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Suitability of fragmentation model in East Asia

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Abstract

This paper examines the suitability of the fragmentation model in all the manufacturing industries in East Asia. Its main contribution is to apply the fully-modified gravity trade model to all the manufacturing industries in East Asia by including the two factors of fragmentation: the differences in location advantages and the levels of service-link costs. The empirics show that the total industry represents the suitability of the fragmentation only in the trade of intermediate goods, probably because the fragmentation accompanies active back-and-forth international transactions of intermediate goods such as processed goods, parts and components. As for the industrial estimation, the fragmentation model best fits the industries of chemicals, steel and machinery, since these industries may involve a large number of multi-layered vertical production processes so that the mechanics of fragmentation can be working well. The more in-depth analysis should, however, be required to support the estimation results with limited samples above.

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1. Introduction

International production networks in East Asia have developed since the 1990s. Kimura (2006) described the East Asian production networks as such movements as active foreign direct investments, development of cross-border production sharing or fragmentation, sophisticated disintegration of production activities and the formation of industrial agglomeration. In his paper, the "18 facts" on the East Asian production networks were identified based on a number of empirical studies using international trade data, micro-data of Japanese Multinational-Enterprises (MNEs) and casual observations.

One of the important findings by Kimura (2006) is that the mechanics of the East Asian production networks are represented by the "vertical" division of labor in intra-industries among a number of countries characterized by different income levels, and that the mechanics are typically found in such sophisticated manufacturing industries as machinery, which involve a large number of multi-layered vertical production processes.

From the theoretical perspective, Kimura (2006) argued that this vertical mechanics in East Asia could be well-illustrated by the "fragmentation theory". The "fragmentation" was clearly defined by Deardorff (2001): the splitting of a production process into two or more steps that can be undertaken in different locations, but that lead to the same final product. The theoretical rationale for the "fragmentation" was provided by Jones and Kierzkowski (1990, 2005). They argued that a firm's decision on whether or not to fragment its production process should depend on the differences in location advantages such as factor prices and the levels of the "service-link costs" to link remotely located production blocks: the greater disparity in factor prices between countries may encourage the use of several international locations for production blocks, and the decline of the service-link costs of production blocks may further facilitate the process of fragmentation at international levels.

Regarding empirics for the fragmentation theory, there have been intensive studies not only for East Asia but also for the other areas of the world: focusing on the fragmentation among European Union countries (e.g. Baldone et al., 2001; Egger and Egger, 2003), those between the U.S. and Mexico (e.g. Hanson et al., 2005), and those among East Asian countries (e.g. Ng and Yeats, 2001; Ando, 2006; Kimura et al., 2007; Taguchi and Ni Lar, 2015). Among these empirical works, it was Kimura et al. (2007) that applied a gravity trade model for examining the fragmentation of machinery industries in East Asia, while contrasting the East Asian fragmentation model with the Europe model, i.e., the horizontal product differential model established by Krugman (1980) and Helpman and Krugman (1985). For explaining the fragmentation, Kimura et al. (2007) modified a gravity model by adding the absolute value of gap in GDP per capita between trading countries as a proxy for location-advantage disparity, i.e., one of the fragmentation factors. Then, it proved that this modified gravity model for fragmentation only applied to the case of East Asia, not to that of Europe. Taguchi and Ni Lar (2015) further developed the modified gravity model proposed by Kimura et al. (2007) by adding a variable capturing the extent of logistics performance in order to examine the role of service-links, i.e., another factor of fragmentation. Taguchi and Ni Lar (2015) still focused on machinery industries, but targeted the area of Mekong region including such latecomers as Cambodia, Lao PDR and Myanmar for identifying the factor to prevent the production networks from extending in that region. Through the analysis based on the fragmentation model, it finally found that the high service-link costs of Cambodia and Myanmar had prevented normal trade flows from Thailand to both of these countries.

