i^{out}}{\sum_{j=1}^n s_j^{out}}, s_i^{out} = \sum_{j=1}^n w_{i \rightarrow j} \quad (17)$$

In terms of direction, DC and SC are more explicit than others. Thus, we analyzed the directional imbalance of node importance using DC and SC.

2.5.2. Spatial Analysis of the Directional Imbalance of Node Importance

In directed networks, the links of the nodes have directions. Therefore, the centrality of nodes should be considered from the perspective of two directions. In-centrality and out-centrality are calculated sequentially, and they have different meanings. For example, in a social network,

the in-degree of a node refers to the node's popularity and prestige, while the out-degree indicates the node's social activity and initiative. Similarly, in INRTNs, a directed link exists from country v_j to country v_i if v_j follows v_i ; then, the in-degree of node (country) (i.e., the number of nodes having directed links pointing to v_i) reflects v_i 's import relationship capacity, while the out-degree of node v_i (i.e., the number of links from v_i to other nodes) represents v_i 's export relationship capacity to some extent. The directional imbalance of node importance influences the function of networks and is also one of the characteristics of the network.

In this paper, we apply bivariate choropleth mapping to display the directional imbalance of node importance. Most GIS and cartography tools only let us select one attribute for classification. How can we get it to use two variables? The solution is to create a third attribute that represents a combination of the two variables by its location in the bivariate color scheme [62]. As shown in Figure 2, the legend of the bivariate choropleth map indicates the meaning of the color under the dual dimension of in-centrality and out-centrality [63].

Figure 2. The legend of a bivariate choropleth map.

In each dimension, the data are graded by quantile classification. The node importance is the rank measure of the node in the network. The rank in all nodes is the key information of node importance. Thus, we graded the countries into three classes by order of node importance. Each class has the same number of countries. Using the quantile classification method gives the same number of values to data classes at the extremes and those in the middle. Each class is equally represented on the map, and the classes are easy to compute. Quantile classification is especially useful for ordinal data. The quantile classification method can be used to compare the results between different choropleth maps.

As shown in Figure 2, the three colored blocks on the diagonal represent relatively equivalent values of node centrality, which means balanced imports and exports, while the other colored blocks represent different levels of imbalance in direction. The three colored blocks at the top left of the diagonal represent an export-oriented imbalance. On the whole, the countries with these three colors have superior export potential and are export-oriented countries. The three colored blocks at the bottom right of the diagonal represent an import-oriented imbalance. On the whole, these countries with these three colors have superior import potential and are import-oriented countries.

Finally, the spatial distribution of node importance can be obtained. The detailed results are presented in the following section.

3. Results

3.1. Dynamic Evolution of Network Features

In this study, we calculated the indicators of network features using the Python package NetworkX [64]. Figure 3 reviews the evolution of INRTNs from different perspectives in the period from 2000–2016. Figure 3 shows that the average clustering coefficient presents an upward trend, among which the values of FOSS and FORE networks increase more dramatically, which means that trade relationships in these two trade systems become tighter between neighbor nodes (trade partners) and so does the transitivity. One small difference is that the rising trend of transitivity is more stable than the average clustering coefficient. From the performance of the two indicators, we find that

different networks have different clustering levels. The order of the level for the two values is AGRI, META, FORE or PEAR, FOSS, and then FERT.

Figure 3. Evolution of six indicators in international natural resource trade networks (INRTNs) from 2000 to 2016.

The assortativity in Figure 3 is negative, which means that INRTNs are disassortative. Countries with high degrees prefer to connect with countries with low degrees. Because of the close geographical location and similar cultures, small countries tend to construct trade relations with hub countries in the same regions. They then form regional economic cooperation organizations with large regional countries as the core, such as the European Union and North American Free Trade Area. The global environment of economic globalization also means that regional economic organizations cannot cut off ties with other regions, so big countries in the region have played a pivotal role in trade communication with other regions of the world. The decline in the assortativity indicates that this trend is constantly strengthening.

The network density of INRTNs has gradually increased, indicating that network cohesion has enhanced and closer relationships have developed between economies participating in global natural resource trade. The network density of the six types of trade networks is different. AGRI has the highest network density, and FERT and PEAR have the lowest density. The economic interaction in AGRI is stronger than the others.

The reciprocity coefficient also presents a slight increase from 2000 to 2016. More countries have developed bilateral trade relations, and the economic complementarity between countries has further enhanced. More countries have joined the global trading system by establishing comparative advantages and participating in the international division of labor.

From the dynamic changes of the six indicators, it can be seen that INRTNs of different products have similar trends. In summary, INRTNs have shown an increase in aggregation, network traffic capabilities have become stronger, and participation has increased.

3.2. The relatively Stable Core–Periphery Structure

To identify the dynamic evolution of the international natural resources trade status, we analyzed the core–periphery structure of the different INRTNs using hierarchical clustering and a visual matrix heatmap. Specifically, Pajek software was used to conduct the hierarchical clustering of the networks. Participating countries were divided into core countries, strong semiperiphery countries, weak semiperiphery countries, and periphery countries. The network locations of the countries in the core–periphery structures and the corresponding geographical locations in the real world are shown in Figures 4–6. In the visual matrix heatmap, the value from row i to column j represents the export value from country i to country j . The value from column i to row j represents the import value from country j to country i . The color blocks in the header of the matrix are the same as the color rendering on the map, representing the classification information of the core–periphery countries. The color rendering of the matrix element indicates whether trade connections between countries exist. Black represents the existence of trade connections, and white means that there is no trade connection. Taking the limitations of the paper length into account, we selected five years—2000, 2004, 2008, 2012, and 2016—by applying equidistant sampling to analyze the core–periphery structure and the directional imbalance of node importance in this study. The detailed information about the structure classification in 2000, 2004, 2008, 2012, and 2016 is provided in Appendix A.

As shown in Figures 4–6, the core–periphery structure of the six INRTNs has been relatively stable with little change, and the trade positions of a small number of countries have changed. The trade links between the core countries are the strongest, and the trade links between the core countries and strong semiperiphery countries are the second strongest, while the trade links between the periphery countries are the weakest. AGRI, FORE, FOSS, and META have more frequent connections than FERT and PEAR.

Figure 4 shows the core–periphery structures of AGRI and FERT in 2000, 2004, 2008, 2012, and 2016. The core countries for AGRI include North American countries, Southeast Asian countries, Russia, the majority of European countries, Oceania, and South Africa, while countries in South America, Central Asia, Western Asia, and Africa are at different levels of the peripheral state. Trades from core countries to core countries, semiperiphery countries, and periphery countries are gradually decreasing in AGRI. The core countries for FERT include the USA, China, India, and some European countries, while Russia, Canada, Oceania, Japan, and South Africa are in the semiperiphery. The majority of African countries are in the periphery. The export connection from the core countries to semiperiphery and periphery countries is stronger than that from semiperiphery and periphery countries to core countries.

Figure 5 shows the core–periphery structures of FORE and FOSS in 2000, 2004, 2008, 2012, and 2016. The core countries for FORE include the USA, China, India, Japan, South Africa, Southeast Asian countries, and the majority of European countries, while the majority of African countries and Western Asian and Central Asian countries are semiperiphery or periphery countries. Oceania, Brazil, and Canada have become strong semiperiphery countries from core countries. The level of trade between core countries and core countries, semiperiphery countries, and periphery countries is gradually decreasing in FORE. The core countries for FOSS include North American countries, China, Japan, India, and the majority of European countries, while the majority of African countries and Central Asian and Western Asian countries are periphery or weak semiperiphery countries. Russia has become a core country from a strong semiperiphery country. Latin American countries are semiperipheral countries. The export connection from the core countries to the semiperiphery and periphery countries is stronger than that from semiperiphery and periphery countries to core countries.

