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Asian Fragmentation and Extensive Margin of International Trade

Chin-Ho Lin*

Department of Economics, Feng Chia University, Taiwan

This paper explores the depth and extent of participation in international machinery production networks to quantify the extent of global production sharing by using highly disaggregated international trade data at the Harmonized System six-digit product level. We examine and quantify changes in the number of product–country pairs exported from East Asian countries to international trading partners during 1996–2013. Specifically, we estimate the probability of exporting in terms of goods being traded with international trading partners in 2013, and analyze whether distinct product categories cause significant differences in performance in the extensive margins of production networks (namely those involving parts and components and final products). Our probit estimate with marginal effects predicts a 14.3% higher probability of exporting parts and components than exporting final products in 2013. Moreover, we further decompose the characteristics of product–country pairs and find that parts and components have a 12.8% higher probability of becoming new product–country pairs and a 14.5% lower probability of becoming disappearing product–country pairs, compared with final products. These marginal effects are robust even if individual East Asian countries are considered.

Keywords: Asian fragmentation, International production networks, Machinery Industry, Extensive margin

JEL classification: F12, F14, F15

* Correspondence to: Department of Economics, Feng Chia University, No. 100, Wenhwa Rd., Seatwen, Taichung, Taiwan Email: cholin@fcu.edu.tw Tel: +886-4-24517250 Ext. 4452 Fax: +886-4-24518737

1 Introduction

The sustained growth of international trade in parts and components, and final products since the 1980s has led to the development of international production networks. The fragmentation of the production process has evolved into a network involving integration stages linking countries in East Asia with global trading partners. This production network constitutes "Factory Asia," which has frequently been discussed during the past two decades and refers to the assembling of products in Asia and the export of finished products (i.e., consumer goods) from Asia to the rest of the world (Baldwin, 2008). This phenomenon has been attributed to the efficient distribution and production networks in East Asia, particularly the production of manufacturing machinery. Although assessing the extent and depth of the production networks presents a major quantitative challenge, previous studies have attempted to explore these trade patterns and estimate their magnitude and effect on international production networks. These issues have attracted considerable scholarly attention[1].

The expansion of international trade has raised the question of whether its growth can be attributed to intensive or extensive margins. Because the substantial development of international trade has largely affected the world economy, gains from trade have been explored in terms of trade margins and provided crucial implications for policy makers. Nevertheless, the intensive margin is a crucial factor in export growth and has higher trade elasticity compared with the extensive margin (Besedeš and Prusa, 2011; Chaney, 2008; Baier *et al.*, 2014). Recent studies on international trade emphasize the importance of a trade pattern in the extensive margin. For the 1986–1992 period, Arkolakis *et al.* (2008) indicate that trade liberalization led to a sizable increase in import variety in Costa Rica. Hummels and Klenow (2005) show that 60% of major exports in greater economies are attributed to the extensive margin. Moreover, Hillberry and McDaniel (2002) use the

[1]Athukorala (2005), Athukorala and Yamashita (2006), Kimua and Ando (2005), Ando (2006), and Kimura (2006) show the expansion of machinery trade in East Asia, with particularly remarkable growth noted in machinery parts and components. Ando and Kimura (2012), Okubo *et al.* (2014), Obashi (2010), and Lin (2016) provide evidence of a higher survival rate for machinery parts and components relative to final products.

Hummels–Klenow decomposition to investigate the extent of US trade with NAFTA partners.

In a subsequent study, Mukerji (2009) finds significant extensive margin growth in exports and imports for the 1990s, as evidenced by the impact of trade liberalization in India. Bernard *et al.* (2009) reveal that the extensive margin primarily causes differences in exports and imports across trading partners. Crozet and Koenig (2010) identify a strong effect of distance on the extensive margin for French firms in 1986–1992. Dutt *et al.* (2013) show that WTO membership positively influences extensive margins but negatively influences intensive margins. Some proposed empirical and theoretical models yield results that focus on extensive margins (Melitz, 2003; Yi, 2003; Arkolakis, 2010; Kehoe and Ruhl, 2013). Moreover, the extensive margin is more important than the intensive margin in some studies (Eaton *et al.*, 2004; Bernard *et al.*, 2007). However, the issue of trade margins of international trade in production networks as well as Asian fragmentation has not been thoroughly explored. The purpose of this paper is to address this gap.

The use of the trade margin in international production networks is limited. Yi (2003) indicates that vertical specialization increases after a reduction in tariffs, resulting in a significant increase in the extensive margin. This is because the international production process can be fragmented into more stages cross border after the elimination of the tariff barrier. Ando and Kimura (2012) follow the approach of Haddad *et al.* (2010) to decompose trade changes into intensive and extensive margins and investigate the response of Japanese exports to two massive shocks, the 2008–2009 Global Financial Crisis and the 2011 Great East Japan Earthquake, in international production networks. Moreover, Ando and Kimura (2013) follow the definitions[2] of Flam and Nordstrom (2011) and Hayakawa *et al.* (2011) and indicate that the extensive margin increasing production fragmentation in Europe is linked with Central and Eastern Europe through machinery imports from East Asia.

Most closely related to our work is Obashi and Kimura (2017), which examine the widening and deepening of international production networks for ASEAN member countries during 2007–2013 by using the highly disaggregated Harmonized

[2] Previous studies provide various definitions of intensive and extensive margins. For further detail, see more detail in Hummels and Klenow (2005), Helpman *et al.* (2008), Haddad *et al.* (2010), and Besedesˇ and Prusa (2011).

System (HS) six-digit product level in machinery. They explore the widening and deepening of machinery production networks between ASEAN and its trading partner during 2007–2013. They particularly indicate that stable development of the back-and-forth trade relationship of Singapore and Thailand with East Asian partners plays a crucial role in international production networks. However, they only focus on trade of parts and components and their analysis period is limited.