The purpose of this paper is to examine the suitability of the fragmentation model in all the manufacturing industries in East Asia. The contribution of this paper is, in the first place, to apply the fully-modified gravity trade model to East Asia including the two factors of fragmentation: the differences in location advantages and the levels of service-link costs, which was developed by Taguchi and Ni Lar (2015). The second contribution is to run separate regressions on trade flows by each manufacturing sector and by each production stage including intermediate goods in East Asia, while Kimura et al. (2007) and Taguchi and Ni Lar (2015) focused only on machinery industries. It is the database named "RIETI-TID" that makes it possible to analyze the fragmentation in all the manufacturing industries. The fragmentation has usually accompanied active back-and-forth international transactions of intermediate goods such as processed goods, parts and components. The RIETI-TID, which is produced by the Research Institute of Economy, Trade and Industry (RIETI) in Japan, covers all trade goods and classifies them according to each production stage based on the BEC (Broad Economic Categories) classification system developed by the UN Statistics Division. The use of RIETI-TID thus enables us to apply the fragmentation model to the trade flows of intermediate goods not only in machinery industries but also in the other manufacturing industries.

The rest of the paper is structured as follows. Section 2 will describe the trends in the trade flows of the goods classified into final and intermediate goods in all the manufacturing industries in East Asia. Section 3 conducts the estimation of the gravity trade model modified for fragmentation, containing methodology, data, estimation results and discussions. The last section summarizes and concludes.

2. Trade Flows of Intermediate Goods in East Asia

As Kimura (2006) pointed out, the international trade data do not present the whole structure of fragmentation, in the sense that they do not detect who is trading with whom, i.e. the firm's activity for fragmentation. The trade data, however, provide a lot of useful information on the cross-border flows of goods, which contributes to the secondary approach to fragmentation. Since the fragmentation has accompanied active back-and-forth international transactions of intermediate goods such as processed goods, parts and components among the multi-layered vertical production processes, the degree in fragmentation can be expressed as the ratio of trade flows of intermediate goods relative to those of final goods.

Table 1 represents trade flows of intermediate goods and final goods in all the manufacturing industries between 1993 and 2013 in the world and in East Asia. The data is retrieved from RIETI-TID 2013 as explained earlier, and the classification is defined in the note of Table 1. The common trend in the world and in East Asia from 1993 to 2013 is that the trade-growth of intermediate goods exceeds that of final good, and thus the trade-ratio of intermediate goods relative to final goods expands. In particular, the trade ratio of intermediate / final goods in East Asia is remarkably rising from 1.34 in 1993 to 2.20 in 2013, while that in the world being from 1.06 to 1.32. This implies great expansion in fragmentation in East Asia. When we look at the trade ratio of intermediate / final goods in East Asia by manufacturing industries, great contributions to the rise of the ratio are identified in such industries as chemicals, steel and machinery if we also consider the volume of trade. We speculate that these industries are characterized by a large number of multi-layered vertical production processes, and thus they might show remarkable expansion in fragmentation.

The next section will put the trade flows in East Asia in a statistical test for examining the suitability of fragmentation model in East Asia.

3. Estimation of Fragmentation Model

This section focuses on the estimation of fragmentation model in East Asia. We first clarify the data and methodology, and then represent the estimation outcomes and discuss them.

3.1 Data and Methodology

For estimation, we construct panel data for the period between 2006 and 2013 with 10 exporters' countries times 10 importers' countries. The reason why we choose 2006 as its starting year is that the key data of Logistics Performance Index that represents the levels of the service-link costs are available only after 2006 as are noted below. The sample in East Asia covers 10 countries: Japan, China, Korea, Taiwan, Indonesia, Malaysia, Philippines, Thailand, Cambodia, and Vietnam.[1] The trade data include not only total value but also industrial values with eight categories: food, textile, wood, chemicals, ceramics, steel, machinery and others. The trade data in each industrial category are further decomposed into production stages: final and intermediate goods. The detail classification in trade data is defined in the note of Table 1.