Figure 6 shows the core–periphery structures of META and PEAR in 2000, 2004, 2008, 2012, and 2016. The core countries for META include North American countries, China, Japan, India, Oceania, Brazil, South Africa, and the majority of European countries, while the majority of African countries and Central Asian and Western Asian countries are semiperiphery or periphery countries. Latin American countries, except Brazil, are semiperiphery countries. The level of trade between core countries and core countries, semiperiphery countries, and periphery countries is gradually decreasing

in META. The core countries for PEAR include the USA, China, India, and some European countries, while the majority of African and Latin American countries are semiperiphery or periphery countries. Oceania, Brazil, and Japan have become strong semiperiphery countries. Russia has become a strong semiperiphery country from a weak semiperiphery country. The level of trade between core countries and core countries, semiperiphery countries, and periphery countries is also gradually decreasing in PEAR.

Figure 4. The core–periphery structures of agricultural product networks (AGRI) and fertilizer networks (FERT).

Figure 6. The core-periphery structures of metal and mineral networks (META) and pearl and gemstone networks (PEAR).

3.3. Spatial Distribution of the Directional Imbalance of Node Importance

The directional imbalance of node importance for INRTNs reflects the role orientation of countries in importing and exporting. This section provides a detailed analysis of the directional imbalance of node importance based on DC and SC for the six types of INRTNs. As presented in Figures 7–12, the results reveal huge differences between DC and SC.

Figure 7. The directional imbalance of node importance for AGRI.

Figure 8. The directional imbalance of node importance for FERT.

Figure 9. The imbalance of directional node importance for FORE.

Figure 10. The directional imbalance of node importance for FOSS.

Figure 11. The directional imbalance of node importance for META.

Figure 12. The directional imbalance of node importance for PEAR.

Figure 7 shows the directional imbalance of node importance for AGRI. Most countries have a relatively balanced centrality, and the value is high, including North American countries, Russia, China, India, Europe, Japan, the Republic of Korea, South Africa, Austria, Brazil, Egypt, and Saudi

Arabia. The situation has not changed much in the past two decades. Some countries show a significant imbalance both in DC and SC, including Mongolia, Bolivia, Kazakhstan, Ukraine, Tanzania, Algeria, and Libya. From the viewpoint of DC, Mongolia, Kazakhstan, Algeria, and Libya are import-oriented countries. Tanzania, Peru, and Burma are export-oriented countries. From the viewpoint of SC, Algeria, Libya, and Venezuela are import-oriented countries. Tanzania and Kenya are export-oriented countries. Mongolia and Argentina switched from being import-oriented countries to export-oriented countries in 2008. Kazakhstan became an import-oriented country from an export-oriented country in 2008.

Figure 8 shows the directional imbalance of node importance for FERT. Most countries have a relatively balanced centrality, and the value is high, including North American countries, Brazil, China, Western Europe, Japan, the Republic of Korea, South Africa, and Austria. The situation has not changed much in the past two decades. Some countries show a significant imbalance both in DC and SC, including Mongolia, Bolivia, Tanzania, Burma, Laos, Vietnam, Ethiopia, and Kenya. From the viewpoint of DC, Ethiopia, Bolivia, Venezuela, Tanzania, and Nigeria are import-oriented countries. Norway and the Republic of Belarus are export-oriented countries. From the viewpoint of SC, Columbia, Burma, Ethiopia, New Zealand, and Pakistan are import-oriented countries. Russia, Saudi Arabia, and Egypt are export-oriented countries. Russia is a balanced and high-centrality country in DC, while it is an imbalanced and export-oriented country from the viewpoint of SC. This means that Russia is an export-oriented country considering the trade value; Russia's fertilizer consumption capacity is insufficient, and import demand is low. Saudi Arabia became an export-oriented country from a balanced country in 2008 in terms of SC.

Figure 9 shows the directional imbalance of node importance for FORE. Most countries have a relatively balanced centrality, and the value is high, including North American countries, Russia, China, India, Europe, Japan, the Republic of Korea, South Africa, Austria, Brazil, Argentina, and Indonesia. The situation has not changed much in the past two decades. Some countries show a significant imbalance both in DC and SC, including Mongolia, Algeria, Libya, and Venezuela. From the viewpoint of DC, Mongolia, Algeria, Libya, and Venezuela are import-oriented countries. Burma, Laos, and Peru are export-oriented countries. From the viewpoint of SC, Saudi Arabia and other countries in Central and Western Asia, Kazakhstan, Columbia, Venezuela, and Mongolia are import-oriented countries. Burma, Laos, and Central African countries are export-oriented countries.

Figure 10 shows the directional imbalance of node importance for FOSS. Most countries have a relatively balanced centrality, and the value is high, including North American countries, Russia, China, India, most European countries, Japan, the Republic of Korea, South Africa, Austria, Brazil, Thailand, and Indonesia. The situation has not changed much in the past two decades. Some countries show a significant imbalance both in DC and SC, including Iran, Pakistan, and Angola. From the viewpoint of DC, Chile, Peru, and Tanzania are import-oriented countries. Venezuela, Iran, Namibia, and Lithuania are export-oriented countries. From the viewpoint of SC, Chile, Peru, Pakistan, Laos, Cambodia, Philippines, and New Zealand are import-oriented countries. Saudi Arabia, Iran, Iraq, and Libya are export-oriented countries. The Philippines became an import-oriented country from an export-oriented country in 2008 in terms of DC. Kazakhstan became an export-oriented country from a balanced country in terms of DC in 2008.

Figure 11 shows the directional imbalance of node importance for META. Most countries have a relatively balanced centrality, and the value is high, including North American countries, Russia, China, India, Europe, Japan, the Republic of Korea, South Africa, Austria, Brazil, Argentina, Saudi Arabia, and Iran. The situation has not changed much in the past two decades. Some countries show a significant imbalance both in DC and SC, including Mongolia, Namibia, and Algeria. From the viewpoint of DC, Algeria and Tanzania are import-oriented countries. From the viewpoint of SC, Algeria and Afghanistan are import-oriented countries. Mongolia, Bolivia, Venezuela, and Zambia are export-oriented countries. Iran became an export-oriented country from a balanced country in 2008 in terms of DC and SC.

Figure 12 shows the directional imbalance of node importance for PEAR. Most countries have a relatively balanced centrality, and the value is high, including North American countries, Russia, China, India, Western Europe, Japan, the Republic of Korea, South Africa, Austria, Brazil, Thailand, and Indonesia. The situation has not changed much in the past two decades. Some countries show a significant imbalance both in DC and SC, including Burma, Zambia, Tanzania, Kenya, and Ethiopia. From the viewpoint of DC, Argentina, Norway, Finland, Algeria, and Iceland are import-oriented countries. Burma, Pakistan, Afghanistan, and Nigeria are export-oriented countries. From the viewpoint of SC, Norway, Finland, Algeria, and Iceland are import-oriented countries. Burma and Afghanistan are export-oriented countries. Sweden became an import-oriented country from a balanced country in 2008 in terms of SC.

