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Does infrastructure facilitate trade connectivity? Evidence from ASEAN

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ADB Working Paper Series

**DOES INFRASTRUCTURE FACILITATE
TRADE CONNECTIVITY?
EVIDENCE FROM ASEAN**

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Abstract

Infrastructural development is crucial for regional trade integration. This study investigates the extent of regional trade interdependence of the Association of Southeast Asian Nations (ASEAN) and its nexus with infrastructure. We selected 13 countries—ASEAN and three other countries (India, the People's Republic of China, and Japan) for the period 1990 to 2018. Using trade network analysis and the panel fixed-effect method, our findings show that: (1) the regional integration in the region is strong and the countries are well interconnected; (2) there is no “center–periphery” structural difference in the region; (3) there are, however, emerging *trade-intensive paths* among a few countries in the region, which implies the emergence of “exports hubs” and “suppliers of intermediate goods”; (4) the nexus between the infrastructure index and the trade connectivity are strong; (5) shipping and air transport developments have improved the trade connectivity; (6) trade costs (barriers) affect the trade connectivity negatively; and (7) foreign direct investment and trade agreements have helped in improving ASEAN's trade connectivity.

Keywords: regional trade integration, trade connectivity, trade network models, trade-intensive paths

JEL Classification: F14, F15, R40

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1. INTRODUCTION

Infrastructure development is crucial for integrating trade across countries. Inadequate development of infrastructure is one of the perpetual obstacles to cross-border trade (Limão and Venables 2001; Donaubauer et al. 2018). The existing literature has confirmed that better infrastructure facilities lead to better trade among countries (Ismail and Mahyideen 2015; Olarreaga 2016). Efficient infrastructure networks increase the linkages to global supply chains and the participation in international production networks. Thus, they facilitate the lowering of transaction costs and economies of scale by reducing the marginal costs (Brooks 2010). Over the past decades, most of the countries around the world have tried to improve their infrastructure facilities. Existing studies have also quantified the effect of trade facilitation by considering the ports, customs, telecommunications, and airports in the context of different countries (Bougheas, Demetriades, and Morgenroth 1999). However, many countries of South and East Asia still face challenges, such as high trade costs, obsolete infrastructure, cumbersome and time-consuming border procedures, and limited financial access (Francois, Manchin, and Pelkmans-Balaoing 2009). Given these challenges, the present study investigates whether infrastructure development leads to better trade connectivity among the Association of Southeast Asian Nations (ASEAN) and three further countries¹ (the People's Republic of China [PRC], Japan, and India), which we refer to henceforth as "ASEAN and three."

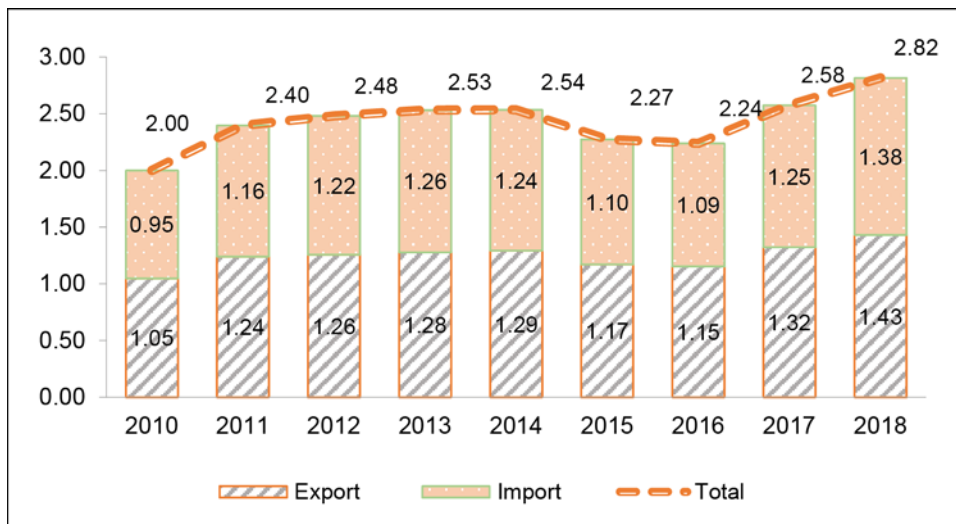
The ASEAN countries have increasingly become active players in global merchandise trade. Figure 1 shows that the trade in ASEAN has increased substantially; it was US\$2 trillion in 2010, and by 2018 it had improved to US\$2.82 trillion. Export growth was nearly US\$1.05 trillion in 2010, which increased to US\$1.43 trillion by 2018. Similarly, imports in the region were worth US\$0.95 trillion in 2010 and grew to US\$1.38 trillion by 2018. Similarly, Figure 2 shows that intra-ASEAN trade decreased over the years from 25% in 2010 to 23% in 2018. However, the region's contribution to world trade is improving, at about 7.2% in 2018. It also highlights the extra-regional trade preference of the region. The quality of the port infrastructure and customs procedures at the borders, which represent the infrastructure quality of ASEAN and three, is close to the efficiency level (Figure 3). This can contribute to the intra-regional trade.

Theoretically, Helpman and Krugman (1985), Krugman (1991), and Baldwin and Okubo (2006) discuss the importance of trade integration. Some recent studies have linked the connectivity² measures with trade and they have analyzed its relationship with infrastructure (Helble 2014; Arvis and Shepherd 2011; Shepherd 2016; Gould et al. Accordingly, the present paper aims to analyze the effect of infrastructure on trade connectivity among ASEAN and India, the PRC, and Japan. Specifically, the paper addresses the following questions: (1) Is there any trade interdependence among ASEAN and three? (2) Are there any center-periphery structures in the trade network? (3) Does the infrastructure affect trade connectivity? (4) Do the trade costs, foreign direct investment (FDI), and trade agreements affect trade connectivity?

¹ We include these three economies with the ASEAN economies because 1) India and the PRC are the largest economies in the world and have started expanding their markets and increasing their integration with ASEAN; 2) Among the Asian giants, Japan maintains well-coordinated economic relationships in the ASEAN.