The equation for estimation is primarily based on the latest version of gravity trade model presented by Baier and Bergstrand (2007), i.e., a theoretically-motivated one using panel data with bilateral fixed effects and multilateral time-varying price resistance terms. We then modified the gravity trade model for our analytical concern with fragmentation by following Kimura et al. (2007) and Taguchi and Ni Lar (2015). The estimation model is specified as follows.

$$\ln\left[X_{ijt}/\left(GDP_{it}*GDP_{jt}\right)\right] = \alpha_1 \ln GAP_{ijt} + \alpha_2 LPI_{ijt} + \alpha_3 D_{ij} + \alpha_4 \ln rex_{ijt} + \alpha_5 T_t + \varepsilon_{ijt} \quad (1)$$

where X_{ijt} is the value of the merchandise trade flow from exporter i to importer j, $GDP_{it}(GDP_{jt})$ is the level of nominal gross domestic product (GDP) in country i (j), GAP_{ijt} is an absolute value of the gap in per capita GDP between i and j, LPI_{ijt} is the Logistics Performance Index as an average of exporter i and importer j, D_{ij} is a bilateral dummy variable between i and j, rex_{ijt} is a bilateral real exchange rate between i and j, T_t is a time dummy from 2006 to 2013, ε_{ijt} is an error term, and ln is a logarithm form.

Regarding the data sources, all the trade data are retrieved from RIETI-TID 2013 of RIETI in Japan.[2] The GDP, per capita GDP and the data for calculating a bilateral real exchange rate, i.e. consumer prices and bilateral nominal exchange rates, are from World Economic Outlook (WEO) Database, October 2015, by the International Monetary Fund.[3] The Logistics Performance Index comes from the World Bank.[4]

We herein pick up several issues to be noted for the model specification. The first issue is how to address the endogeneity bias in gravity model equation. As Baier and Bergstrand (2007) pointed out, the explanatory variables in gravity model are influenced by considerable unobserved time-invariant heterogeneity among country pairs, and this omitted variable bias is the major source of endogeneity. Then, they proposed that the unobserved time-invariant bilateral variables were best controlled by using bilateral "fixed effects" in the gravity equation using panel data.[5] Following their suggestion, the equation (1) includes a bilateral dummy

[1] We herein exclude Hong Kong and Singapore due to transit-trading economies, and also exclude Brunei due to oil producing country, respectively.
[2] See http://www.rieti-tid.com/.
[3] See http://www.imf.org/external/pubs/ft/weo/2015/02/weodata/index.aspx.
[4] See http://lpi.worldbank.org/.
[5] Baier and Bergstrand (2007) examined the validity of usual techniques using instrumental variables and

variable between i and j, D_{ij}, to control unobserved time-invariant bilateral variables. This bilateral dummy variable contains all the time-invariant bilateral elements such as distance and commonality of language and land-border between country pairs. There would be another potential endogeneity bias created by simultaneity: GDP is a function of net exports. Although the simultaneity bias is considered to be not so large in the literature, the equation (1) has GDPs of exporters and importers on the left hand side.

The second issue is how to deal with multilateral time-varying price resistance terms, which is required by the gravity trade model with recent formal theoretical developments. Anderson and van Wincoop (2003) suggested the use of country-specific fixed effects as the method for accounting for multilateral price terms in cross section. In a panel setting, however, the multilateral price terms would be time-varying. One way to control for price changes is to introduce, similarly to Rose (2000) and Vandenbussche and Zanardi (2010), the bilateral real exchange rate that varies over time and tracks price changes. Thus, the equation (1) includes a bilateral real exchange rate, rex_{ijt}, to account for the theoretically-motivated multilateral time-varying price resistance terms. The bilateral real exchange rate is defined as the relative prices with the importer's prices in the denominator. The coefficient, α_4, is expected to have a negative sign.