4. Discussions and Policy Implications

4.1. The Globalization and Complexity of International Natural Resource Trade

The globalization of international natural resource trade has gradually increased in the past two decades due to the increasing number of trade relationships and the steady increase over time in network feature indicators, including the average clustering coefficient, transitivity, and network density. The number of trade relationships for different product types of international natural resources has increased overall. Meanwhile, network feature indicators, such as the average clustering coefficient, have increased steadily over time. This increase indicates that a growing number of countries are beginning to realize the benefits and self-advantages of natural resource trades and are actively participating in the international natural resource trade markets. However, the last trend in network density from 2012 to 2016 diverges from its previous growth trend from 2000 to 2012 and shows a slight downward trend. This change indicates that the cohesiveness of INRTNs has weakened. This change may have resulted from the global and regional trade situation and trade protection policies in core countries.

The international natural resource trade has become highly complex because of diverse supply–demand relationships and volatile international situations. In the 21st century, the decreasing trade costs of natural resources, the rising prices of the world market for natural resources, and the huge demand for natural resource commodities have caused the scale of natural resource trade to expand. The proportion of natural resource trade in the global trade of goods has been increasing, which has played a pivotal role in the world economy. International natural resource trade involves a wide range of product types, which can be divided into renewable and nonrenewable resources, including agricultural products, fertilizers, forestry products, fossil fuels, metals and minerals, and pearls and gemstones. Different countries have complex and dynamic supply–demand relations for different trade products. Changes in the reciprocity coefficient reveal that countries are actively seeking complementary trade strategies, and trade relations are increasing.

These findings suggest that globalization is still the main melody of natural resource trade, the complexity of which is also increasing.

4.2. Core–periphery Structure of International Natural Resource Trade Relationships

INRTNs have relatively stable core–periphery structure characteristics. A few core countries hold the initiative of global trade; they control the world trade channels, the raw material, and the cheap labor of the semiperiphery and periphery countries and continue to strengthen their core position with appropriate trade strategies. Additionally, core countries have two-way import and export trade relationships with themselves and countries with other classifications, which means that the trade markets are centered on the core countries. The trade relationships that are related to semiperiphery countries and periphery countries are characterized by trade that caters to core countries. There are stable and consistent phenomena in the different types of natural resource trade networks: the trade relationships between semiperiphery and periphery countries are weaker, and the trade relationships

among periphery countries are weakest. The core countries are no longer just a few traditional developed countries. Some developing countries, such as China and India, have emerged among the core countries in international natural resource networks.

The findings on the core–periphery structure of global natural resource trade relationships imply that heterogeneous international natural resource trades, uneven trade development, and the economic growth of countries in the process of globalization will remain unchanged for a long time. Meanwhile, the international natural resource trade networks with stable core–periphery structures will be robust against the random failure of nodes (e.g., the sudden political unrest of an energy exporter). The existence of core countries may contribute to the functional stability of the overall networks. However, the interdependency between countries on their policies and trades is a standard that cannot be overlooked. Countries should play up the advantages of their roles and enhance their indispensability in the network. Core countries should continue to strengthen their scientific and technological power, optimize their industrial structure, facilitate trade links with other countries, and enhance their core position in the entire trade network. Semiperipheral countries need to attach more importance to technological innovation, create a reasonable industrial structure, and strengthen trade relations with their trade partners. Periphery countries are advised to pay close attention to the changes in import and export policies of trade partners, seek stable trading partners, and actively expand their multilateral trade relations with several reciprocal countries.

4.3. The Spatial Distribution of Countries' Roles in the International Natural Resource Trade Network

The characteristics of countries' roles in the international natural resource trade networks are revealed by two facets. On the one hand, the directional imbalance of node importance for each country of the international natural resource trade networks is analyzed based on DC and SC. For each country, there are certain differences in trade roles in different product trade networks. Recognizing the roles or positions in complex international trade networks is vital for every country. The directional imbalance of node importance reflects the role orientation of imports and exports. DC focuses on the presence or absence of trade relations and directly measures trade partnerships. SC focuses on the weights of trade activities, and the weights are the normalized values of trade. Both DC and SC are important indicators for analyzing the directional imbalance of node importance. The difference in the imbalance analysis results for DC and SC means that the quality of trade varies considerably despite the maturity of the trade relationship. On the other hand, generally speaking, the countries with imbalanced roles in INRTNs are spatially concentrated in the Southern Hemisphere or the southern part of the Northern Hemisphere. These countries are undeveloped and developing countries. In contrast, the balanced countries are located in the Northern Hemisphere and are developed countries. The balance of import–export trade is closely related to the country's economic development level. Countries with balanced node importance have high-level economic development. Therefore, strengthening south–south cooperation is an important means by which developing and undeveloped countries can respond to challenges jointly. Strengthening south–south cooperation, promoting north–south dialogue, and calling on developed countries to earnestly fulfill their promises of market access, increased aid, and debt relief will help promote economic globalization toward achieving common prosperity for all countries.

5. Conclusions

Natural resources are necessary for each country's economic development and even an important factor for international security and global sustainable development. The geographically uneven distribution of natural resources and diverse supply–demand relationships prompt an increasing number of countries to participate in the international natural resource trade, allowing them to seek more trade relationships with appropriate trade strategies. In the context of intricate international trade relationships, competitive international trade markets, and successive regional upheavals, it is crucial for policymakers, managers, and practitioners in related trade industries to understand the

evolution of the networked and spatial characteristics of INRTNs and to master a methodological framework for analyzing and mining the features of trade networks.

Therefore, this paper applies complex network theory and spatial analysis to systematically and empirically investigate the networked and spatial characteristics of international natural resource networks by constructing a series of weighted and directed networks involving six kinds of natural resource products from 2000 to 2016. Specifically, the network density and average clustering coefficient of the international natural resource trade networks have increased gradually. Other indicators, such as assortativity and the reciprocity coefficient, were also computed. The results of these indicators reveal the process of globalization of international natural resource trade networks and reflect the complexity of trade markets. Moreover, the trade networks for diversified global natural resources are revealed to have maintained uniformly stable core–periphery structures in the past two decades of global natural resource trade development. The core countries that dominate whole networks are not only developed countries but also developing countries, such as China and India, which have started to gradually join the queue of core countries. Furthermore, in terms of node importance, we explore the spatial distribution of the directional imbalance based on DC and SC. The results of an exploratory analysis of networked and spatial characteristics of INRTNs shed light on the dynamic evolution of network features, the relatively stable core–periphery structure, and the spatial distribution of the directional imbalance of node importance. Theoretically speaking, the methodology presented in this paper can be used to research other kinds of product trades. Our study can provide useful information to assist in developing and realizing national policies and international treaties for sustainable development. The sound and orderly operation of the natural resource international trade market is an important prerequisite for achieving sustainable economic development in countries around the world. Our research can also be used to monitor the development of international trade and provide assistance for the implementation of sustainable development policies related to resources and the economy.

Although complex network methods have been thoroughly applied in the study of INRTNs, it is difficult to obtain accurate international trade data for natural resources. Since natural resources involve many products, it is difficult to obtain data from various countries. The research in this article is an exploratory analysis of the available data. Further supplementary data or third-party data are needed for cross-validation. The detection of network characteristics based on uncertain data will be a valuable study. There are multiple complex geopolitical factors, such as political systems, international relations, and economic and cultural aspects, and it is difficult to quantify them with simple models. It becomes difficult to quantitatively analyze the geographical mechanism of the international natural resource trade network. Therefore, this is also a research direction for further breakthroughs in the future. Meanwhile, in the context of the trend of deglobalization post-COVID-19, the impact of the COVID-19 outbreak has been felt strongly by international trade and global supply chains. How post-COVID-19 deglobalization will impact INRTNs is also an attractive study direction.