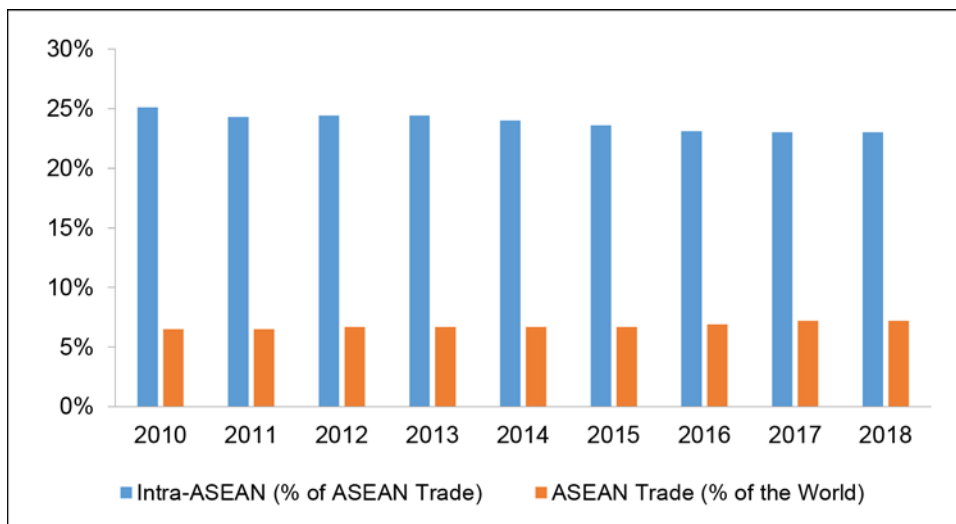
² "An intrinsic characteristic of 'connectivity' is it is synonymous with the networks, which consists of interconnected nodes. Therefore, connectivity is an attribute of a network and which is a measure of how well connected anyone node other nodes in the network" (World Bank-OECD 2019; PP:1) <https://www.oecd.org/g20/summits/osaka/G20-DWG-Background-Paper-Infrastructure-Connectivity.pdf>.

Figure 1: ASEAN Trade in Goods 2010–2018 (US\$ trillion)



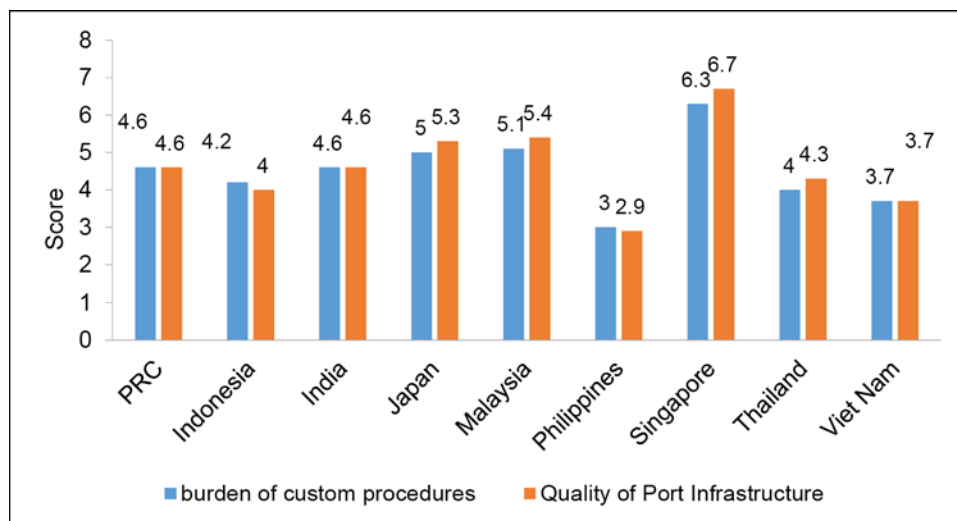
Note: This figure reports the exports, imports, and total goods trade of ASEAN countries with the world.
 Data source: ASEAN Integration Report (2019).

Figure 2: Intra-ASEAN and ASEAN (Percentage of Total World Trade) 2010–2018



The table shows the intra-ASEAN trade to the total ASEAN trade and the percentage of ASEAN trade in the world trade. The intra-ASEAN trade is between 25% and 23% from 2010 to 2018.
 Data source: ASEANstat database (retrieved February 2020).

Figure 3: The Port Infrastructure and Burden of Customs Procedures' Quality in Selected ASEAN Countries and the three Additional Countries in 2018



Note: The figure rates the quality of ports as 1=extremely underdeveloped to 7=well developed and efficient and border customs procedures as 1=extremely inefficient to 7=extremely efficient. It shows that Singapore has excellent quality of port infrastructure and less burdensome customs procedures. Malaysia and Japan follow, with scores ranging from 5 to 5.4. The rest of the ASEAN countries fall below 5.

Source: World Economic Forum, Global Competitiveness Report. Accessed from WDI (2019).

Our approach to testing the above issues is as follows. To examine the trade interconnectedness, we apply trade network analysis to 13 countries (ASEAN and three) for the period 1990–2018. We use network centrality parameters, such as density, degree, closeness, eigenvector, betweenness, and clustering, to examine the trade structure. We find that there is trade connectedness in the region, and we proceed to the next step to estimate the role of the different modes of transport in supporting trade. We also construct two control variables to estimate the role of policy and foreign investments. We apply the panel fixed-effect model. Our empirical findings suggest that (i) there is high trade integration among ASEAN, India, the PRC, and Japan; (ii) the trade density and interconnectedness have increased substantially, implying increasing trade reciprocity; (iii) there is no dominant *center* and *periphery* within the region; (iv) Japan, Thailand, Singapore, Malaysia, and the PRC act as export hubs and suppliers of intermediate goods; (v) hard infrastructure is critical in trade connectivity; (vi) trade costs (tariffs) negatively affect trade connectivity; and (vii) foreign direct investment (FDI) and free trade agreements foster trade connectivity.

We can summarize our contributions to the existing literature as follows: first, our study is one of the first attempts to examine the link between trade and infrastructure through the network perspective in the context of ASEAN. Second, the literature has thus far ignored the “center-periphery relationship” within the ASEAN; hence, this study also attempts to bridge this divide. Third, our finding a “*trade intensive path*” within the ASEAN and India, PRC, and Japan provides a source to frame appropriate policies in the region. Finally, this study supplements the existing literature on infrastructure and trade, such as Arvis and Shepherd (2011), Helble (2014), and Shepherd (2016).

The organization of the paper is as follows. Section 2 discusses a review of the literature concerning trade network analysis, regional trade integration, and the nexus between infrastructure and trade. Section 3 presents the data, and section 4 describes the methodology. Section 5 discusses the results. Section 6 concludes.

2. LITERATURE REVIEW

It is possible to divide the literature broadly into four strands: (A) theoretical background; (B) network analysis and trade; (C) trade integration and its impact; and (D) the role of infrastructure and trade.

2.1 Theoretical Background

The classical and neoclassical trade theories emphasize comparative advantage models and ignores the transport costs. However, the new trade theory identified transport cost and increasing returns as the determinants of trade patterns. Many studies have examined the importance of trade interconnectedness and its positive spillover effects (Krugman 1991; Baldwin and Okubo 2006). The Helpman and Krugman's (1985) model proved the importance of scale (economies of scale) in determining trade patterns. Importantly, transport costs play a crucial role in trade integration (Krugman and Venables 1990). The authors argued that a reduction in transport costs and trade costs intensifies trade integration. An increase in trade integration reduces geodesic distance between countries over the years. Importantly, for a single country, the doubling in the number of trading countries eventually lowers transport costs (Krugman 1991). Similarly, trade facilitation plays a significant role in trade interconnectedness. The quality of both soft and hard infrastructural development matters in regional trade integration. An increase in trade barriers or costs and poor quality of the infrastructure negatively affect the trade connectivity in the regions.