The third issue is how to modify the gravity trade model for a fragmentation analysis, i.e., the inclusion of the two key factors of fragmentation: the differences in location advantages and the levels of service-link costs. The location advantages contain such many elements as factor prices, agglomeration effects, infrastructure services and policy environment. Since the availability of the data for expressing such location advantages is limited except for per capita GDP, as Kimura et al. (2007) described, we insert an absolute value of the gap in per capita GDP between country pairs (GAP) as a proxy of the differences in location advantages. As for the service-link costs, following Taguchi and Ni Lar (2015), we use the Logistics Performance Index (LPI) as a proxy of the reverse of them. Both of the coefficients, α_1 and α_2, are expected to be significantly positive. The data of LPI published by the World Bank are available only in 2006, 2009, 2011 and 2013, and we assume that the LPI during 2006 – 2008, 2009-2010 and 2011-2012 would be the same as the LPI in 2006, 2009 and 2011.[6]

The final issue is about estimation methodology. The Ordinary Least Square supposes that the dependent variable be observed a continuous and unrestricted scale. The trade values as a

control functions for removing omitted variable bias, but concluded that these techniques were not reliable enough to provide stable estimates.

[6] The LPI is published by the World Bank in 2007, 2010, 2012 and 2014. Since the data are produced based on the questionnaire in the previous year, however, we identify the data as the one of the year before its publication. The data are complemented in the vacant years as above since the data for four years are not necessarily following a linear trend.

dependent variable that this study samples, however, are only partially observed at positive values. Thus, we adopt the censored regression model (Tobit model) with a dependent variable left-censored at zero and with the distribution for the error term normal value.

3.2 Estimation Outcomes and Discussions

This section focuses on the estimation outcomes and discussions on fragmentation model in East Asia. Table 2 reports the estimation results of the fragmentation model in East Asia, on total manufacturing industry and each industry with eight categories, in terms of the sum of final and intermediate goods and intermediate goods. The main points we observe here are as follows. First, regarding the total industry, the fragmentation model is suitable in the trade of intermediate goods in the sense that all the variables of the gap in per capita GDP, logistics performance index and bilateral real exchange rate have expected signs in their coefficients with significant levels. On the other hand, the model is not perfectly suitable for the trade of the sum of final and intermediate goods, since the coefficient of bilateral real exchange rate is not significant. Second, when we look at the estimation results in each industry, it is in the industries of chemicals, steel and machinery that the fragmentation model are fully suitable in both the sum of final and intermediate goods and intermediate goods. The industries of textile, ceramics and others are also following the fragmentation model only in their intermediate goods, just like the total industry. Since the estimations above are based on the relatively small sample size and short time period, however, the more in-depth analysis should be provided to support the estimation outcomes by conducting, for instance, micro-analyses at firm levels.

We interpret the estimation outcomes above in the following ways. Regarding the total industry, it is only in the trade of intermediate goods that the fragmentation model is suitable. It might be because the fragmentation accompanies active back-and-forth international transactions of intermediate goods such as processed goods, parts and components. The reason why the sum of final and intermediate goods does not follow the fragmentation model is that some of final goods might follow the horizontal product differential model established by Krugman (1980) and Helpman and Krugman (1985). As for the industrial estimation, the fragmentation model best fits the industries of chemicals, steel and machinery, since these industries might involve a large number of multi-layered vertical production processes so that the mechanics of fragmentation can be working well. On the other hand, the industries of food and wood do not show any suitability to the fragmentation model. It might be because these industries have simple production process rather than sophistical multi-layered vertical production processes. In particular, the food industry shows relatively small trade ratio of intermediate / final goods by around 0.1, and this observation is consistent with the outcome of fragmentation model estimation in food industry, i.e., unsuitability of fragmentation model. In fact, the industries of food and wood have their main production bases in developing county with natural resources, thereby giving less incentives to create the “vertical” division of labor in intra-industries among a number of countries characterized by different income levels. Figure 2 shows us the clear contrast between the share of food and wood in exports and that of transportation equipment: the export shares of food and wood are higher in the lower-income and resource-supplying economies, whereas the export share of transportation equipment is higher in the higher income economies.