Author Contributions: Conceptualization, Q.D. and Y.W.; data curation, Y.W.; formal analysis, Y.W.; methodology, Y.W., R.Z.; software, Y.W. and R.Z.; supervision, F.R. and Q.D.; visualization, Y.W.; writing—original draft preparation, Y.W.; writing—review and editing, Y.W., Q.D., and F.R. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Key Research and Development Program of China, grant number 2016YFC0803106; and the National Natural Science Foundation of China, grant number No. 41571438.

Acknowledgments: We thank resourcetrade.earth for publishing the detailed trade data, which ensured the completion of our empirical research.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A Classification List of Core–Periphery Structure

Table A1. Classification list of the core–periphery structure of AGRI, FERT, and FORE.

Country Code	Country	AGRI						FERT						FORE					
		2000	2004	2008	2012	2016	2000	2004	2008	2012	2016	2000	2004	2008	2012	2016			
NIC	Nicaragua	1	2	1	1	1	4	4	2	2	1	4	3	4	4	1			
SSD	South Sudan	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
BLZ	Belize	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
PNG	Papua New Guinea	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
BWA	Botswana	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
CPV	Cabo Verde	1	1	1	4	1	1	1	1	1	1	1	1	1	1	1			
VEN	Venezuela	1	2	1	1	1	4	4	2	2	1	4	3	4	1	1			
CUB	Cuba	1	2	1	1	1	4	4	1	1	1	4	3	1	1	1			
MDA	Moldova	1	2	3	2	2	1	1	1	2	1	4	1	1	2	1			
NPL	Nepal	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
QAT	Qatar	1	1	1	1	2	4	1	2	2	1	4	4	2	2	3			
KHM	Cambodia	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
GEO	Georgia	1	1	1	2	1	1	1	1	2	1	4	1	1	2	1			
DOM	Dominican Rep.	1	2	1	1	2	4	4	2	2	1	4	3	4	4	3			
AZE	Azerbaijan	1	1	1	2	1	1	1	1	2	1	4	1	1	2	1			
ARM	Armenia	1	1	1	2	2	1	1	1	2	1	4	1	1	2	1			
PRK	Korea PRK	1	1	1	4	4	1	1	1	1	1	1	1	1	1	1			
KGZ	Kyrgyzstan	1	1	1	2	1	1	1	1	2	1	4	1	1	1	1			
LBY	Libya	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1			
BFA	Burkina Faso	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
TCD	Chad	1	1	1	4	4	1	1	1	1	1	1	1	1	1	1			
TKM	Turkmenistan	1	1	1	1	1	1	1	1	1	1	4	1	1	1	1			
AND	Andorra	1	1	1	4	4	1	1	1	1	1	4	1	1	1	1			
LAO	Lao PDR	1	1	4	1	1	1	1	1	1	1	1	1	1	1	1			
ERI	Eritrea	1	1	1	4	4	1	1	1	1	1	1	1	1	1	1			
PYF	French Polynesia	1	1	1	1	4	1	1	1	1	1	4	1	1	1	1			
NER	Niger	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
MOZ	Mozambique	1	2	3	2	1	1	1	2	2	1	1	1	1	1	1			
KWT	Kuwait	1	1	1	1	2	1	1	2	2	1	4	4	2	2	3			
BHS	Bahamas	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
TTO	Trinidad and Tobago	1	1	1	1	1	1	4	2	2	1	4	3	4	1	1			
BIH	Bosnia Herzegovina	1	2	1	2	2	4	1	2	2	1	4	4	2	2	4			
AFG	Afghanistan	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
PAN	Panama	1	2	1	1	2	4	4	2	2	1	4	3	4	4	3			
COG	Congo COG	1	1	1	1	1	1	1	1	1	1	4	4	2	4	3			
HND	Honduras	1	2	1	1	2	4	4	2	2	1	4	3	4	4	3			
SLV	El Salvador	1	2	1	1	2	4	4	2	2	1	4	3	4	4	1			

Table A1. Cont.

Country Code	Country	AGRI					FERT					FORE				
		2000	2004	2008	2012	2016	2000	2004	2008	2012	2016	2000	2004	2008	2012	2016
MMR	Myanmar	1	1	1	1	2	1	1	1	1	1	4	1	1	4	3
TJK	Tajikistan	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
BOL	Bolivia	1	2	1	1	2	1	1	1	2	1	4	3	1	4	3
UZB	Uzbekistan	1	1	1	1	1	1	1	2	2	1	4	1	1	1	1
HTI	Haiti	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
KAZ	Kazakhstan	1	2	3	2	1	1	1	2	2	1	4	1	1	2	1
RWA	Rwanda	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
AGO	Angola	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1
JAM	Jamaica	1	2	1	1	1	1	1	1	1	1	4	3	1	1	1
GAB	Gabon	1	1	1	1	1	1	1	1	1	1	4	4	2	4	3
SUR	Suriname	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
COD	Congo COD	1	1	1	1	1	1	1	1	1	1	1	1	1	4	1
SLE	Sierra Leone	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
FJI	Fiji	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
GMB	Gambia	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
SWZ	Swaziland	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
BDI	Burundi	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
SDN	Sudan	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
CAF	Central African Rep.	1	1	1	4	4	1	1	1	1	1	1	1	1	4	1
LBR	Liberia	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MNG	Mongolia	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
DZA	Algeria	1	2	1	2	2	4	3	2	2	1	4	4	1	2	1
PRY	Paraguay	1	2	3	2	2	1	1	1	2	1	4	3	1	4	3
GUY	Guyana	1	1	1	1	1	1	1	1	1	1	4	1	1	1	1
YEM	Yemen	1	1	3	2	1	1	1	2	2	1	1	1	1	1	1
ARG	Argentina	2	3	3	2	3	4	4	2	2	4	4	3	4	4	3
CHE	Switzerland	2	3	2	3	3	3	2	4	4	3	3	2	3	3	4
ITA	Italy	2	3	2	3	3	2	2	3	3	2	3	2	3	3	2
RUS	Russian Federation	2	3	2	3	3	3	2	3	3	3	2	4	3	3	4
DEU	Germany	2	3	2	3	3	2	2	3	3	2	3	2	3	3	2
ZAF	South Africa	2	3	2	3	3	2	2	3	3	3	3	2	3	3	2
KOR	Korea KOR	2	3	2	3	3	4	3	4	4	3	3	2	3	3	4
POL	Poland	2	3	2	3	3	3	2	4	4	3	2	2	3	3	4
GBR	United Kingdom	2	3	2	3	3	2	2	3	3	2	3	2	3	3	2
CAN	Canada	2	3	2	3	3	2	2	2	3	3	3	2	3	3	4
THA	Thailand	2	3	2	3	3	4	3	4	4	4	3	2	3	3	4
CHN	China	2	3	2	3	3	2	2	3	3	2	3	2	3	3	2
PRT	Portugal	2	3	2	2	3	4	2	4	4	3	3	2	3	3	2
USA	United States	2	3	2	3	3	2	2	3	3	2	3	2	3	3	2
IDN	Indonesia	2	3	2	3	3	4	3	4	4	4	3	2	3	3	4
FRA	France	2	3	2	3	3	2	2	3	3	2	3	2	3	3	2
HUN	Hungary	2	3	3	2	2	3	3	2	4	3	2	4	2	2	4

Table A1. Cont.