2.2 Network Analysis and Trade

Many studies discuss social and economic aspects using network analysis. This study examines the networks in the realm of international trade. Some early studies analyzed networks in the context of trade protectionism, specifically, the relationship between the "center" and "periphery" during times of high protectionism. Specifically, research has investigated the relationship between the "center" and the "periphery" during periods of high protectionism. The works of Snyder and Kick (1979) and Smith and White (1992) examined the world system theory and the world economic system that prevailed during the 1980s. However, the period after 1990 witnessed considerable changes in the world economic system. Globalization and technological developments facilitated trade integration among countries. However, few studies examined binary trade networks between countries, and measured trade flow to find its intensity (De Benedictis and Tajoli 2011). Some studies applied the weighted network approach to analyze the pattern of trade integration (Garlaschelli and Loffredo 2004). Kali and Reyes (2007) discussed the hierarchical structure of core and periphery positioning in global trade. Similarly, Amador and Cabral (2016) examined networks of Global Value Chains (GVCs).

Gould, Kenett, and Panterov (2018) analyzed multidimensional connectivity with the application of trade networks. They found that migration, internet connection, and FDI are the main channels determining growth. Arvis and Shepherd (2011) applied network connectivity to analyze the world air transport for 211 countries. The study analyzed the hub-and-spoke relationship in air transport networks. In a recent study, Vidya et al. (2020) examined trade interconnectedness in a cross-country sample of 50 countries using the network model. The study finds that the emerging economies of Asia, such as India and PRC, have become leaders in world trade networks. However, over the years, there is no reduction in the geodesic distance among them, which implies scant gains

from trade due to trade integration. Most recently, Vidya and Prabheesh (2020) found that world trade is changing after the Covid-19 pandemic.

2.3 Trade Integration and its Impact

Most studies on trade integration have emphasized the elimination of barriers and trade costs to promote economic integration (Kahnert et al. 1969). Some studies show that that trade integration promotes economic growth (Rodriguez and Rodrik 2000). Specifically, they have found that regional and preferential trade agreements facilitated the improvement of regionalization among member countries (Frankel, Stein, and Wei 1995; Thangavelu and Chongvilaivan 2009). Furthermore, most of these studies have found that regionalization can increase the growth, competitiveness, and investments in the member countries. Studies have also pointed out the prevalence of barriers preventing the ASEAN countries from achieving the fullest benefit from regional trade integration. Among these are the non-tariff barriers (NTBs) in the region.

2.4 Role of Infrastructure in Trade

Prior literature (Anderson and Wincoop 2004; Brooks and Menon 2008) has analyzed the relationship between international trade and infrastructure and found that there is a substantial impact on the latter. Portugal-Perez and Wilson (2012) analyzed the role of physical and soft infrastructure in trade facilitation. They found that infrastructure plays a crucial role in Southeast Asian countries. Francois and Manchin (2013) and Donaubauer et al. (2018) constructed an infrastructure index and found a significant impact on trade. These infrastructure indices captured a larger set of variables—transport, communication, financial, and so on. Energy is yet another significant variable that impacts trade (Garsous 2012). Helble (2014) included shipping, air connectivity, and frequency, in their analysis of Pacific nations. They found that direct connectivity and frequency had a high impact on trade. Similarly, trade cost, as a proxy for tariff rates affects trade relationships, as demonstrated by Novy (2013).

3. DATA

The paper used the data on bilateral trade in goods among the ASEAN, specifically Indonesia, Thailand, Brunei Darussalam, Singapore, the Philippines, Malaysia, Viet Nam, Cambodia, Myanmar, and the Lao People's Democratic Republic (Lao PDR). We also added three Asian countries from different regions: India, the PRC, and Japan. We first conducted the network analysis to check the interdependence among the ASEAN and the three countries for the continuous period 1990–2018. We chose 1990 as the starting year of the analysis because of the complete data available from this year. We accessed the bilateral data from the WITS World Bank database.

For the network analysis, we constructed a bilateral trade matrix. The matrix is nothing but a representation of each cell showing the exports from country one to country two and their imports. As the first step, we established the trade interconnectedness, and later we moved to the second step, which was to analyze the nexus between trade connectivity and infrastructure. We applied the panel fixed-effect model for estimation purposes to the period 1990–2018 (see Table 1 for a description of our data, sources, and sample).

Table 1: Data and Variable Description for the Panel Estimations

Variable	Description	Definition	Source
Dependent Variable			
$Trade_Connectivity_{ijt}$	Trade connectivity	Natural logarithm of eigenvector centrality (EVC) based on the matrix of bilateral trade flows derived using network analysis	Author's calculations
Independent Variable			
$GDPPC_{it}$	GDP per capita	Natural logarithm of per capita GDP in ppp terms	World Development Indicators (WDI)
$Infra_{it}$	Infrastructure index	Natural logarithm of the infrastructure index. The index is the PCA of four indicators: fixed telephone subscriptions (per 100 people), air transport (freight) million ton-km, energy use (kg of oil equivalent per capita), and electric power consumption (kwh per capita)	Author's own calculation based on WDI
TC_{ijt}	Trade cost	Natural logarithm of the simple average of the aggregate tariff	WITS-TRAINS
$Transport_Air_{it}$	Air transport	Natural logarithm of air transport freight (million ton-km)	WDI
$Power_{it}$	Power consumption	Natural logarithm of electric power consumption (kwh per capita)	WDI
$Ship_connectivity_{it}$	Shipping connectivity index	Natural logarithm of the liner shipping connectivity index	WDI
FDI_{it}	Foreign direct investment	Natural logarithm of FDI inflows in US\$ million	WDI
$FDI_{it} \times RTA_{it}$	FDI multiplied by free trade agreement	FDI and FTA are the number of free trade agreements for each country specific to the region	WDI

4. METHODOLOGY AND EMPIRICAL MODEL

4.1 Network Model Estimation

To explore the trade interdependence among the ASEAN and three, first, we estimated the network model. We constructed an undirected matrix of networks for a total 13 countries from 1990 to 2018. Subsequently, we undertook the following steps. We calculated an export matrix X , and the value of X_{ij} shows the average exports from and imports to countries. We term this the “trade matrix” henceforth. Importantly, we used a trade matrix to construct an undirected network graph among the countries. Notably, an edge occurs between two nodes and if the value of the threshold is greater than 0. We considered a threshold of 0 here.

A network model explains the nexus between different elements, such as nodes and edges. Generally, nodes act as individual actors and edges show the relationships between the nodes. Every node has an in-degree and an out-degree. An in-degree is the number of incoming edges, representing imports, and the out-degree is the number of outgoing edges, representing exports. Table 2 provides the terms and descriptions of the parameters that we used in the network analysis.