In line with previous studies, we particularly focus on extensive margins, which demonstrate a significant increase in the range of goods being exported, as observed by economists. We concentrate on exploring the extent of extensive margins in international machinery production networks in East Asian countries[3], examining whether Asian fragmentation matter for the extensive margin of international trade. To do so, we explore the depth and extent of participation in international production networks to quantify the extent of global production sharing between East Asian countries and other major trading regions (including intra regional trade involving East Asian countries) by using highly disaggregated international trade data at the HS six-digit product level for parts and components, and final products[4]. We count and examine the changes in the number of product–country pairs[5] exported from East Asian countries to international trading partners[6] during 1996–2013. We then specifically estimate the probability of exporting in terms of goods being traded with international trading partners in 2013.

We focus on the machinery production networks for East Asian member countries because fragmentation in East Asia provides the most notable instance. Although member countries exhibit different income levels, historical backgrounds, and degrees of participation in production networks, most countries are increasingly active players in such networking. With respect to geographical extension and the sophistication of international production networks, East Asian countries have a crucial role in trade links with other parts of the world. We document the number of

[3] East Asian countries herein are Brunei, China, Indonesia, Japan, Cambodia, Korea, Lao PDR, Myanmar, Malaysia, Philippines, Singapore, Thailand, and Vietnam, representing a total of 13 countries.

[4] The HS product classifications related to the machinery industry are numbered from HS 84 to 92, consisting of general machinery (HS 84), electric machinery (HS 85), transport equipment (HS 86–89), and precision machinery (HS 90–92).

[5] The product–country pairs referred to in this paper are non-zero country–product pairs. Feenstra (1994), Hummels and Klenow (2005), and Broda and Weinstein (2006) classify a good as not traded while the value of trade is $0.

[6] The trading partners in our data set are 128 countries, listed in Appendix Table A1.

product–country pairs centered on China, Japan, and Korea, followed by Singapore, Malaysia, and Thailand. Indonesia, the Philippines, and Vietnam also present positive signs for engaging in transactions in the machinery trade. Although the degree of participation by Brunei, Cambodia, Myanmar, and Lao PDR is limited, these countries increasingly join production networks. International production networks are continuously deepening and widening, particularly those involving the trade of parts and components

To more effectively quantify whether parts and components and final products differ regarding the extent and magnitude of the change in the extensive margin, we first examine the probability of exporting for product–country pairs in 2013 by using probit regression. Subsequently we further compare the performance difference with respect to the distinct status of product–country pairs based on the definition of Debaere and Mostashari (2010) for two types of product. Our major finding is that parts and components have a 14.3% higher probability of being exported in 2013 compared with final products. Then, if initially there are no exports in 1996, parts and components exhibit a 12.8% higher probability of being exported in 2013 (new product–country pairs); if there are initially exports in 1996, parts and components have a 14.5% lower probability of product–country pairs disappearing in 2013 (disappearing product–country pairs) compared with final products.

The remainder of this paper is organized as follows. Section 2 describes the development of the number of product–country pairs in machinery production networks in 1996–2013 and explores the extent of extensive margins based on the status of product–country pairs. Data sources and econometric models are offered in Section 3. Section 4 provides the empirical results. Section 5 presents the policy implications of the study findings, and Section 6 provides the conclusion.

2 Extensive Margin of Trade in Machinery Industry

Given the fact that the importance of machinery trade to East Asian countries in export has rapidly expanded over the past two decades, regional integration of production networks has expanded to include global production chains, resulting in closer trade relationships within this network. However, in addition to examining trade values, we focus on the extensive margin of product–country pairs. To quantify the magnitude of participation in machinery production networks and calculate the number of product–country pairs, we exploit international trade data from the UN Comtrade database[7].

To avoid the product code of updates undergoing classification errors[8], we adjust the current version of HS product classification so as to be consistent with HS 1988/1992 version for our analysis period from 1996 to 2013. We utilize import statistics throughout this paper, including when we count the number of product–country pairs exported. As stated by Obashi and Kimura (2017), this is due to import statistics being more reliable because "a country of origin is more closely verified because of tariff regulations, and the final destination may not be known at the time of export." Regarding the classification of parts and components, and final products, we are able to identify a particular product at the six-digit level or a type of products at the four-digit level, in line with the definition provided by Kimura and Obashi (2010).

2.1 Development of Product–country Pairs

Figure 1 shows the trend for the numbers of product–country pairs exported to major trading partners from East Asian countries at the HS six-digit level for the machinery industry from 1996 to 2013. The vertical axis represents the number of product–country pairs. The blue solid, red dashed, and green dashed lines refer to all machinery products, parts and components, and final products, respectively. All

[7] This database publically publishes the value of imports expressed as thousands of USD for a wide range of countries, recording them at the six-digit HS level.
[8] Our analysis period covers different versions of HS classification, such as HS 1996, HS 2002, HS 2007, and HS 2012. The product code might slightly differ and change based on the specific version of HS classification. To address this problem, we employ a conversion table to convert all versions of HS 1992 classification.

machinery products have obviously increased, and a particularly increase occurred after 2000. The number of product–country pairs exceeds 350,000 for 2013, compared with approximately 165,000 for 1996. Furthermore, the number of product–country pairs for the two types of product exhibits a surprising increase over time. Regarding a comparison of the products, parts and components have fewer product–country pairs for both 1996 and 2013. However, this gap has already reduced, implying that the number of product–country pairs involving parts and components trade presents more pronounced growth. The specific difference in the number of product–country pairs reaches approximately 14,000 in 1996 but falls to approximately 6,000 in 2013, suggesting that the importance of import demand for parts and components from trade partners increases over time.