Country Code	Country	AGRI					FERT					FORE				
		2000	2004	2008	2012	2016	2000	2004	2008	2012	2016	2000	2004	2008	2012	2016
IRL	Ireland	2	3	2	2	3	3	3	4	4	3	2	2	3	3	4
JPN	Japan	2	3	2	3	3	2	3	4	4	4	3	2	3	3	4
MYS	Malaysia	2	3	2	3	3	4	3	4	4	4	3	2	3	3	4
SGP	Singapore	2	3	2	3	3	4	3	4	4	4	3	2	3	3	4
NLD	Netherlands	2	3	2	3	3	2	2	3	3	2	3	2	3	3	2
IND	India	2	3	2	3	3	4	2	3	3	2	3	2	3	3	2
TUR	Turkey	2	3	2	3	3	4	3	4	4	3	2	4	3	3	2
BEL	Belgium	2	3	2	3	3	2	2	3	3	2	3	2	3	3	2
NZL	New Zealand	2	3	2	3	3	4	3	2	4	4	3	4	3	3	4
NOR	Norway	2	3	2	2	3	3	2	4	4	3	2	2	3	3	4
GRC	Greece	2	3	2	2	3	4	3	2	4	3	2	4	2	2	4
FIN	Finland	2	3	3	2	3	3	2	4	4	3	3	2	3	3	4
BGR	Bulgaria	2	3	2	2	2	4	3	2	4	3	2	4	2	2	4
BRA	Brazil	2	3	3	2	3	4	4	2	2	4	4	2	3	3	4
AUT	Austria	2	3	2	3	2	3	2	4	4	3	2	2	3	3	4
CZE	Czech Rep.	2	3	2	3	3	3	2	4	4	3	2	4	3	3	4
AUS	Australia	2	3	2	3	3	4	3	4	4	3	3	2	3	3	4
ESP	Spain	2	3	2	3	3	2	2	3	3	2	3	2	3	3	2
SWE	Sweden	2	3	2	2	3	3	2	4	4	3	3	2	3	3	4
DNK	Denmark	2	3	2	3	3	3	2	4	4	3	3	2	3	3	4
NAM	Namibia	3	2	3	2	1	1	1	1	1	1	1	1	1	4	3
CHL	Chile	3	2	3	2	2	2	2	2	4	3	4	3	4	4	4
TGO	Togo	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1
LKA	Sri Lanka	3	3	2	2	3	4	1	2	4	4	4	4	2	4	3
SYR	Syria	3	2	3	2	1	1	1	2	2	1	4	4	2	4	1
LUX	Luxembourg	3	2	3	2	2	1	1	1	1	1	4	4	2	2	4
MKD	Macedonia	3	2	1	2	2	4	1	2	2	1	4	4	1	2	1
VNM	Vietnam	3	3	2	2	2	4	3	4	4	4	4	4	3	3	4
ZMB	Zambia	3	2	3	2	1	1	1	2	2	1	1	1	1	1	1
MWI	Malawi	3	2	3	2	1	1	1	2	2	1	1	1	1	1	1
MLI	Mali	3	1	1	1	1	1	1	1	2	1	1	1	1	1	1
ZWE	Zimbabwe	3	2	3	2	1	1	1	2	2	1	1	1	1	1	1
COL	Colombia	3	2	3	2	2	4	4	2	2	4	4	3	4	4	3
BGD	Bangladesh	3	3	2	2	2	1	1	2	2	1	4	4	2	2	1
IRN	Iran	3	2	3	2	2	4	1	2	2	1	4	4	2	2	1
MDG	Madagascar	3	2	3	2	1	1	1	1	1	1	1	1	1	1	1
URY	Uruguay	3	2	3	2	2	4	4	1	2	4	4	3	1	4	3
TZA	Tanzania	3	2	3	2	2	4	1	2	2	1	4	1	2	1	3
GHA	Ghana	3	2	3	2	2	1	1	1	2	1	4	4	2	4	3
LBN	Lebanon	3	2	2	2	2	4	3	2	4	1	4	4	2	2	3
PHL	Philippines	3	2	2	2	2	4	3	2	4	4	4	4	2	4	3
SEN	Senegal	3	2	3	2	2	1	1	1	2	1	1	1	1	1	1
CYP	Cyprus	3	2	3	2	2	4	3	2	2	1	4	4	2	2	3
TUN	Tunisia	3	2	3	2	3	4	3	4	4	1	4	4	2	2	3

Table A1. *Cont.*

Country Code	Country	AGRI					FERT					FORE				
		2000	2004	2008	2012	2016	2000	2004	2008	2012	2016	2000	2004	2008	2012	2016
LVA	Latvia	3	2	3	2	2	3	3	4	4	3	2	4	2	2	4
SVN	Slovenia	3	2	3	2	2	4	3	2	4	1	2	4	2	2	4
ECU	Ecuador	3	2	3	2	2	4	4	2	2	4	4	3	4	4	3
GIN	Guinea	3	1	1	1	1	1	1	1	1	1	4	1	1	1	1
HRV	Croatia	3	2	3	2	2	4	3	2	2	1	2	4	2	2	4
UGA	Uganda	3	2	3	2	2	4	1	2	2	1	4	1	2	1	1
GTM	Guatemala	3	2	3	2	2	4	4	2	2	1	4	3	4	4	3
CIV	Cote d'Ivoire	3	2	3	2	2	1	1	1	2	1	4	4	2	4	3
ARE	United Arab Emirates	3	2	2	3	3	4	3	4	4	3	4	4	3	3	2
ETH	Ethiopia	3	2	3	2	2	1	1	2	2	1	1	1	1	1	1
UKR	Ukraine	3	3	2	3	2	3	2	3	4	3	2	4	2	2	4
SVK	Slovakia	3	2	3	2	2	3	3	2	4	3	2	4	2	2	4
MEX	Mexico	3	2	2	2	3	4	4	2	2	3	4	3	4	4	3
SAU	Saudi Arabia	3	2	2	2	2	4	3	4	4	3	4	4	2	2	3
EGY	Egypt	3	2	2	2	3	4	3	4	4	3	4	4	2	2	4
PER	Peru	3	2	3	2	2	4	4	2	2	4	4	3	4	4	3
KEN	Kenya	3	3	3	2	2	4	1	2	2	1	4	1	2	1	1
BLR	Belarus	3	2	3	2	2	3	3	4	4	3	2	4	2	2	4
LTU	Lithuania	3	2	3	2	2	3	3	4	4	3	2	4	2	2	4
NGA	Nigeria	3	2	3	2	2	4	1	1	2	1	4	4	2	4	3
ALB	Albania	3	2	1	2	1	1	1	1	2	1	4	1	1	2	1
MRT	Mauritania	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1
ISL	Iceland	3	2	3	2	2	1	1	1	1	1	4	1	1	2	1
BEN	Benin	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1
CMR	Cameroon	3	2	1	2	1	1	1	1	2	1	4	4	2	4	3
EST	Estonia	3	2	3	2	2	3	3	4	4	3	2	4	2	2	4
JOR	Jordan	3	1	3	2	2	4	3	4	4	3	4	4	2	2	3
MAR	Morocco	3	3	3	2	3	4	3	4	4	3	4	4	2	2	3
CRI	Costa Rica	3	2	3	2	2	4	4	2	2	1	4	3	4	4	3
ROU	Romania	3	3	3	2	2	4	3	2	4	3	2	4	3	3	4
PAK	Pakistan	3	3	2	2	3	1	1	2	2	1	4	4	2	2	3
BTN	Bhutan	4	4	4	4	4	0	0	0	0	0	1	1	1	1	1
ATF	French Southern Territories	4	4	4	4	4	1	1	1	1	1	1	1	1	1	1
ESH	Western Sahara	4	4	4	4	4	0	0	0	0	0	0	0	0	0	0
VAT	Holy See	4	4	4	4	4	0	0	0	0	0	1	1	1	1	1
VUT	Vanuatu	4	1	4	4	4	1	1	1	1	1	1	1	1	1	1
GNQ	Equatorial Guinea	4	1	1	4	1	1	1	1	1	1	1	1	1	1	1
NCL	New Caledonia	4	1	1	1	4	1	1	1	1	1	1	1	1	1	1

Table A1. Cont.