Table 2: Definition of the Parameters in the Network Models

Term	Description of the Network Parameter
Degree centrality	This shows the position of a node in a network and its importance in a network structure. It represents the trade interconnectedness.
Eigenvector centrality (EVC)	This indicates the significance of each node to other nodes around it. In this study, the countries that show high EVC are highly connected to all the countries. This represents the connectivity measure.
Closeness centrality	The parameter that defines how close one node is to all the remaining nodes. It includes the topological distance between the countries. The parameter measures the geodesic distance.
Betweenness centrality	The number of short paths that pass through the vertex. It represents the dependency.
Density	This represents the trade density among the countries.
clustering coefficient	This shows the network density.

Note: Table 2 describes the definition and implications of the parameters used in the network model.

4.2 Empirical Model

As the second step, we analyzed the impact of infrastructure on trade. We estimated the following three empirical models using the panel estimation fixed-effect model, in which the dependent variable “trade connectivity” is the eigenvector centrality that we derived from the network model. “Connectivity is considered as a key ‘policy’ concept and lacks a rigorous empirical framework” (Arvis and Shepherd 2011). Hence, this study ³uses a rigorous approach to perform a panel estimation on the sample.

$$\ln(\text{Trade_Connectivity}_{ij}) = \beta_0 + \beta_1 \ln(\text{GDPPC}_i) + \beta_2 \ln(\text{Infra}_{i_t}) + \beta_3 \ln(\text{TC}_{ij}) + u_{it} \quad (1)$$

$$\ln(\text{Trade_Connectivity}_{ij}) = \beta_0 + \beta_1 \ln(\text{TC}_{ij}) + \beta_2 \ln(\text{Transport_Air}_{i_t}) + \beta_3 \ln(\text{Power}_{i_t}) + \beta_4 \ln(\text{FDI}_{i_t}) + u_{it} \quad (2)$$

$$\ln(\text{Trade_Connectivity}_{ij}) = \beta_0 + \beta_1 \ln(\text{Infra}_{i_t}) + \beta_2 \ln(\text{TC}_{ij}) + \beta_3 \ln(\text{Ship_connectivity}_{i_t}) + \beta_4 \ln(\text{FDI}_{i_t} \times \text{FTA}_{i_t}) + u_{it} \quad (3)$$

The above equations (1–3) represent the bilateral trade data; i stands for the home country and j stands for the trading partner countries. *Trade_Connectivity* denotes the eigenvector centrality (EVC) of the bilateral trade of the respective countries. EVC measures connectivity all the countries for the nodes in the network graphs.⁴ *GDPPC* denotes the GDP per capita, which is the proxy for economic development. *Infra* denotes the infrastructure index, and we construct it using the principal component analysis (PCA) summation of four variables. These variables are as follows; fixed telephone lines (per 100 people), air transport freight in ton-km, energy use in kg of oil equivalent per capita denomination, and electric power consumption in kwh per capita. We expected a positive association between infrastructure and trade, showing that regional infrastructure indicators such as transport, communication, and energy are important factors for trade connectivity.

³ In this section, we modeled the estimation in line with Shepherd (2016).

⁴ Studies in the literature have previously used the EVC (De Benedictis et al. 2014; Shepherd 2016), which measures each country’s position in the trade network.

Similarly, we obtain the simple average of aggregate tariff data for each country by dividing the aggregate tariff rate of each country by the sum of countries. As TC increases, the trade connectivity among the countries decreases, implying a negative relationship.

To minimize the possible omitted variable bias in the main variables, we included the control variables FDI_{it} and FTA_{it} . We based the rationale underlying our selection of these variables on previous studies on the trade and infrastructure nexus (Francois and Manchin 2013). FDI_{it} is the foreign direct investment inflows to each country for the period 1990–2018. As the FDI inflow increases, it increases the trade connectivity among the countries. Similarly, FTA_{it} shows the number of free trade agreements among the ASEAN and the three countries. We considered FTA_{it} as a trade policy variable.

In the second model (2), there are two new variables. They are $Transport_Air$ and $Ship_connectivity$. $Transport_Air$ is the air transport and freight in million ton-kilometers. It defines the volume of the freight in millions of tons. We took this variable from the WDI of the World Bank.

In the third model (3), we added a new variable, $Ship_connectivity$, which is the shipping connectivity index. It measures the world shipping networks of each country.

In addition, the β_i s in the models are the parameters to estimate and the models express all the variables in logarithmic form (\ln). Table 1 contains a description of the explanatory variables and the dependent variable.

5. RESULTS AND DISCUSSION

This section discusses the estimation results. Section 5.1 presents the network analysis results, and section 5.2 presents the panel fixed-effect results.

5.1 Results and Discussion of Network Analysis

We consider 13 countries in a bilateral trade matrix for the years 1990, 1992, 1995, 2000, 2005, 2010, 2015, and 2018. A visual representation of the network graphs can provide vital information on trade integration. The complete results from 1990–2018 are difficult to present in this paper because of their complexity. Therefore, we show the network parameters of certain years in Table 3 and include full period of study from 1992 to 2018 and the full series in Table 1 Appendix I.

Trade density improved from 0.679 in 1990 to 0.846 in 2018. This highlights the increasing trade density among the ASEAN, India, the PRC, and Japan.

Similarly, the *degree centrality* (DC) measures the trade interconnectedness. The DC is between 0 and 1. The DC of the ASEAN and three increased from 1990 to 2018 (see Table 3). The value in 1990 was around 0.662, and it spiked to 0.795 in 1995. Later it rose to 0.962 between 2000 and 2005. The high degree centrality is due to the increased trade reciprocity. There are a number of RTAs and FTAs among the ASEAN and three.

In 1990, the *closeness centrality* was around 0.788, and it increased to 0.967 by 2000 and rose to 0.907 by 2018. This implies that the geodesic distance has decreased among the ASEAN and three, thus suggesting that the countries have become closer over the years.

Table 3: Parameters of the Network Analysis

Year	Density	Degree Centrality	Eigenvector Centrality	Betweenness Centrality	Closeness Centrality	Clustering Coefficient
1990	0.679	0.662	0.269	0.029	0.788	0.843
1992	0.679	0.679	0.269	0.029	0.788	0.843
1995	0.795	0.795	0.273	0.019	0.855	0.874
2000	0.962	0.962	0.277	0.003	0.967	0.965
2005	0.962	0.962	0.277	0.003	0.967	0.965
2010	0.868	0.929	0.277	0.012	0.934	0.988
2015	0.879	0.941	0.277	0.012	0.934	0.988
2018	0.846	0.905	0.277	0.009	0.907	0.980

Note: This table discusses the results of the parameters of the network analysis.

Source: Author's analysis using network models.