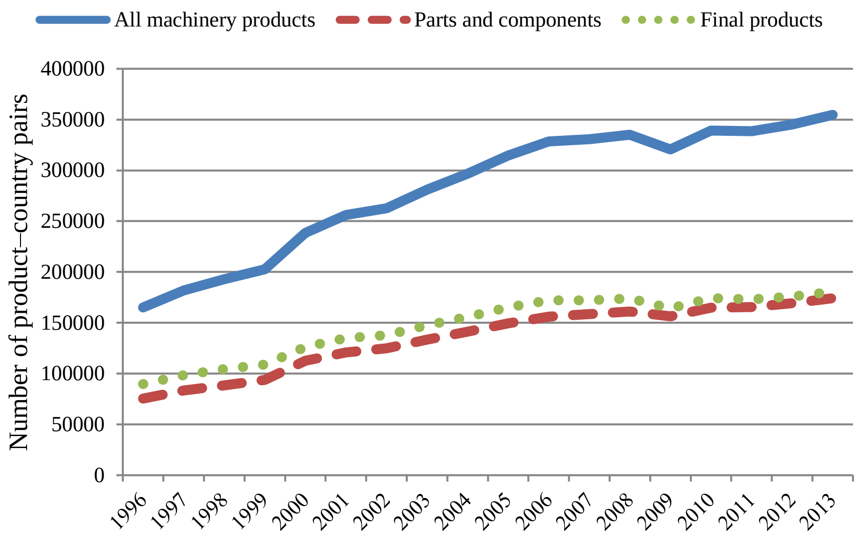

Figure 1. Trend of the Number of Product–country Pairs in 1996–2013

2.2 Characteristics of Product–country Pairs

In this sub-section, we explore the changes in the number of product–country pairs, particularly the extensive margin. Debaere and Mostashari (2010) analyze the trade pattern of exported goods into four types. We follow their definition and apply it to product–country pairs. First, all exported product–country pairs refer to those traded either at the beginning or end of the time frame[9]. Second, new product–country pairs refer to those traded at the end of the time frame but not the beginning. Third, disappearing product–country pairs refer to those traded at the beginning but not the end of the time frame. Fourth, continuous product–country pairs refer to those traded both at the beginning and end of the time frame.

Table 1 displays the number of machinery industry product–country pairs that exported from East Asian countries to trading partners during 1996–2013 with corresponding trade patterns. The columns of all exported product–country pairs present the number of product–country pairs traded with respect to all machinery products, parts and components, and final products.[10] The remaining columns list the percentage of all exported product–country pairs.[11]

Table 1. Machinery Exports to Trading Partners at the HS Six-digit Level over 1996-2013: Product–country Pairs

	All machinery products				Parts and components				Final products			
Exporters	All	New	Dis.	Con.	All	New	Dis.	Con.	All	New	Dis.	Con.
Brunei	1,111	0.67	0.24	0.09	562	0.67	0.24	0.08	549	0.67	0.23	0.10
China	95,986	0.68	0.03	0.29	39,486	0.68	0.02	0.30	56,500	0.68	0.04	0.28
Indonesia	23,182	0.73	0.09	0.18	12,733	0.76	0.06	0.18	10,449	0.13	0.00	0.87
Japan	72,981	0.32	0.17	0.51	32,623	0.33	0.11	0.56	40,358	0.32	0.22	0.47
Cambodia	1,377	0.86	0.11	0.03	679	0.85	0.11	0.03	698	0.87	0.11	0.02
Korea	55,632	0.53	0.11	0.36	25,944	0.52	0.07	0.41	29,688	0.54	0.14	0.32
Lao PDR	613	0.81	0.18	0.01	313	0.79	0.20	0.01	300	0.84	0.16	0.01
Myanmar	808	0.79	0.17	0.04	424	0.80	0.16	0.04	384	0.77	0.18	0.05
Malaysia	34,973	0.61	0.11	0.28	17,643	0.64	0.06	0.29	17,330	0.59	0.15	0.26
Philippines	16,875	0.69	0.11	0.20	9,732	0.71	0.07	0.22	7,143	0.66	0.16	0.18
Singapore	39,086	0.49	0.15	0.35	19,443	0.52	0.10	0.38	19,643	0.46	0.21	0.33
Thailand	35,798	0.67	0.09	0.24	18,606	0.69	0.05	0.25	17,192	0.65	0.13	0.22
Vietnam	15,896	0.93	0.02	0.05	8,444	0.93	0.02	0.05	7,452	0.92	0.03	0.04
East Asia	394,318	0.58	0.10	0.32	186,632	0.60	0.07	0.34	207,686	0.57	0.13	0.30

Note: “All” refers to all exported product–country pairs. “New” refers to new product–country pairs. “Dis.” refers to disappearing product–country pairs. “Con.” refers to continuous product–country pairs.

[9] All exported product–country pairs here do not include product–country pairs that do not appear in both 1996 and 2013 but appear during the 1997–2012 period.

[10] The number of all exported product–country pairs is the aggregation of the number of new, disappearing, and continuous product–country pairs.

[11] Thus, we can confirm what percentage of all exported product–country pairs a particular trade pattern accounts for, and if necessary, obtain exact number of product–country pairs.

First, we focus on the pooled sample for East Asian countries. A total of 394,318 all exported product–country pairs are identified for all machinery products. However, 58% of those product–country pairs are new, 10% are disappearing product–country pairs, and 32% are continuous. This suggests that disappearing product–country pairs accounted for a small proportion in 2013, implying that trade links between East Asian countries and its trading partners are not likely to dissolve. The product comparison for parts and components and final products indicates that the number of product–country pairs of parts and components is lower than that of final products for all exported product–country pairs; however, the difference is negligible. Note that the proportion of new and continuous product–country pairs is slightly greater for parts and components. Notably, final products exhibit a large proportion of disappearing product–country pairs, with a magnitude of 13% compared with 7% for parts and components[12].