Country Code	Country	AGRI					FERT					FORE				
		2000	2004	2008	2012	2016	2000	2004	2008	2012	2016	2000	2004	2008	2012	2016
FLK	Falkland Isds (Malvinas)	4	4	4	4	4	0	0	0	0	0	1	1	1	1	1
GNB	Guinea-Bissau	4	1	1	4	4	1	1	1	1	1	1	1	1	1	1
SLB	Solomon Isds	4	1	4	4	4	1	1	1	1	1	1	1	1	1	1
SGS	South Georgia and the South Sandwich Isds	4	4	4	4	4	0	0	0	0	0	0	0	0	0	0
IRQ	Iraq	4	1	1	1	1	1	1	2	2	1	1	1	1	1	1
LSO	Lesotho	4	4	4	4	4	0	0	0	0	0	1	1	1	1	1
SOM	Somalia	4	1	1	4	1	0	0	0	0	0	1	1	1	1	1
DJI	Djibouti	4	1	1	4	1	1	1	1	1	1	1	1	1	1	1
SMR	San Marino	4	4	4	4	4	0	0	0	0	0	1	1	1	1	1
BRN	Brunei Darussalam	4	1	1	1	4	1	1	1	1	1	1	1	1	1	1
TLS	Timor-Leste	4	1	4	4	4	0	0	0	0	0	1	1	1	1	1
	Areas, nes	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2
	Other Asia, nes	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Oceania, nes	4	4	4	4	4	0	0	0	0	0	0	0	0	0	0
	Bunkers	4	4	4	4	4	0	0	0	0	0	4	4	4	4	
	Other Africa, nes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Free Zones	3	3	3	3	3	3	3	3	3	3	4	4	3	4	4
	Other Europe, nes	3		3	3	3	3	3	3	3	3	4	4	4	4	4
	Special Categories	4	4	4	4	4	4	3	3	3	3	0	0	0	0	0
	Latin American Integration Association, nes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	North America and Central America, nes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

1: core country; 2: strong semiperiphery country; 3: weak semiperiphery country; 4: periphery country; 0: no data.

Table A2. Classification list of the core–periphery structure of FOSS, META, and PEAR.

Key	Country	FOSS					META					PEAR				
		2000	2004	2008	2012	2016	2000	2004	2008	2012	2016	2000	2004	2008	2012	2016
PRY	Paraguay	1	1	1	4	1	1	1	1	3	4	1	1	1	1	1
NPL	Nepal	1	1	1	4	4	1	1	1	1	1	1	1	1	1	1
LAO	Lao PDR	1	1	1	4	4	1	1	1	1	1	1	1	1	1	1
VUT	Vanuatu	1	1	1	4	4	1	1	1	1	1	0	0	0	0	0
PNG	Papua New Guinea	1	1	1	4	1	1	1	1	1	1	1	1	1	1	1
ERI	Eritrea	1	1	1	4	4	1	1	1	1	1	0	0	0	0	0
CPV	Cabo Verde	1	1	1	4	1	1	1	1	1	1	0	0	0	0	0
ZMB	Zambia	1	1	1	1	1	1	4	2	3	1	2	1	3	2	1
SLE	Sierra Leone	1	1	1	4	1	1	4	2	3	1	1	1	1	1	1
CAF	Central African Rep.	1	1	1	4	4	1	1	1	1	1	1	1	1	1	1
KHM	Cambodia	1	1	1	4	1	1	1	1	1	1	1	1	1	1	1
AND	Andorra	1	1	1	4	4	1	1	1	1	1	2	1	1	1	1
BWA	Botswana	1	1	1	1	1	1	1	1	1	1	1	1	3	2	2
VAT	Holy See	1	1	1	4	4	1	1	1	1	1	0	0	0	0	0
RWA	Rwanda	1	1	1	1	1	1	1	1	1	3	1	1	1	1	1
BRN	Brunei Darussalam	1	1	1	4	1	1	1	1	1	1	1	1	1	1	1
COG	Congo COG	1	1	1	1	1	1	4	2	3	1	1	1	1	1	1
MMR	Myanmar	1	1	1	4	1	1	1	1	1	1	1	1	1	1	1
BDI	Burundi	1	1	1	1	4	1	1	1	1	1	0	0	0	0	0
PYF	French Polynesia	1	1	1	4	4	1	1	1	1	1	2	3	3	2	1
FJI	Fiji	1	1	1	4	1	1	1	1	1	1	1	1	1	1	1
AGO	Angola	1	1	1	1	1	1	4	2	3	1	1	1	1	1	1
GNQ	Equatorial Guinea	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
BFA	Burkina Faso	1	1	1	1	1	1	4	2	3	1	1	1	1	1	1
MOZ	Mozambique	1	1	3	1	1	1	4	2	3	1	1	1	1	2	1
BTN	Bhutan	1	1	1	4	4	1	1	1	1	1	0	0	0	0	0
ZWE	Zimbabwe	1	1	1	1	1	1	4	2	3	1	2	1	1	1	1
SLB	Solomon Isds	1	1	1	4	4	1	1	1	1	1	0	0	0	0	0
SSD	South Sudan	1	1	1	1	1	1	1	1	3	1	1	1	1	1	1
DJI	Djibouti	1	1	1	4	4	1	1	1	1	1	0	0	0	0	0
NCL	New Caledonia	1	1	1	4	4	1	1	1	3	1	1	1	1	1	1
GRL	nan	1	1	1	4	4	1	1	1	1	1	1	1	1	1	1
CUB	Cuba	1	2	1	4	1	3	4	1	3	4	1	1	1	1	1
JAM	Jamaica	1	2	1	4	1	3	4	2	3	4	1	1	1	1	1
TLS	Timor-Leste	1	1	1	4	4	1	1	1	1	1	0	0	0	0	0
SOM	Somalia	1	1	1	4	4	1	1	1	1	1	0	0	0	0	0
BOL	Bolivia	1	1	1	4	1	3	4	2	3	4	2	4	1	2	1
MNG	Mongolia	1	1	1	4	1	1	4	1	1	1	1	1	1	1	1

Table A2. Cont.