Similarly, the *eigenvector centrality* explains the *connectivity* measure. The median value in 1990 was 0.269; in 2000, it was 0.277, and this value remained unchanged until 2018. The metric as almost stable from 2000 to 2018. Hence, it implies that the countries that trade in the regions trade closely and are well connected within the region but not with the rest of the region. Explicitly, trade connectivity became centripetal in ASEAN.

The *betweenness centrality*, which represents the *dependency*, fell to 0.029 in 1990 and to 0.003 in 2000. Later, the metric shows catching up to 0.012 (2010–2015) and a further fall to 0.009 in 2018. Hence, it indicates that there is growing trade integration in the region. The theory states that high betweenness centrality implies that the country plays an important role in connecting other countries, probably as an intermediary that consumes raw materials and produces finished goods (Zhao 2017). In the present study, Japan, Thailand, Singapore, Malaysia, and the PRC act as export hubs and suppliers of intermediate goods.

Similarly, the network density appears as a clustering coefficient. The network density was around 0.843 during 1990, and it increased to 0.965 (2000) and 0.980 in 2018. Hence, it indicates growing regional trade integration and trade interconnectedness. Therefore, we can discern from the trade integration before and after ASEAN-10⁵ that the trade intensity among the member countries increased substantially after the year 2000. The trade relationships among the member countries and Japan, India, and the PRC became denser, more interconnected, and increasingly close over the years. Importantly, trade in the region turned asymmetric and highly regionalized. In fact, trade connectivity became centripetal in ASEAN.

The results from the EVC are from the bilateral trade links (see Table 4). In 1990, the highest connectivity scores were for India, Japan, Thailand, and Malaysia and the lowest connectivity scores were for Brunei Darussalam, Viet Nam, Cambodia, and the Lao PDR. The post-trade liberalization (post-1995) resulted in a tangible improvement in connectivity in the intra-regional trade. Except for Brunei Darussalam, almost all the ASEAN and India, PRC and Japan improved their trade connectivity. In 2015, Myanmar made drastic changes to its connectivity trends.

⁵ The ASEAN-10 formed on 30 April 1999.

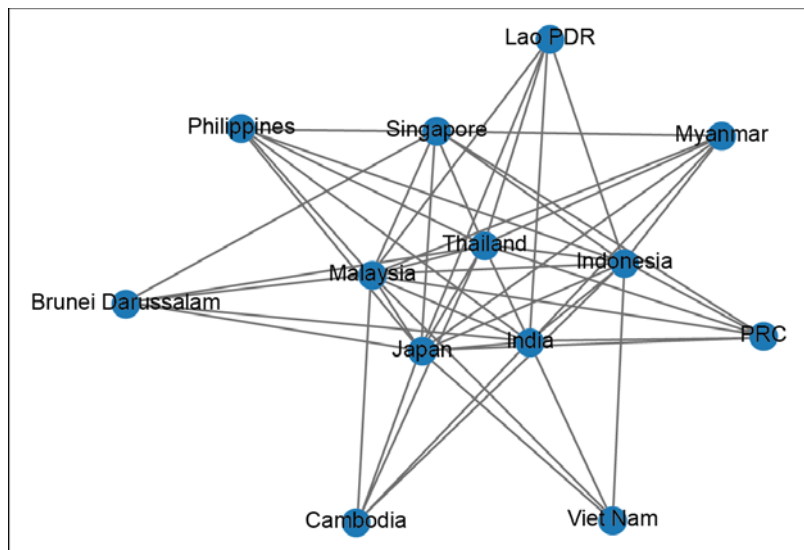
Table 4: Eigenvector Centrality (Connectivity) for Bilateral Trade in Goods, 1990–2018

Country	1990	1992	1995	2000	2005	2010	2015	2018
India	0.35	0.30	0.32	0.29	0.29	0.28	0.28	0.28
Japan	0.35	0.30	0.32	0.29	0.29	0.28	0.28	0.28
Malaysia	0.35	0.30	0.32	0.29	0.29	0.28	0.28	0.28
Thailand	0.35	0.30	0.32	0.29	0.29	0.28	0.28	0.28
Indonesia	0.33	0.30	0.30	0.29	0.29	0.28	0.28	0.28
Singapore	0.29	0.30	0.32	0.29	0.29	0.28	0.28	0.28
PRC	0.23	0.30	0.32	0.29	0.29	0.28	0.28	0.28
Myanmar	0.23	0.27	0.22	0.25	0.25	0.28	0.30	0.31
Philippines	0.23	0.22	0.22	0.29	0.29	0.28	0.28	0.28
Cambodia	0.20	0.22	0.22	0.29	0.29	0.28	0.28	0.24
Lao PDR	0.20	0.20	0.22	0.25	0.25	0.28	0.28	0.24
Viet Nam	0.20	0.25	0.22	0.29	0.29	0.28	0.28	0.24
Brunei Darussalam	0.19	0.27	0.19	0.25	0.25	0.28	0.28	0.28

Note: The table shows the indicator of a country’s overall place in the world trade network.
 Source: Author’s analysis.

Figure 4 provides the network graphs of the ASEAN and India, the PRC and Japan for the year 1990. In 1990, the countries in the *center* were Thailand, Malaysia, Japan, and India, whereas the periphery included Brunei Darussalam, the Philippines, Singapore, the Lao PDR, Cambodia, Indonesia, Myanmar, the PRC, and Viet Nam. Strikingly, the map reveals a thick black line passing through a few countries. We call it the *trade-intensive path*. The path starts in Singapore, passes through Thailand, reaches India, and stretches to Viet Nam. The networks highlight the trade connections and emergence of within interconnections.

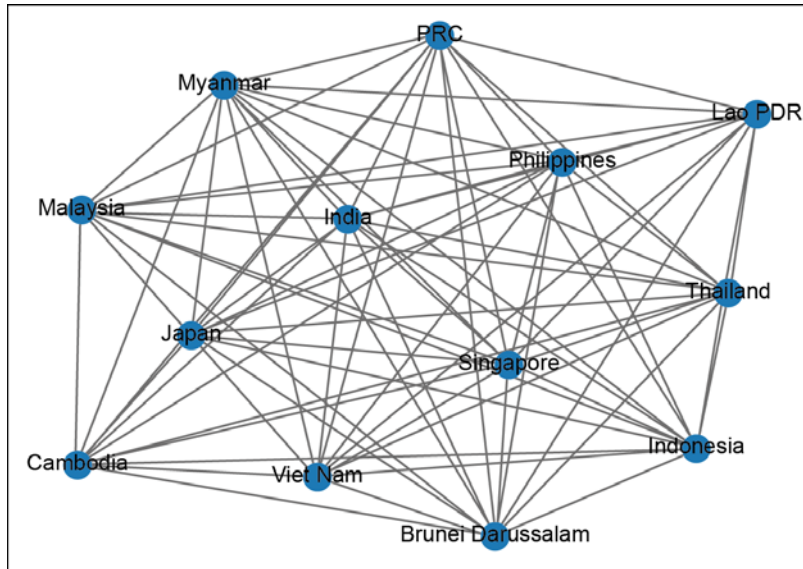
Figure 4: Network of Trade in Goods, 1990



Source: Author’s analysis.