To examine whether the change of product–country pairs appeared in the country dimension during 1996–2013, we analyze the international production networks on the basis of individual East Asian countries according to the definition of product characteristics. China, Japan, Korea, Malaysia, Singapore, and Thailand are major producers of all machinery products and are involved in all product–country pairs traded with their trading partners. Next are Indonesia, the Philippines, and Vietnam, which are active in machinery product transactions. Notably, Vietnam has a lower proportion of continuous product–country pairs (5%) but has the highest proportion of new product–country pairs (93%). By contrast, Brunei, Cambodia, Lao PDR, and Myanmar present extremely rare product–country pairs, implying that they are relatively inactive in participating in machinery production networks. We find that the proportion of new product–country pairs for Brunei, Cambodia, Lao PDR, and Myanmar is 67%–86% of all exported product–country pairs. This proportion is higher than that of other East Asian countries except for Vietnam, Indonesia, and China. The four countries also have relatively lower proportions of continuous product–country pairs (1%–9%). In particular, Brunei, Lao PDR, and Myanmar have a higher proportion of disappearing product–country pairs (17%–24%). We conclude that although the extent of participation in machinery

[12] The finding of trade in parts and components being likely to offer longevity than that of final products is consistent with the findings of previous studies on Asian fragmentation that have adopted the statistical technique of survival analysis.

production networks for these countries is lagging considerably behind other East Asian countries, they present positive signs of gradually becoming involved in these networks.

Next, in Japan, Korea, and Singapore, approximately 32%–53% of all product–country pairs are new product–country pairs, 11%–15% are disappearing product–country pairs, and 35%–51% are continuous product–country pairs. We can infer that relatively large economies exhibit active and stable development in such production networks. In the cases of Indonesia, Malaysia, Thailand, and the Philippines, 61%–73% of all product–country pairs are new, 9%–11% are disappearing, and 18%–28% are continuous. We can infer that these countries actively attempt to join these production networks despite having relatively small economies. As for China and Vietnam, both countries present the lowest proportion of disappearing product–country pairs (2% and 3%, respectively). However, the reasons for this composition of product–country pairs differ between China and Vietnam. For China, the reason for the lower proportion of disappearing product–country pairs is the higher proportion of new and continuous product–country pairs (68% and 29%); this implies that China is active in joining machinery production networks while simultaneously maintaining stable development. By contrast, Vietnam has a rather low proportion of continuous product–country pairs (5%), but its proportion of new product–country pairs (93%) is quite high, implying that most increases in product–country pairs in Vietnam can be attributed to this newly active participant joining these networks.

With respect to product comparison, parts and components clearly have higher proportion for new and continuous product–country pairs, and less proportion for disappearing product–country pairs relative to final products. In particular, 93% and 92% of all exported product–country pairs for Vietnam are new product–country pairs in terms of parts and components and final products trade, respectively. The three highest proportions of continuous product–country pairs of parts and components are exhibited by Japan, Korea, and Singapore at 56%, 41%, and 38%, respectively. Notably, the proportion of continuous product–country pairs of final products for Indonesia is 87%, indicating that the country has maintained high stability in exporting final products to trading partners.

3 Data and Empirical Model

3.1 Data Sources

Our objectives are to determine changes in the range of product–country pairs that East Asian countries export to trading partners, and to quantify the importance of machinery parts and components in international production networks. The major data source is trade data obtained from UN Comtrade. Our exporters include East Asian countries. Thus, we could obtain trade data at the HS six-digit product level because the product codes are consistent across countries at the first HS six-digit product level. The trade data are publicly available along with information on both exports and imports for each country and are expressed in thousands of current US dollars. Due to the availability of data for our sample East Asian countries, our analysis covers the period from 1996 to 2013 with various samples in terms of products and time.

In addition to trade data, we include other factors that may affect the probability of exporting such as several traditional measures of bilateral trade resistance used in the gravity literature. Data on gravity variables are obtained from the gravity database of the Centre d'Etudes Prospectives et d'Informations Internationales (CEPII). The CEPII covers the harmonized data of gravity variables for each country pair from 1948 to 2015. Subsequently, we then retain the sample period of interest and merge this period with the trade data.

3.2 Econometric Analysis

To explore the changing range of product–country pairs adopted for bilateral trade between countries and to quantify the contribution of machinery parts and components to these changes, we examine the probability of exporting goods traded from East Asian countries to trading partners in 2013. In addition, we control for whether product–country pairs existed in 1996. The objective is to determine whether the previous existence of a product–country pair is likely to have maintained trade relationship in 2013. Specifically, our dependent variable is a binary indicator that is "1" if country *i* exported a good to the destination country *j* in 2013 and "0" if it did not. The equation is expressed as follows:

$$Y_{ij,k} = 1[Y^*_{ij,k} > 0] \quad (1)$$

$$\begin{aligned} Y^*_{ij,k} = \beta_0 + \beta_1 P\&C_k + \beta_2 Status1996_{ij,k} + \beta_3 \ln Distance_{ij} \\ + \beta_4 Contiguity_{ij} + \beta_5 Language_{ij} + \beta_6 RTA_{ij} \\ + \beta_7 \ln GDP_i + \beta_8 \ln GDP_j + \beta_9 \ln\ abs.GDPpc^{diff}_{ij} \\ + \beta_{10} Intra\ \ regional\ \ trade_{ij} * P\&C_k + \varepsilon_{ijk} \end{aligned} \quad (2)$$

where *i* is an East Asian origin country, *j* is 1 of the 128 countries in our data set, and *k* is the HS six-digit product. $Y_{ij,k}$ refers to a latent variable, the value of which illustrates whether non-zero trade flow was exported in 2013. $P\&C_k$ represents a dummy variable that takes "1" if a particular HS six-digit product is from the machinery parts and components category, and "0" is it is not. $Status1996_{ij,k}$ is a dummy variable that takes "1" if good k was exported from country *i* to *j* in 1996 (which would imply that a product–country pair existed in 1996) and "0" if it was not. The country pair–specific explanatory variables commonly used in the estimation of gravity equations are included in our model. We include the natural log of the bilateral distance between country *i* and country *j* as proxy for trade costs[13].