Key	Country	FOSS					META					PEAR				
		2000	2004	2008	2012	2016	2000	2004	2008	2012	2016	2000	2004	2008	2012	2016
GNB	Guinea-Bissau	1	1	1	4	4	1	1	1	1	1	0	0	0	0	0
ETH	Ethiopia	1	1	1	1	1	1	4	2	3	3	1	1	3	2	1
TZA	Tanzania	1	1	3	1	1	4	4	2	3	3	2	3	3	2	2
BGD	Bangladesh	1	1	3	1	1	1	4	2	3	1	1	1	1	1	1
AFG	Afghanistan	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
COD	Congo COD	1	1	1	4	1	1	1	1	3	1	1	1	1	1	1
FLK	Falkland Isds (Malvinas)	1	1	1	4	4	1	1	1	1	1	0	0	0	0	0
PRK	Korea PRK	1	2	1	4	4	1	4	1	3	1	1	1	1	1	1
TJK	Tajikistan	1	1	1	4	4	1	4	1	1	1	0	0	0	0	0
GUY	Guyana	1	1	1	4	1	3	4	2	3	4	1	1	1	1	1
SWZ	Swaziland	1	1	1	4	4	1	1	1	1	1	1	1	1	1	1
MAR	Morocco	1	2	1	1	3	4	2	4	4	3	1	4	4	2	2
MRT	Mauritania	1	1	1	4	1	1	4	2	3	1	1	1	1	1	1
HTI	Haiti	1	1	1	4	4	1	1	1	3	4	1	1	1	1	1
SUR	Suriname	1	1	1	4	1	1	1	1	3	4	1	1	1	1	1
TCD	Chad	1	1	1	4	4	1	1	1	1	1	1	1	1	1	1
GMB	Gambia	1	1	1	4	1	1	1	2	1	1	1	1	1	1	1
UGA	Uganda	1	1	1	1	1	1	4	2	3	3	1	1	1	1	1
URY	Uruguay	1	1	1	4	1	3	4	2	3	4	2	1	3	2	2
MWI	Malawi	1	1	1	1	4	1	1	1	1	1	1	1	1	1	1
LSO	Lesotho	1	1	1	4	4	1	1	1	1	1	1	1	1	1	1
SDN	Sudan	1	1	1	1	1	1	1	1	3	1	1	1	1	1	1
PAK	Pakistan	1	2	3	1	3	4	2	3	2	2	2	1	3	2	2
ARM	Armenia	1	2	1	1	1	1	4	4	4	3	2	4	4	2	2
NAM	Namibia	1	1	1	1	3	1	4	2	3	3	2	1	3	2	2
GIN	Guinea	1	1	1	4	1	1	4	2	3	1	1	1	1	1	1
ATF	French Southern Territories	1	1	1	4	4	1	1	1	1	1	0	0	0	0	0
SMR	San Marino	1	1	1	4	4	1	1	1	1	1	0	0	0	0	0
DOM	Dominican Rep.	1	2	1	1	1	3	4	2	3	4	1	1	1	1	1
DNK	Denmark	2	3	4	3	3	2	3	4	2	2	2	3	3	4	2
SGP	Singapore	2	2	3	2	3	2	3	3	2	2	2	3	3	4	3
IND	India	2	4	4	2	2	2	3	3	2	2	3	2	2	3	4
IDN	Indonesia	2	2	3	1	3	2	3	3	2	2	2	3	3	4	3
LVA	Latvia	2	3	2	3	3	4	4	4	4	3	1	1	4	2	2
BRA	Brazil	2	4	3	1	3	2	3	4	2	2	3	2	2	3	3
DZA	Algeria	2	2	3	1	3	4	2	4	4	3	1	1	4	1	1
POL	Poland	2	3	2	3	2	2	3	4	2	2	2	3	3	4	3
TUN	Tunisia	2	2	3	1	3	4	2	4	4	3	2	1	1	1	1
EST	Estonia	2	3	2	3	3	4	4	4	4	3	1	4	4	2	2
FIN	Finland	2	3	2	3	3	2	2	4	2	2	2	4	4	2	2

Table A2. Cont.

Key	Country	FOSS					META					PEAR				
		2000	2004	2008	2012	2016	2000	2004	2008	2012	2016	2000	2004	2008	2012	2016
THA	Thailand	2	2	3	2	3	2	3	3	2	2	4	2	2	3	4
IRL	Ireland	2	3	2	3	3	2	2	4	4	3	3	2	2	4	3
EGY	Egypt	2	2	3	1	3	4	2	3	2	2	1	1	4	1	1
BGR	Bulgaria	2	3	2	3	3	2	2	4	4	3	2	4	4	2	2
SAU	Saudi Arabia	2	2	3	1	3	4	2	4	2	2	2	4	4	2	1
CIV	Cote d'Ivoire	2	2	1	1	1	1	4	2	3	1	1	1	1	1	1
SVK	Slovakia	2	2	2	3	3	2	2	4	4	3	2	4	4	2	2
CZE	Czech Rep.	2	3	2	3	3	2	3	4	2	2	3	2	2	3	3
NOR	Norway	2	3	4	3	3	2	2	4	2	2	2	4	4	2	2
SVN	Slovenia	2	2	2	3	3	2	2	4	4	3	2	4	4	2	1
ZAF	South Africa	2	4	4	2	3	2	3	3	2	2	3	3	2	4	3
HRV	Croatia	2	3	2	3	3	2	2	4	4	3	2	1	4	2	2
HUN	Hungary	2	3	2	3	3	2	2	4	4	3	2	4	4	2	2
PRT	Portugal	2	2	3	1	3	2	2	4	2	2	2	4	4	2	2
ROU	Romania	2	3	2	3	3	2	2	4	4	3	1	4	4	2	2
MKD	Macedonia	2	2	1	1	3	1	4	4	4	3	1	1	1	1	1
AUT	Austria	2	3	2	3	3	2	3	4	2	3	3	2	2	3	3
MYS	Malaysia	2	2	3	2	3	2	3	3	2	2	2	3	3	4	2
IRN	Iran	2	2	3	1	3	4	2	4	4	3	2	4	4	1	1
ARE	United Arab Emirates	2	2	4	2	2	4	2	3	2	2	2	4	2	4	4
AUS	Australia	2	2	3	2	3	2	3	3	2	2	3	2	2	3	3
SWE	Sweden	2	3	4	2	2	2	3	3	2	2	2	4	3	2	2
LTU	Lithuania	2	3	2	3	3	4	4	4	4	3	2	4	1	2	2
GEO	Georgia	3	2	1	1	1	1	4	4	4	3	1	1	1	1	1
MEX	Mexico	3	2	3	1	3	3	2	4	4	2	2	3	3	2	3
YEM	Yemen	3	2	3	1	1	1	4	2	1	1	1	1	1	1	1
SYR	Syria	3	2	3	1	1	4	2	4	4	1	1	1	1	1	1
CMR	Cameroon	3	2	1	1	1	1	4	2	3	1	1	1	1	1	1
KWT	Kuwait	3	2	3	1	3	4	4	4	4	3	1	1	4	2	1
NGA	Nigeria	3	2	1	1	3	1	4	2	3	3	2	1	1	2	1
CRI	Costa Rica	3	2	1	4	1	3	4	2	3	4	1	4	1	1	1
PHL	Philippines	3	2	3	1	3	4	2	4	4	3	2	3	3	2	2
NER	Niger	3	2	1	1	1	1	4	2	3	1	1	1	1	1	1
KEN	Kenya	3	1	3	1	1	4	2	2	3	1	2	1	3	2	1
BEN	Benin	3	1	1	1	1	1	1	2	3	1	1	1	1	1	1
BIH	Bosnia Herzegovina	3	2	1	1	3	1	4	4	4	3	1	1	1	1	1
IRQ	Iraq	3	2	1	1	1	1	1	1	1	1	0	0	0	0	0
BHS	Bahamas	3	2	1	4	1	3	1	1	3	4	1	1	1	1	1
HND	Honduras	3	2	1	4	1	3	4	2	3	4	1	1	1	1	1
UKR	Ukraine	3	3	2	3	3	4	3	3	2	3	2	4	3	2	2

Table A2. Cont.