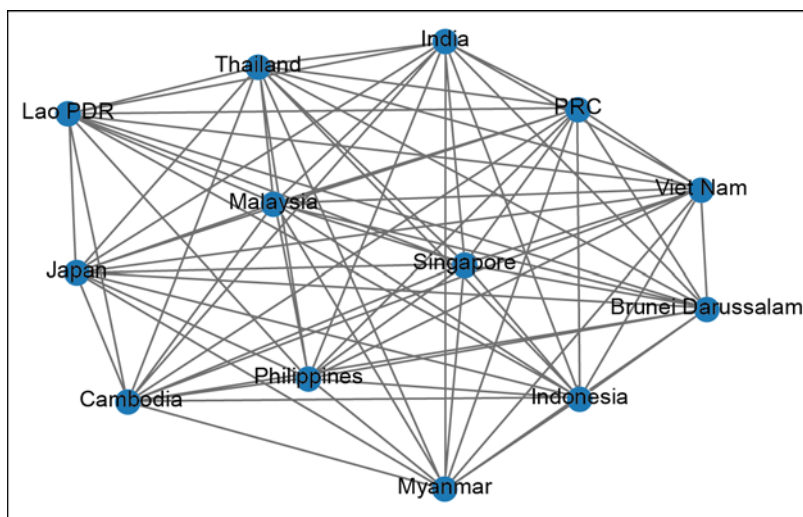
We plotted year 1992 (Figure 5) to show a complex network graph. It was in the 1990s that most of the countries in Asia began to liberalize their markets. Trade openness and liberalization helped expand and diversify trade across borders. India, Singapore, Japan, the Philippines, and Viet Nam are the center of the networks. The *trade-intensive path* was between the PRC, Japan, and Cambodia.

Figure 5: Network of Trade in Goods, 1992



Source: Author's analysis.

Figure 6: Network of Trade in Goods, 2000

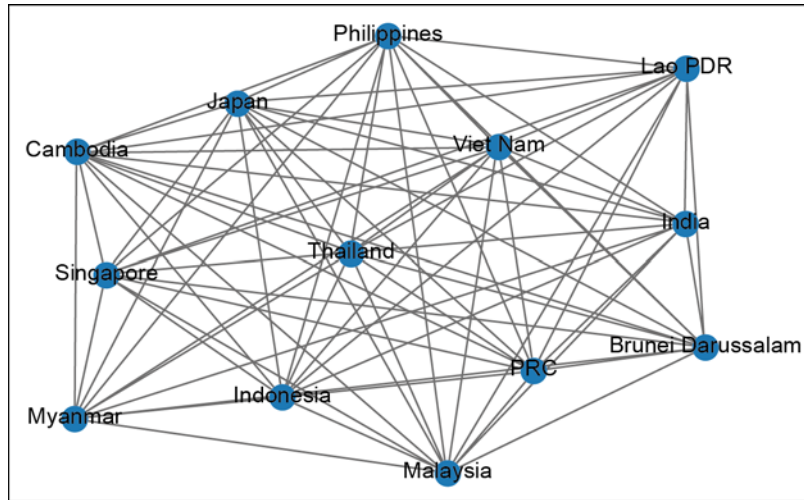


Source: Author's analysis.

Noticeably, by 2000 (Figure 6), there was a substantial change in the trade connectivity. Malaysia and Singapore concentrated on the center and were the main centrifugal force in deciding the trade relationships. Although we can see multiple thick lines (*trade-intensive paths*) on the map, the most prominent among them is Thailand–Malaysia–the Philippines–India. Another striking feature of the trade connectivity map for the year 2005 is the leadership of Thailand. Thailand became the

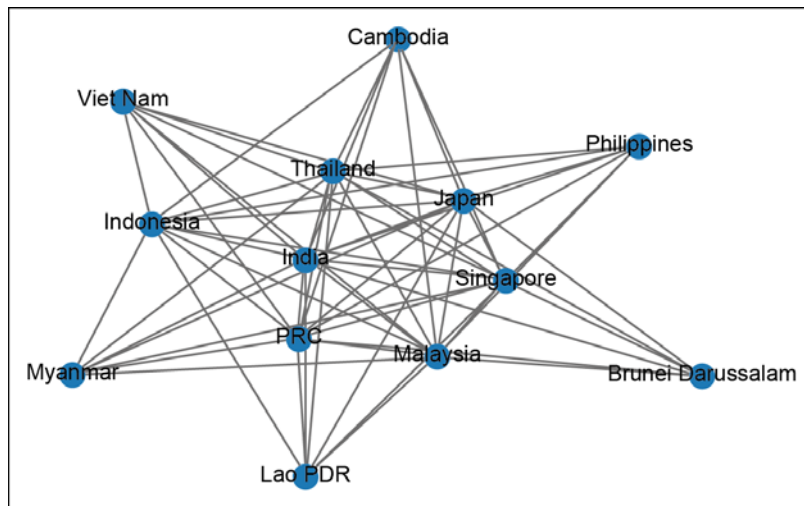
core or dominant country in ASEAN and three. As Figure 7 shows, most of the nodes and edges pass through Thailand, implying the emergence of the country as a reliable trade partner for many. We can also consider it as the export hub that supplies raw materials.

Figure 7: Network of Trade in Goods, 2005



Source: Author's analysis.

Figure 8: Network of Trade in Goods, 2015

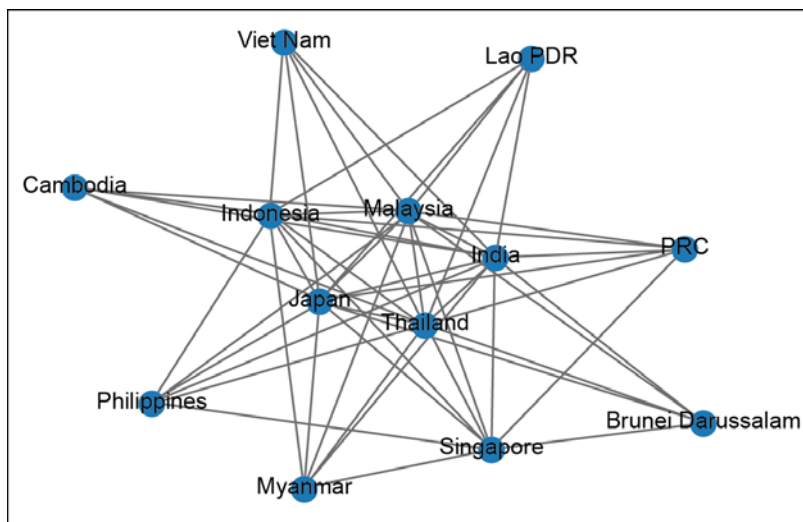


Source: Author's analysis.