In addition, we include some dummy variables in the gravity literature that are likely to affect the probability of a product being exported. $Contiguity_{ij}$ is a variable that takes a value of "1" if the pair of countries in question share a border. $Language_{ij}$ is a variable that takes a value of "1" if a common language is spoken by at least 9% of the population. If the countries have signed a regional trade agreements (RTAs), the dummy variable is "1"; otherwise, the dummy variable is considered to be "0." Moreover, we include the natural log of gross domestic product (GDP) for the origin and destination countries in 2013, respectively. Changing the size of production and product demand would affect the degree of participation in international production sharing, which is crucial for the extensive

[13] Obashi and Kimura (2017) indicate that bilateral distance may affect the export frequency for zero and non-zero trade flow within international production networks because non-final products cross borders multiple times through global value chains.

margin. Furthermore, we include the natural log of the absolute value of the difference in GDP per capita between the origin and destination countries to control for differences in location advantages. This is because the difference in GDP per capita between two countries is generally considered a proxy for the international wage differentials that are the factors affecting the fragmentation of production across borders. $Intra\ regional\ trade_{ij} * P\&C_k$ is the interaction term for indicating whether intra–regional parts and components contribute to enhancing the probability of exporting in 2013[14].

To better quantify the changing of extensive margins on product–country pairs in international production networks, we consider whether parts and components and final products differ in performance in terms of the status of product–country pairs. We focus primarily on new and disappearing product–country pairs in two specifications with different definitions for dependent variables[15]. The equation is as follows:

$$\begin{aligned} Y^*_{ij,k} = \beta_0 + \beta_1 P\&C_k + \beta_2 \ln Distance_{ij} + \beta_3 Contiguity_{ij} \\ + \beta_4 Language_{ij} + \beta_5 RTA_{ij} + \beta_6 \ln GDP_i + \beta_7 \ln GDP_j \\ + \beta_8 ln\ \ abs.GDPpc^{diff}_{ij} + \varepsilon_{ijk} \end{aligned} \quad (3)$$

For the analysis of new product–country pairs, we investigate the probability of exporting in 2013 for those product–country pairs that do not appear in 1996. $Y_{ij,k}$ is "1" if exports of product *k* from an East Asian country *i* to destination country *j* were observed in 2013 and "0" for any other outcome. We limit the samples to product–country pairs that do not appear in 1996 but may or may not appear in 2013.

For the analysis of disappearing product–country pairs, we investigate the probability of not exporting in 2013 for those product–country pairs that appear in 1996. $Y_{ij,k}$ is "1" if exports of product *k* from an East Asian country *i* to destination country *j* were not observed in 2013 and "0" for any other outcome. The samples are limited to product–country pairs that appear in 1996 but may or may not appear in 2013.[16]

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[14] Summary statistics for variables are listed in the Appendix in Table A2.
[15] The estimated results for continuous product–country pairs present similar magnitudes of disappearing product–country pairs but with opposite signs.
[16] As noted in the descriptive statistics in Table 1, we expect that the trading of parts and components has

4 Results

4.1 Baseline Results in International Production Networks

We initially examine the probability of a product being exported to quantify the change in the extensive margin, notably the product–country pair, by employing probit regression[17]. In particular, we conduct regression on the empirical model for all machinery products, parts and components, and final products. Our dependent variable is a binary indicator that takes “1” if a non-zero export flow existed for a given HS six-digit product from a particular East Asian origin country to a particular destination market in 2013, and “0” if it did not[18].

Table 2 presents the probit estimates for all machinery products with two specifications with and without the interaction term of P&C and East Asian countries dummies[19]. We report the coefficients and marginal effects for each specification, and cluster robust standard errors based on country pairs. Because our probit estimates belong to a nonlinear model, the effects of the variables are made more intuitively meaningful and informative by the magnitude of marginal effects[20]. To better quantify the effects of the estimates, we focus on the marginal effects for two distinct specifications reported in columns 2 and 4 of Table 2.

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a higher probability of producing new product–country pairs and a lower probability of producing disappearing product–country pairs, compared with the trade of final products.

[17] Wooldridge (2002) indicates that a statistical issue emerges for a probit estimator with fixed effects, leading to an inconsistent estimation of β.

[18] All explanatory variables used in this paper are log transformed except for the dummy variables.

[19] The total sample (665,935) in our specification comprises all product–country pairs (394,318) as well as product–country pairs that do not appear in both 1996 and 2013 but appear during 1997–2012 (271,617). This is because we control the dummy variable of status 1996, implying that we cannot exclude the possibility that a product–country pair with that export status is observed in neither 1996 nor 2013.

[20] Specifically, we provide the marginal effects at the means (MEMs).

Table 2. Probit Estimates for Statistical Determinants of Export Status Over (1996–2013)

	Positive exports in 2013			
	All machinery products			
	(1)	(2)	(3)	(4)
	Coefficient	Marginal effect	Coefficient	Marginal effect
P&C	0.361***	0.143***		
	(0.007)	(0.003)		
Status 1996	0.604***	0.240***	0.604***	0.240***
	(0.023)	(0.009)	(0.023)	(0.009)
Log distance	-0.127***	-0.051***	-0.083***	-0.033***
	(0.028)	(0.011)	(0.029)	(0.011)
Language	0.030	0.012	0.038	0.015
	(0.041)	(0.016)	(0.039)	(0.006)
Contiguity	-0.009	-0.003	0.010	0.004
	(0.145)	(0.057)	(0.141)	(0.056)
RTA	0.033	0.013	-0.020	-0.008
	(0.039)	(0.015)	(0.037)	(0.015)
Log GDP of origin country	0.204***	0.081***	0.193***	0.077***
	(0.012)	(0.005)	(0.012)	(0.005)
Log GDP of destination country	0.097***	0.039***	0.095***	0.038***
	(0.009)	(0.003)	(0.008)	(0.003)
Log abs. difference in GDP per capita	-0.027**	-0.011**	-0.025*	-0.010*
	(0.014)	(0.005)	(0.014)	(0.005)
Intra regional trade*P&C			0.338***	0.134***
			(0.037)	(0.015)
Number of observations	665,935		665,935	
Log pseudolikelihood	-412377.3		-417671.1	
Prob>chi2	0.000		0.000	
R2	0.104		0.092	

Note: The dependent variable is a binary indicator taking a value of 1 if a good is exported to a particular country of destination from an origin country of East Asia in 2013, and 0 otherwise. Results for the constant term are not reported but are included in the regressions. Standard errors, clustered by country pair, are listed in parentheses. * Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

Columns 1 and 2 of Table 2 present our baseline results. To explore whether a significant variation exists for the probability of exporting between parts and components and final products, the magnitude of P&C (i.e., β_1) is our main focus. The MEMs for binary explanatory variables show how the predicted probability of exporting changes as the binary explanatory variable changes from 0 to 1, holding all other variables at their means. As revealed in column 2 of Table 2, P&C exhibits a positive and statistically significant marginal effect on the probability of exporting. Therefore, the MEM for P&C of 0.143 suggests that the predicted probability of exporting is 14.3% greater for parts and components than for final products, which supports our hypothesis that the number of product–country pairs is increasing when exported from East Asian countries to trading partners, particularly for the trading of parts and components.