4. Concluding Remarks

This paper examined the suitability of the fragmentation model in all the manufacturing industries in East Asia. Its main contribution is to apply the fully-modified gravity trade model to all the manufacturing industries in East Asia by including the two factors of fragmentation: the differences in location advantages and the levels of service-link costs. The empirics showed that the total industry represented the suitability of the fragmentation only in the trade of intermediate goods, probably because the fragmentation accompanies active back-and-forth international transactions of intermediate goods such as processed goods, parts and components. As for the industrial estimation, the fragmentation model best fitted the industries of chemicals, steel and machinery, since these industries might involve a large number of multi-layered vertical production processes so that the mechanics of fragmentation could be working well. The more in-depth analysis should, however, be needed to support the estimation results with limited samples above.

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Table 1 Trade Flows of Intermediate Goods vs. Final Goods in East Asia

Expoter to Importer		Final Goods (a)	Intermediate Goods (b)	b/a
World to World (bil.$)				
	1993	1,502.9	1,598.2	1.06
	2013	6,011.0	7,950.5	1.32
East Asia to East Asia (bil. $)				
	1993	172.9	231.1	1.34
	2013	703.0	1,549.6	2.20
Food				
	1993	18.7	1.5	0.08
	2013	59.7	8.0	0.14
Textile				
	1993	23.6	28.2	1.19
	2013	59.1	54.2	0.92
Wood				
	1993	12.4	16.5	1.33
	2013	24.4	53.6	2.19
Chemicals				
	1993	4.5	29.7	6.59
	2013	26.3	248.5	9.42
Ceramics				
	1993	0.7	4.9	6.65
	2013	1.1	30.0	25.86
Steel				
	1993	1.9	32.3	16.21
	2013	5.7	198.3	34.61
Machinery				
	1993	91.5	91.5	1.00
	2013	470.7	736.9	1.57
Others				
	1993	19.3	6.2	0.32
	2013	55.6	13.7	0.25

Note: The classification is defined as follows:

Final goods: sum of "capital goods" and "consumption goods" in sub-category

Intermediate goods: sim of "processed goods" and "parts and components" in sub-category

East Asia: Japan, China, Hong Kong, Korea, Taiwan, Singapore, Indonesia, Malaysia, Philippines, Thailand, Brunei (Darussalam), Cambodia, and Vietnam

Food: Food and related agriculture, forestry and fisheries

Wood: Pulp, paper and wood products (including rubber, leather and oil) and related agriculture, forestry and fisheries

Chemicals: Chemical products (including plastics)

Ceramics: Ceramic and cement products, related mining

Steel: Iron and steel, nonferrous metal and metal products, related mining

Machinery: General machinery, electrical machinery, home electronics, appliances, transportation equipment, precision machinery

Others: Toys and sundries

Source: RIETI-TID 2013

Table 2 Estimation Outcomes of Fragmentation Model in East Asia

Dependent variables	Industry Total: *Xij/(GDPi*GDPj)* Sum of Final & Intermediate Goods	Intermediate Goods
ln*GAP* : per capita GDP	1.117***	1.261***
	(0.111)	(0.151)
LPI : Logistics Performance Index	0.496***	0.634***
	(0.074)	(0.100)
In*rex* : Bilateral Real Exchange Rate	0.123	-0.465**
	(0.144)	(0.196)
Number of observations	720	720

Dependent variables	Food: *Xij/(GDPi*GDPj)* Sum of Final & Intermediate Goods	Intermediate Goods
ln*GAP* : per capita GDP	0.544**	0.172
	(0.238)	(0.296)
LPI : Logistics Performance Index	0.316**	0.270
	(0.159)	(0.197)
In*rex* : Bilateral Real Exchange Rate	0.900***	0.522
	(0.310)	(0.384)
Number of observations	720	720