Figure 8 presents the map for 2015. The nodes and edges in the trade network became denser but less complicated. The 2015 map is more symmetric and definite in the relationships among countries than the previous trade networks. The 2015 map is more symmetric and definite in the relationships among countries than the previous trade networks. Some of the explicit routes are (i) Cambodia–Thailand–India–the PRC; (ii) Japan–Singapore–Thailand; (iii) Japan–India–Thailand; and (iv) Thailand–Malaysia–Japan.

The most recent trade network map is for the year 2018 (see Figure 9). Unlike the previous maps, it represents a more transparent and distinct trade interconnection. The *central* countries in the network are Indonesia, Japan, Thailand, India, and Malaysia. We presume the *trade-intensive paths* are apparently Indonesia–Japan–Malaysia; (ii) Japan–Malaysia–Thailand; and (iii) Malaysia–Thailand–India.

Figure 9: Network of Trade in Goods, 2018



Source: Author's analysis.

5.2 Results and Discussion—Trade Connectivity and Its Determinants

Table 5 shows the results of three basic tests that we conducted as a primary step before proceeding to the panel data model. The tests are the likelihood ratio (LR), F-test, and Hausman specification test. The test results of the LR and the F-test reject the null hypotheses $H_0: \sigma_u^2 = 0$ and $H_0: \sigma_u^2 = \sigma_\lambda^2 = 0$ at the 1% level of significance, showing the presence of both country and time effects in the data. The Hausman specification test is significant at the 1% level (Table 6). It rejects the null hypothesis stating that individual country-specific effects are uncorrelated with the regressors in the model. Hence, we conclude that the fixed-effect model is preferable to the random-effect model. The panel unit root results, which Table 2 Appendix II presents, do not show any evidence of non-stationarity in the panel.

Table 6 presents the fixed-effect model results. The results infer that all the independent variables in the models are statistically significant and exhibit the theoretically expected sign. The variable $GDP_{PC_{it}}$ has a positive relationship with trade connectivity, indicating that a rise in GDP per capita positively influences the trade connectivity among the countries. Likewise, the variable $Infra_{it}$, the infrastructure index, shows a positive and significant impact on trade connectivity. Hence, the development of hard infrastructure is crucial for trade connectivity. This is similar to the findings of Francois and Manchin (2013).

Table 5: LR and F-test Results for the Significance of the Country and the Time Effect

Type of Test	$H_0 : s_u^2 = 0$	P-value	Model 2	$H_0 : s_u^2 = s_t^2 = 0$	P-value	Model 3	$H_0 : s_u^2 = s_t^2 = 0$	P-value
LR	χ^2 (01)=261.08	0.00	LR	χ^2 (01)=178.95	0.00		χ^2 (01)=4.04	0.00

Table 6: Panel Fixed-Effect Model

Variables	Model 1	Model 2	Model 3
<i>GDPPC_{it}</i>	0.340 (0.113)***		
<i>Infra_{it}</i>	0.017*** (0.006)		0.011*** (0.003)
<i>TC_{ijt}</i>	-0.177 (0.018)	-0.218 (0.019)	-0.011 (0.023)
<i>Transport_Air_{it}</i>		0.017*** (0.006)	
<i>Power_{it}</i>		0.072*** (0.020)	
<i>Ship_connectivity_{it}</i>			0.022*** (0.011)
<i>FDI_{it}</i>		0.575*** (0.232)	
<i>FDI_{it} × FTA_{it}</i>			0.006*** (0.002)
Constant	1.520*** (0.123)	1.942*** (0.152)	0.730 *** (0.131)
N	279	279	279
<i>Adj R²</i>	0.28	0.32	0.32
F-stat	14.29 (0.00)	13.13 (0.00)	9.74 (0.00)
Hausman spec	17.89 (0.00)	20.66 (0.00)	129.50 (0.00)

Note: Standard errors are in parentheses below the parameter estimates. Statistical significance is as follows: (10) *; (5) **; and (1) ***.

Conversely, *TC_{ijt}*, the trade costs, representing the simple average bilateral tariff rates among the countries in the region, shows a negative and significant impact. The results show that an increase in the trade costs negatively affects the trade connectivity among the countries. The variable shows a significant but negative effect on, and a very small percentage change in, the trade connectivity. The theoretical underpinning (Krugman 1991) pointed out that a reduction in trade costs leads to a greater geographical concentration of production and trade integration. Importantly, when the trade costs of the intermediate inputs drop substantially, they facilitate fragmented trade in different locations of the region (WTO) 2008).

In the second model, instead of the infrastructure index, we included *Transport_Air_{it}* and *Power_{it}* as separate infrastructural variables. Both the variables are positive and significant. However, they show a very small amount of change in the dependent variable. Apart from the infrastructural variables, we included the control variable *FDI_{it}*. As expected, it shows a positive and significant impact. The FDI coefficient influences the host countries in multiple ways, such as the development of multinational firms in the

host country, technological development, and infrastructural development. Hence, the positive spillover benefits the acceleration of strong trade connectivity. Similarly, the interaction of FDI with FTAs reveals the policy implication. The ASEAN have a high number of FTAs. The impact of more FTAs among the ASEAN and India, PRC, and Japan, has encouraged more FDI, contributing to trade growth.

The third model highlights that $Infra_{it}$, the infrastructure index, and $Ship_connectivity_{it}$, the shipping connectivity, show a positive and significant change. To capture the benefits of the policy, we included an interaction term, free trade agreement (FTA_{it}), along with FDI_{it} . The positive and significant interaction term conveys that trade agreements play a crucial role in eliciting foreign investments and facilitating better trade connectivity. Finally, in Table 3 Appendix III, we report the findings from the robustness test based on two-stage least squares (2SLS). This methodology takes into account any endogeneity issues between the variables in the model. The findings from the 2SLS estimation also do not alter the overall conclusion.

6. CONCLUSION AND POLICY IMPLICATIONS

The paper investigated the trade interdependence of ASEAN economies and the nexus between infrastructure and trade connectivity. We considered 13 countries—the ASEAN countries and three selected partners (India, the PRC, and Japan)—for the period 1990 to 2018. We used network analysis to estimate trade interdependence and the panel fixed effects model to estimate the determining factors of trade connectivity.

The first result confirms the growing and high trade integration among ASEAN and three. Trade density and interdependence increased substantially over the years from 1990. However, there are no dominant center and periphery within the region. Many developing countries in the region have moved to the center. In 1990, countries like India, Japan, Indonesia, Malaysia, Thailand, and Singapore were at the center. However, by the mid-1990s, many developing economies, such as the Philippines, Myanmar, and Viet Nam, approached the center of the trade networks. Hence, trade integration has benefitted the developing economies of the ASEAN and three countries. Trade integration and intensity increased substantially after 2000. The trade relationship of ASEAN with India, the PRC, and Japan improved Significantly.