Other binary explanatory variables have different marginal effects. A product exported to a destination country in 1996 was 24% more likely to be exported in 2013, implying that past experience can strengthen the export probability in subsequent years. However, the marginal effects are insignificant if the two countries share the border, if a common language is spoken by at least 9% of the population, and if both countries share RTAs.

MEMs measure the instantaneous rate of change of continuous variables. However, the marginal effect may or may not be similar to the change in the probability of exporting when an independent variable increases by one unit; this depends on how the independent variable is scaled. Nevertheless, we can still examine the significance, signs, and magnitude of the marginal effects to provide explicit implications of these estimates. We also find that the marginal effect of distance is negative and significant, implying that a larger distance lowered the probability of exporting in 2013. The signs of other continuous variables similarly fit our expectations and are significant; the larger size of production in the origin country, the larger demand in country of destination, and the smaller wage differentials between the origin and destination countries help promote the probability of exporting.

Columns of 3 and 4 in Table 2 present the estimated specification results of the interaction term between East Asian countries and P&C to quantify the magnitudes of the marginal effects on intra-regional trade. Notably, the trading of parts and components between East Asian countries would increase by 13.4% of the probability of exporting in 2013[21]. The magnitudes of marginal effect of the other explanatory variables exhibit slight decreases.

Table 3 reveals the probit estimate for parts and components and for final products. We focus on the marginal effects and find that a good exported in 1996 is positively associated with the 25.9% and 22% higher probabilities of exporting parts and components and exporting final products in 2013, respectively. The marginal

[21] Lao PDR and Myanmar are not in the list of the 128 importers due to the data limitation. Therefore, the inter- and intra-regional trade effects may be affected potentially, but with a negligible effect because their sample must be relative relatively small less from the perspective of their samples in on the exporter side.

effect of distance is negative and significant for the trading of not only parts and components but also final products. This implication denotes that lower service link costs would affect the incidence of non-zero trade flows. Although the language spoken and RTAs are not significant in the specification, their signs fit our expectations. However, regarding the marginal effects of the natural log of GDP in the origin and destination counties being positively significant, the magnitude differs in the comparison between parts and components and final products. Finally, the wage differentials are more likely to affect the probability of exporting final products.

Table 3. Probit Estimates for the Determinants of Export Status Based on Product Comparison

	Positive exports in 2013			
	Parts and components		Final products	
	(1)	(2)	(3)	(4)
	Coefficient	Marginal effect	Coefficient	Marginal effect
Status 1996	0.678***	0.259***	0.552***	0.220***
	(0.027)	(0.010)	(0.022)	(0.009)
Log distance	-0.115***	-0.044***	-0.137***	-0.055***
	(0.031)	(0.012)	(0.028)	(0.011)
Language	0.045	0.017	0.023	0.009
	(0.043)	(0.017)	(0.040)	(0.016)
Contiguity	-0.090	-0.035	0.034	0.013
	(0.158)	(0.060)	(0.137)	(0.055)
RTA	0.035	0.014	0.032	0.013
	(0.042)	(0.016)	(0.038)	(0.015)
Log GDP of origin country	0.196***	0.075***	0.210***	0.084***
	(0.013)	(0.005)	(0.012)	(0.005)
Log GDP of destination country	0.118***	0.045***	0.083***	0.033***
	(0.009)	(0.003)	(0.009)	(0.003)
Log abs. difference in GDP per capita	-0.018	-0.007	-0.033**	-0.013**
	(0.014)	(0.005)	(0.014)	(0.006)
Number of observations	291,050		374,885	
Log pseudolikelihood	-174961.9		-236853.7	
Prob>chi2	0.000		0.000	
R2	0.108		0.088	

Note: The dependent variable is a binary indicator taking a value of 1 if a good is exported to a particular country of destination from an origin country of East Asia in 2013, and 0 otherwise. Results for the constant term are not reported but are included in the regressions. Standard errors, clustered by country pair, are listed in parentheses. * Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

4.2 New and Disappearing Product–country Pairs

Table 4 shows the specifications of new and disappearing product–country pairs, excluding $status1996$ and intra-regional trade of East Asian countries dummies[22]. The marginal effects, presented in columns 2 and 4, are statistically significant and consistent with our expectations. Most signs of marginal effects are contradict the probabilities of new and disappearing product–country pairs emerging. We find that the probability of new product–country pairs emerging increases if a product is categorized under parts and components (column 2 in Table 4). However, parts and components significantly lower the probability of product–country pairs disappearing (column 4 in Table 4). Our expectation that parts and components are more likely to become new product–country pairs and less likely to become disappearing product–country pairs in 2013, compared with final products, is thereby confirmed. With a 12.8% higher probability of becoming new product–country pairs and a 14.5% lower probability of becoming disappearing product–country pairs for parts and components. Regarding the continuous variables of marginal effects, the closer the distance, the higher production scale and product demand in the origin and destination countries leads to a higher (lower) probability of becoming new (disappearing) product–country pairs. Moreover, it is remarkable that more factors may affect the probability of becoming a disappearing product product–country pair. If a pair of countries shares RTAs, the probability of that product–country pairs disappearing would fall by 5.6%. Furthermore, fewer disappearing product–country pairs are predicted when the difference in GDP per capita between the origin and destination countries is smaller.