Dependent variables	Textile: *Xij/(GDPi*GDPj)* Sum of Final & Intermediate Goods	Intermediate Goods
ln*GAP* : per capita GDP	0.947***	1.796***
	(0.128)	(0.226)
LPI : Logistics Performance Index	0.266***	0.481***
	(0.086)	(0.151)
In*rex* : Bilateral Real Exchange Rate	0.071	-1.604***
	(0.167)	(0.295)
Number of observations	720	720

Source: RIETI-TID 2013, the International Monetary Fund and the World Bank

Dependent variables	Wood: *Xij/(GDPi*GDPj)*	
	Sum of Final & Intermediate Goods	
		Intermediate Goods
ln*GAP* : per capita GDP	0.798***	1.205***
	(0.149)	(0.222)
LPI : Logistics Performance Index	0.298***	0.329**
	(0.099)	(0.148)
In*rex* : Bilateral Real Exchange Rate	0.514***	-0.246
	(0.193)	(0.289)
Number of observations	720	720

Dependent variables	Chemicals: *Xij/(GDPi*GDPj)*	
	Sum of Final & Intermediate Goods	
		Intermediate Goods
ln*GAP* : per capita GDP	1.117***	1.105***
	(0.200)	(0.239)
LPI : Logistics Performance Index	0.821***	0.837***
	(0.134)	(0.160)
In*rex* : Bilateral Real Exchange Rate	-1.304***	-1.375***
	(0.261)	(0.311)
Number of observations	720	720

Number of observations	720	720

Dependent variables	Ceramics: *Xij/(GDPi*GDPj)*	
	Sum of Final & Intermediate Goods	
		Intermediate Goods
ln*GAP* : per capita GDP	0.830***	0.830***
	(0.260)	(0.283)
LPI : Logistics Performance Index	0.309*	0.379**
	(0.173)	(0.189)
In*rex* : Bilateral Real Exchange Rate	-0.541	-0.680*
	(0.338)	(0.368)
Number of observations	720	720