Moreover, the study found “trade-intensive paths” within the region, as the network maps show. A prominent path among them is Thailand–Malaysia–Japan. The emergence of Thailand as a leader is notable. Thailand is the only country in the center of most of the network maps for the period 1990–2018. Specifically, during 1990, 2005, 2015, and 2018, Thailand was at the center. Similarly, India approached the center in 1992, 2015, and 2018.

In terms of other parameters of the network maps, we find that trade density has increased substantially. The geodesic distance among ASEAN and India, the PRC, and Japan has decreased over the years. Importantly, the closeness has narrowed. The trade interlinkages are dense and hence, we find a strong trend of trade regionalization. The high degree centrality is due to the increased trade reciprocity and the RTAs and FTAs in the region and with India, the PRC, and Japan. The countries are well connected within the region but not with the rest of the region. Explicitly, trade connectivity has become centripetal in the ASEAN. In this study, Japan, Thailand, Singapore, Malaysia, and the PRC act as export hubs and suppliers of intermediate goods.

Our second analysis aimed to connect trade connectivity and infrastructural development; for this, we estimated a fixed-effect panel model. We found a positive relationship between connectivity and infrastructure but a negative effect of the variable trade cost (a proxy for trade barriers) on trade connectivity. Similarly, air transport and shipping connectivity play a crucial role in increasing trade connectivity. Apart from infrastructural developments, the reduction of tariffs and non-tariff barriers in reducing the trade costs. A reduction in trade costs can enhance trade facilitation and future trade prospects for the region. The increasing trade fragmentation advocates barrier-free markets and reduces cost and time at the borders. Hence, technology plays a crucial role in the digitization process and trade facilitation. We recommend developing the quality of infrastructure and investment in soft infrastructure (trade facilitation programs). This study found that the ASEAN and India, PRC and Japan are export hubs for intermediate markets within the region; this can expand the connectivity beyond the region too. The ASEAN and India, PRC and Japan can develop the region as both exporters and suppliers for Asia and Europe. We argue that, given the high intra-regional trade connectivity among ASEAN, policy makers in this region should consider “trade-intensive paths” to position the production and supply among the ASEAN and its leading partners. Moreover, the ongoing Covid-19 pandemic encourages the movement toward regional supply chains and regionalization in trade.

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APPENDIX I

Table A1: Parameters of the Network Analysis, 1990–2018

Year	Density	Degree Centrality	Eigenvector Centrality	Betweenness Centrality	Closeness Centrality	Clustering Coefficient
1990	0.679	0.662	0.269	0.029	0.788	0.843
1991	0.679	0.679	0.269	0.029	0.788	0.843
1992	0.758	0.811	0.275	0.024	0.846	0.898
1993	0.846	0.980	0.274	0.014	0.886	0.897
1994	0.859	0.859	0.274	0.013	0.895	0.902
1995	0.795	0.795	0.273	0.019	0.855	0.874
1996	0.859	0.859	0.274	0.013	0.895	0.902
1997	0.923	0.978	0.276	0.007	0.938	0.937
1998	0.910	0.910	0.276	0.008	0.929	0.931
1999	0.872	0.872	0.275	0.012	0.904	0.907
2000	0.962	0.962	0.277	0.003	0.967	0.965
2001	0.857	0.917	0.277	1.551	0.925	0.976
2002	0.987	0.987	0.277	0.001	0.988	0.987
2003	0.987	0.987	0.277	0.001	0.988	0.987
2004	0.987	0.987	0.277	0.001	0.988	0.987
2005	0.962	0.962	0.277	0.003	0.967	0.965
2006	0.987	0.987	0.277	0.001	0.988	0.987
2007	0.987	0.987	0.277	0.001	0.988	0.987
2008	0.987	0.987	0.277	0.001	0.988	0.987
2009	0.987	0.987	0.277	0.001	0.988	0.987
2010	0.868	0.929	0.277	0.012	0.934	0.988
2011	0.868	0.929	0.277	0.012	0.934	0.988
2012	0.868	0.929	0.277	0.012	0.934	0.988
2013	0.868	0.929	0.277	0.012	0.934	0.988
2014	0.879	0.941	0.277	0.012	0.934	0.988
2015	0.879	0.941	0.277	0.012	0.934	0.988
2016	0.868	0.929	0.277	0.012	0.934	0.988
2017	0.857	0.917	0.277	0.013	0.925	0.976
2018	0.846	0.905	0.277	0.008	0.907	0.985

Source: Author's own calculations.

APPENDIX II

**Table A2: Panel Unit Root Results
Im–Pesaran–Shin Unit Root Test**

Variables	Statistics (P-value)
<i>Trade_Connectivity_{it}</i>	–4.541 (0.00)*
<i>TC_{ijt}</i>	–6.823 (0.00)*
<i>Ship_connectivity_{it}</i>	–4.317 (0.00)*
<i>Power_{ij}</i>	–2.887 (0.00)*
<i>Transport_Air_{it}</i>	–3.413 (0.00)*
<i>Infra_{it}</i>	–5.29 (0.00)*
<i>GDPPC_{it}</i>	–6.75 (0.00)*

* and ** indicate the significance levels of 1% and 5%, respectively.

APPENDIX III

Table A3: Robustness Check—Two-Stage Least Squares (2SLS)

Variables	Model 1	Model 2	Model 3
$GDPPC_{it}$	0.340 (0.11)*		
$Infra_{it}$	0.228 (0.35)**		
TC_{ijt}	1.490 (0.43)*	3.329 (1.58)*	3.262 (2.39)*
$Transport_Air_{it}$		0.146 (0.22)	
$Power_{it}$		0.394 (0.45)	
$Ship_connectivity_{it}$			1.170 (0.80)
FDI_{it}		0.575 (0.23)	
$FDI_{it} \times FTA_{it}$			0.266 (0.29)
Constant	10.07 (2.29)	30.46 (9.44)	12.573 (15.3)
N	206	101	101
$Adj R^2$	0.28	0.32	0.32
Under-identification test (Anderson canon. corr. LM statistic) c^2 (Chi-sq)	68.02*	44.65*	21.27*
Weak identification test (Cragg–Donald Wald F statistic)	68.35*	24.83*	19.93*
Sargan statistic (over-identification test of all instruments)/Hansen J statistic c^2 (Chi-sq)	6.35*	21.16*	6.65*
Endogeneity test of endogenous regressors c^2 (Chi-sq)	22.18*	17.22*	15.34*

Note: Standard errors are in parentheses below the parameter estimates. Statistical significance is as follows: (10) *; (5) **; and (1) ***.