[22] The sample (500,818) in columns (1) and (2) comprises new product–country pairs (229,201) and product–country pairs that do not appear in both 1996 and 2013 but appear during the 1997–2012 (271,617). Moreover, the sample (165,117) in columns (3) and (4) comprises disappearing product–country pairs (39,637) and continuous product–country pairs (125,480).

Table 4. Estimated Results for the Distinct Status of Product–country Pairs

	All machinery products			
	New		Disappearing	
	(1)	(2)	(3)	(4)
	Coefficient	Marginal effect	Coefficient	Marginal effect
P&C	0.323***	0.128***	-0.490***	-0.145***
	(0.008)	(0.003)	(0.012)	(0.004)
Log distance	-0.135***	-0.054***	0.114***	0.034***
	(0.032)	(0.013)	(0.037)	(0.011)
Language	0.006	0.002	-0.039	-0.011
	(0.043)	(0.017)	(0.057)	(0.017)
Contiguity	-0.015	-0.006	-0.049	-0.014
	(0.154)	(0.061)	(0.211)	(0.062)
RTA	-0.028	-0.011	-0.190***	-0.056***
	(0.047)	(0.019)	(0.039)	(0.012)
Log GDP of origin country	0.201***	0.080***	-0.209***	-0.062***
	(0.013)	(0.005)	(0.015)	(0.004)
Log GDP of destination country	0.089***	0.035***	-0.131***	-0.039***
	(0.009)	(0.004)	(0.013)	(0.004)
Log abs. difference in GDP per capita	-0.023	-0.009	0.035**	0.010**
	(0.015)	(0.006)	(0.018)	(0.005)
Number of observations	500,818		165,117	
Log pseudolikelihood	-318225.7		-83395.2	
Prob>chi2	0.000		0.000	
R2	0.050		0.084	

Note: "New" refers to new product–country pairs. "Disappearing" refers to disappearing product–country pairs. The results for the constant term are not reported but are included in the regressions. Standard errors, clustered by country pair, are listed in parentheses. * Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

4.3 Country-by-country Comparison

Table 5 presents the results for each East Asian country that exports to trading partners with identical statistical analysis and explanatory variables, concentrating on the machinery industry and the separate estimation of each specification for the 13 countries in our data set. Only the coefficients and marginal effects of the P&C dummy (β_1) are reported because they are the main focus of this paper[23]. The signs of coefficients and marginal effects for new and disappearing product–country pairs are expected to be contradictory. In 10 of the 13 countries, we find that parts and components trade presents a higher probability of new product–country pairs forming than that presented by final product trade. The probability of becoming a new product–country pair is highest for the Philippines (15.9%), followed by

[23] Notably, we still include other variables in the regression, the signs of which mostly align with our expectations.

Thailand (15.5%), Indonesia (15.2%), and Malaysia (14.7%). This suggests that those countries are active exporters of parts and components for 2013 in both intra– and inter–regional trade. Notably, Myanmar exhibits statistically significant positive marginal effects (3.3%); although this is at the 5% level and the effect size is smaller than those of other countries. The results of other countries such as Brunei, Cambodia, and Lao PDR are insignificant, but all fit the sign of expectation. The results in Column 4 reveals that in 10 of the 13 countries, parts and components show a lower probability of becoming disappearing product–country pairs compared with final products. The lowest magnitude is for the Philippines (21.6%), followed by Singapore (19.7%), Thailand (18.9%), and Malaysia (18.8%). The magnitude of the marginal effect varies across countries. Parts and components trade in Myanmar also presents significantly negative marginal effects with a relatively lower probability of becoming a disappearing product–country pairs (5.2%). A similar low probability presents in China, with parts and components differing by only 5.2% from final products. As for Brunei, Cambodia, and Lao PDR, the marginal effects remain nonsignificant; however, Cambodia and Lao PDR present negative signs.

Table 5. New and Disappearing Product–country Pairs: Country-by-country Comparison

	All machinery products					
	New			Disappearing		
	P&C			P&C		
	β_1		N	β_1		N
Exporter	(1) Coefficient	(2) Marginal effect		(3) Coefficient	(4) Marginal effect	
Brunei	0.076	0.020	4,004	0.102	0.031	365
	(0.067)	(0.017)		(0.200)	(0.062)	
China	0.214***	0.074***	93,147	-0.316***	-0.052***	30,893
	(0.020)	(0.006)		(0.031)	(0.005)	
Indonesia	0.399***	0.152***	43,891	-0.476***	-0.173***	6,280
	(0.021)	(0.009)		(0.042)	(0.015)	
Japan	0.345***	0.133***	59,420	-0.526***	-0.160***	49,521
	(0.025)	(0.011)		(0.024)	(0.007)	
Cambodia	0.087	0.028	4,632	-0.379	-0.068	193
	(0.056)	(0.018)		(0.279)	(0.050)	
Korea	0.311***	0.123***	65,299	-0.525***	-0.152***	26,123
	(0.019)	(0.008)		(0.023)	(0.007)	
Lao PDR	0.114	0.031	2,427	-0.001	-0.000	116
	(0.074)	(0.019)		(0.055)	(0.002)	
Myanmar	0.133**	0.033**	3,459	-0.244**	-0.052**	172
	(0.056)	(0.014)		(0.120)	(0.026)	
Malaysia	0.380***	0.147***	52,972	-0.583***	-0.188***	13,475
	(0.020)	(0.008)		(0.030)	(0.010)	
Philippines	0.426***	0.159***	32,127	-0.589***	-0.216***	5,264
	(0.021)	(0.008)		(0.044)	(0.016)	
Singapore	0.378***	0.142***	52,028	-0.580***	-0.197***	19,883
	(0.021)	(0.009)		(0.021)	(0.008)	
Thailand	0.395***	0.155***	56,366	-0.583***	-0.189***	11,715
	(0.020)	(0.008)		(0.031)	(0.011)	
Vietnam	0.256***	0.102***	31,046	-0.343***	-0.125***	1,117
	(0.025)	(0.010)		(0.080)	(0.029)	

Note: "New" refers to new product–country pairs. "Disappearing" refers to disappearing product–country pairs. Results for the constant term and other explanatory variables are not reported but are included in the regressions. Standard errors, clustered by country pair, are listed in parentheses. ∗ Significant at the 10% level. ∗∗ Significant at the 5% level. ∗∗∗ Significant at the 1% level.