Key	Country	FOSS					META					PEAR				
		2000	2004	2008	2012	2016	2000	2004	2008	2012	2016	2000	2004	2008	2012	2016
NZL	New Zealand	3	2	3	1	3	2	2	4	4	2	2	3	3	4	2
TTO	Trinidad and Tobago	3	2	3	1	1	3	4	2	3	4	1	1	1	1	1
TKM	Turkmenistan	3	2	1	1	1	1	1	1	1	1	0	0	0	0	0
SEN	Senegal	3	2	1	1	1	1	4	2	4	3	1	1	1	1	1
GTM	Guatemala	3	2	1	4	1	3	4	2	3	4	1	1	1	1	1
CYP	Cyprus	3	2	3	3	3	4	4	4	4	3	2	4	4	2	1
COL	Colombia	3	2	3	1	3	3	4	2	3	4	2	3	3	2	2
AZE	Azerbaijan	3	2	2	3	3	1	4	1	4	3	1	1	1	1	1
LKA	Sri Lanka	3	2	3	1	3	4	2	4	3	3	2	3	3	4	2
NIC	Nicaragua	3	2	1	4	1	3	4	2	3	4	1	1	1	1	1
MDA	Moldova	3	2	1	1	1	1	4	4	4	3	1	1	1	1	1
ARG	Argentina	3	2	3	1	3	3	2	2	4	4	2	4	4	2	1
BLR	Belarus	3	2	2	3	3	4	4	4	4	3	1	1	1	1	1
ISL	Iceland	3	2	2	3	3	4	4	4	4	3	2	4	4	2	1
MDG	Madagascar	3	1	3	1	1	1	4	2	3	1	2	3	3	2	2
PAN	Panama	3	2	1	1	1	3	4	2	3	4	2	4	4	1	1
QAT	Qatar	3	2	3	1	3	4	4	4	4	3	1	1	4	1	1
LBY	Libya	3	2	3	1	1	1	4	4	1	1	1	1	1	1	1
ALB	Albania	3	2	1	1	3	1	4	4	4	3	1	1	1	1	1
UZB	Uzbekistan	3	2	1	1	1	1	4	1	1	1	1	1	1	1	1
JOR	Jordan	3	1	3	1	3	4	2	4	4	3	1	1	4	2	1
MLI	Mali	3	1	1	4	1	1	4	2	3	1	1	1	1	1	1
CHL	Chile	3	2	3	1	1	3	2	2	4	4	2	4	4	2	2
PER	Peru	3	2	1	1	1	3	2	2	4	4	2	3	3	2	2
ECU	Ecuador	3	2	1	1	1	3	4	2	3	4	1	1	1	1	1
VEN	Venezuela	3	2	3	1	1	3	4	2	3	4	2	4	4	1	1
VNM	Vietnam	3	2	3	1	3	4	2	3	2	3	2	4	3	2	1
KAZ	Kazakhstan	3	2	2	3	3	4	2	4	4	3	1	1	1	2	1
LUX	Luxembourg	3	2	2	3	3	2	2	4	2	2	2	4	4	2	2
GHA	Ghana	3	1	1	1	1	1	4	2	4	3	1	1	3	1	1
LBR	Liberia	3	1	1	4	1	1	1	1	3	1	1	1	1	1	1
TGO	Togo	3	1	1	1	1	1	4	2	3	1	1	1	1	1	1
BLZ	Belize	3	2	1	4	4	1	1	1	1	4	1	1	1	1	1
SLV	El Salvador	3	2	1	4	1	3	4	2	3	4	1	1	1	1	1
KGZ	Kyrgyzstan	3	2	1	3	1	1	4	1	4	1	1	1	1	1	1
GAB	Gabon	3	2	1	1	1	1	4	2	3	1	1	1	1	1	1
LBN	Lebanon	3	2	3	1	3	4	2	4	4	3	2	4	3	2	2
GBR	United Kingdom	4	4	4	2	2	2	3	3	2	2	3	2	2	3	3
GRC	Greece	4	3	4	3	2	2	2	4	2	2	2	4	3	2	2
KOR	Korea KOR	4	4	4	2	2	2	3	3	2	2	3	2	2	3	3
FRA	France	4	4	4	2	2	2	3	3	2	2	4	2	2	3	4

Table A2. Cont.

Key	Country	FOSS					META					PEAR				
		2000	2004	2008	2012	2016	2000	2004	2008	2012	2016	2000	2004	2008	2012	2016
CHE	Switzerland	4	4	4	2	2	2	3	3	2	2	4	2	2	3	3
TUR	Turkey	4	3	4	2	2	2	3	3	2	2	2	3	3	4	3
USA	United States	4	4	4	2	2	2	3	3	2	2	4	2	2	3	4
NLD	Netherlands	4	4	4	2	2	2	3	3	2	2	3	3	3	4	3
ITA	Italy	4	4	4	2	2	2	3	3	2	2	4	2	2	3	4
ESP	Spain	4	4	4	2	2	2	3	3	2	2	3	2	2	4	3
RUS	Russian Federation	4	3	2	3	2	2	3	3	2	2	2	3	3	4	3
DEU	Germany	4	4	4	2	2	2	3	3	2	2	4	2	2	3	4
BEL	Belgium	4	4	4	2	2	2	3	3	2	2	4	2	2	3	4
CAN	Canada	4	4	4	2	2	2	3	3	2	2	2	3	3	4	3
CHN	China	4	4	4	2	2	2	3	3	2	2	3	2	2	3	4
JPN	Japan	4	4	4	2	2	2	3	3	2	2	3	2	2	3	3
	Areas, n.e.s.	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2
	Other Asia, n.e.s.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Oceania, n.e.s.	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	Bunkers	4	4	4	4	4	4	4	4	4	4	0	0	0	0	0
	Other Africa, n.e.s.	3	3	2	3	3	4	4	4	4	4	0	0	0	0	0
	Free Zones	3	3	3	3	4	4	3	4	4	4	4	4	4	4	4
	Other Europe, n.e.s.	3	4	3	4	4	4	3	4		4	4	4	4	4	4
	Special Categories	2	2	2	2	2	3	2	3	3	3	0	0	0	0	0
	Latin American Integration Association, n.e.s.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	North America and Central America, n.e.s.	3	3	3	3	4	0	0	0	0	0	0	0	0	0	0

1: core country; 2: strong semiperiphery country; 3: weak semiperiphery country; 4: periphery country; 0: no data.

Appendix B

Table A3. The detailed information of the unknown regions.

Name	Explanation
Areas, n.e.s.	Used (a) for low-value trade and (b) if the partner designation was unknown to the country or if an error was made in the partner assignment. The reporting country did not send us the details of the trading partner in those specific cases. Sometimes reporters do this to protect company information.
Other Asia, n.e.s.	Refers to the unknown regions in East Asia, excluding China.
Oceania, n.e.s.	Refers to the unknown regions in Oceania.
Bunkers	Ship stores and aircraft supplies, which consist mostly of fuels and food.
Other Africa, n.e.s.	Refers to the unknown regions in Sub-Saharan Africa.
Free zones	Belong to the geographical and economic territory of a country but not to its customs territory. For the purpose of trade statistics, the transactions between the customs territory and the free zones are recorded.
Other Europe, n.e.s.	Refers to the unknown regions in Europe.
Special Categories	Used by a reporting country if it does not want the partner breakdown to be disclosed. The use of this partner code depends on the combination of reporting country, trade flow, and specific commodity.
Latin American Integration Association, n.e.s.	Refers to the unknown regions in South America.
North America and Central America, n.e.s.	Refers to the unknown regions in North America and Central America.

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