Source: RIETI-TID 2013, the International Monetary Fund and the World Bank

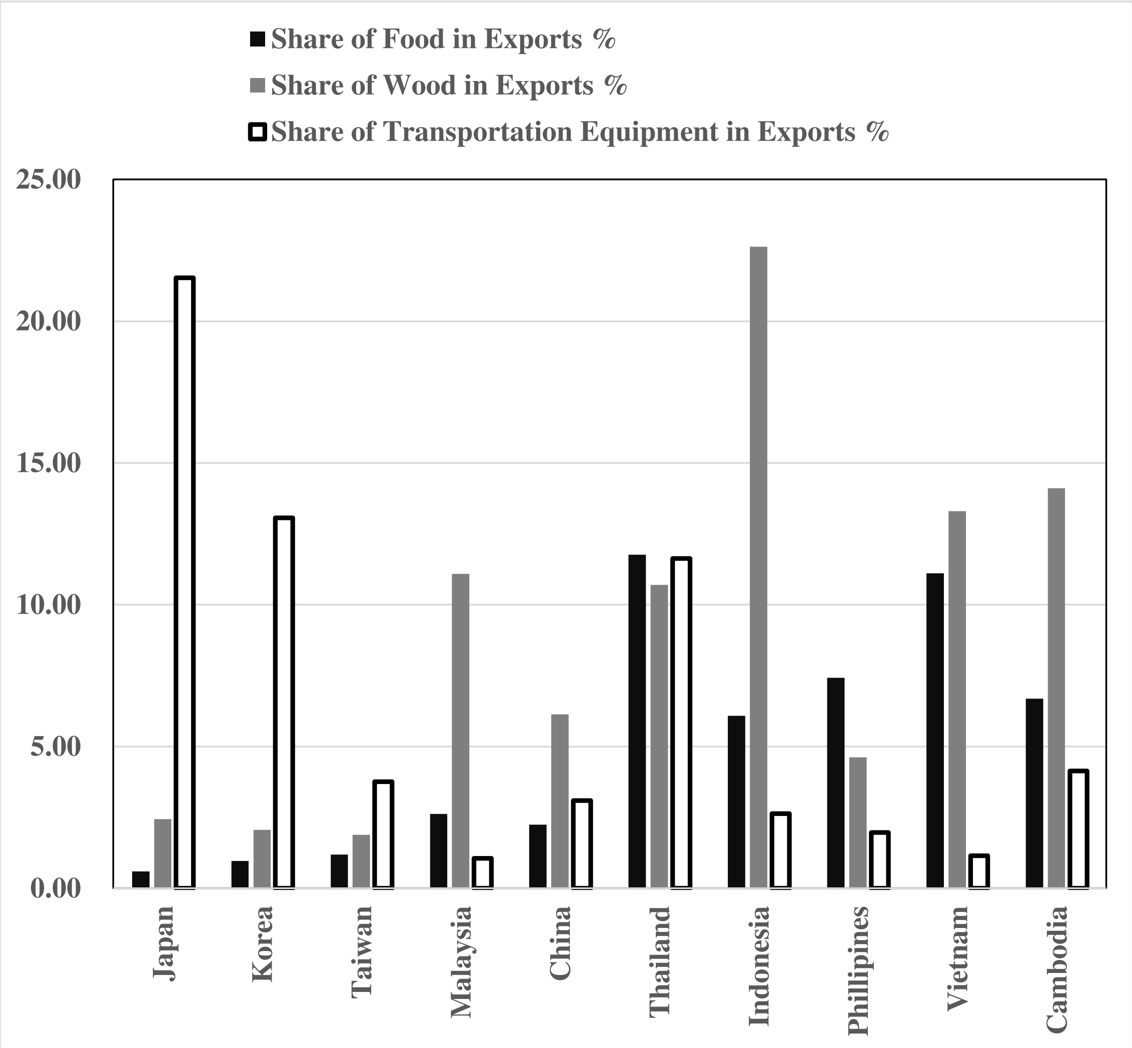
Dependent variables	Steel: *Xij/(GDPi*GDPj)*	
	Sum of Final & Intermediate Goods	
		Intermediate Goods
ln*GAP* : per capita GDP	1.589***	1.709***
	(0.259)	(0.295)
LPI : Logistics Performance Index	0.686***	0.673***
	(0.173)	(0.197)
In*rex* : Bilateral Real Exchange Rate	-1.746***	-1.973***
	(0.337)	(0.384)
Number of observations	720	720

Dependent variables	Machinery: *Xij/(GDPi*GDPj)*	
	Sum of Final & Intermediate Goods	
		Intermediate Goods
ln*GAP* : per capita GDP	1.194***	1.137***
	(0.184)	(0.219)
LPI : Logistics Performance Index	0.457***	0.526***
	(0.123)	(0.146)
In*rex* : Bilateral Real Exchange Rate	-0.621***	-0.946***
	(0.240)	(0.285)
Number of observations	720	720

Dependent variables	Others: *Xij/(GDPi*GDPj)*	
	Sum of Final & Intermediate Goods	
		Intermediate Goods
ln*GAP* : per capita GDP	0.675***	1.438***
	(0.164)	(0.236)
LPI : Logistics Performance Index	0.202*	0.570***
	(0.109)	(0.157)
In*rex* : Bilateral Real Exchange Rate	0.196	-1.678***
	(0.213)	(0.307)
Number of observations	720	720

Source: RIETI-TID 2013, the International Monetary Fund and the World Bank

Figure 1 Share of Food, Wood and Transportation Equipment in Exports in 2013



Source: RIETI-TID 2013