5 Policy Implication

Our findings provide meaningful economic implications for East Asian countries that have a higher probability of exporting parts and components than exporting final products, particularly in intra-regional trade of East Asian countries. The findings support the rapid development of marked growth in parts and components trade, resulting in frequent back- and- forth transactions and an increase in product–country pairs in parts and components across the year. Subsequently, we find that parts and components have a higher probability of becoming new product–country pairs and lower probability of becoming disappearing product–country pairs, relative to final products. Developing and least developed countries that aspire to engage in this production chain can obtain useful information and find opportunities to become new participants. Regarding already-active participation in machinery production networks, such as for developed countries, our findings strengthen confidence in the trade of parts and components and reassure them that they are able to maintain close trade relationships with trading partners without breaking up. Moreover, RTA is the crucial factor that contributes to lower disappearing product–country pairs. This is because tariff reductions cause lower transaction costs; therefore, exporters are more likely to enter the destination market. This is consistent with the results found by Yi (2003) that tariff reductions also contribute to the growth of the extensive margin in vertical specialization. The estimated results of country-by-country specification explicitly reveal specific policy implications for individual East Asian countries. Most countries demonstrate expected signs in the probability of becoming new and disappearing product–country pairs and the results are statistically significant. The difference varies by the magnitude of coefficient, with stronger impacts being observed in Indonesia, the Philippines, Malaysia, and Thailand. This comprehensive examination of machinery production networks provides policy makers the chance to reconsider the redistribution of trade patterns in terms of parts and components and final products.

6 Conclusion

This paper uses highly disaggregated international trade data at the HS six-digit product level during 1996–2013 to investigate the extensive margin of trade in machinery. We document how the degree of involvement of international production networks increases, particularly the number of product–country pairs exported to major trading partners from East Asian countries. China, Singapore, Japan, and Korea present stable development that involves in global production sharing. In addition to the already-active regions in production networks, Indonesia, Thailand, Vietnam, Malaysia, and the Philippines shows signs of joining production networks and its degree of participation exhibits unprecedented growth. Furthermore, we look at the status of product–country pairs and find that parts and components have a higher proportion of new and continuous product–country pairs and a lower proportion of disappearing product–country pairs compared with final products. Our probit model shows the probability of exporting in 2013 and provides evidence that parts and components have a 14.3% higher probability of exporting than do final products. The marginal effect is robust while considering the interaction term of parts and components in East Asian countries in our specification. Finally, our findings indicate that parts and components are statistically significant with a 12.8% higher probability of becoming new product–country pairs and 14.5% lower probability of becoming disappearing product–country pairs. The country dimension is statistically significant in 10 of the 13 countries, and the magnitude of the marginal effects varies across countries, although the sign is as expected. The results provide informative and meaningful policy implications for countries in the early stages of involvement in international production networks.

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Appendix

Appendix Table A1: Trading Partners

Afghanistan	Costa Rica	Hungary	Malawi	Peru	Turkey
Albania	Croatia	Iceland	Malaysia	Philippines	Turkmenistan
Algeria	Cuba	India	Maldives	Poland	Uganda
Argentina	Cyprus	Indonesia	Mali	Portugal	Ukraine
Australia	Czech Republic	Iran	Malta	Qatar	United Arab Emirates
Austria	Denmark	Ireland	Mauritius	Romania	United Kingdom
Bangladesh	Dominica	Israel	Mexico	Russia	United States
Barbados	Ecuador	Italy	Moldova	Rwanda	Uruguay
Belarus	Egypt	Jamaica	Mongolia	Saudi Arabia	Venezuela
Belgium	El Salvador	Japan	Morocco	Senegal	Vietnam
Belize	Estonia	Jordan	Mozambique	Singapore	Yemen
Bhutan	Fiji	Kazakhstan	Myanmar	Slovak	Zambia
Bolivia	Finland	Kenya	Namibia	Slovenia	Zimbabwe
Brazil	France	Korea	Nepal	South Africa	
Brunei	Gabon	Kuwait	Netherlands	Spain	
Bulgaria	Germany	Latvia	New Zealand	Sri Lanka	
Burkina Faso	Ghana	Lebanon	Nicaragua	Suriname	
Cambodia	Greece	Libya	Nigeria	Swaziland	
Cameroon	Grenada	Lithuania	Norway	Sweden	
Canada	Guatemala	Luxembourg	Oman	Switzerland	
Chile	Guyana	Macao	Pakistan	Tanzania	
China	Honduras	Macedonia	Panama	Thailand	
Colombia	Hong Kong	Madagascar	Paraguay	Tunisia	

Appendix Table A2: Summary of the Statistics for Variables

	Mean	SD	Min	Max	N
P&C	0.437	0.496	0.000	1.000	665,935
Status 1996	0.248	0.432	0.000	1.000	665,935
Log distance	8.911	0.689	6.226	9.886	665,935
Language	0.115	0.320	0.000	1.000	665,935
Contiguity	0.035	0.185	0.000	1.000	665,935
RTA	0.223	0.416	0.000	1.000	665,935
Log GDP of origin country	27.740	1.525	23.143	29.855	665,935
Log GDP of destination country	25.833	1.936	20.063	30.451	665,935
Log abs. difference in GDP per capita	9.435	1.347	0.971	11.605	665,935
Intra regional trade*P&C	0.056	0.231	0.000	1.000	665,935

Notes: SD is standard deviation and N is number of observations. P&C refers to parts and components.