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Essays on machinery production networks and the globalizing world economy: a comparison between Latin America and East Asia

Graduate School of Economics, Keio University
Mateus Silva Chang

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by:

Mateus Silva Chang

Supervisors:
Fukunari Kimura
Professor of Economics

Yoshimasa Shirai
Professor of Economics

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LIST OF ABBREVIATIONS

BEC – Broad Economic Categories

CAN – Andean Community

CEE – Central and Eastern Europe

CEPII – Centre d’Etudes Prospectives et d’Informations Internationales

EA – East Asia

EU – European Union

FTA – Free Trade Agreements

GDP – Gross Domestic Product

GVC – Global Value Chains

HS – Harmonized System

ICIO – Inter-Country Input-Output

ICT – Information and Communication Technology

IO – Input-Output

ISIC – International Standard Industrial Classification of All Activities

JAMA – Japan Automobile Manufacturers Association

JETRO – The Japan External Trade Organization

LA – Latin America

LPI – Logistic Performance Index

MRIO – Multi-Region Input-Output

NA – North America

NAFTA – North American Free Trade Agreement

OECD – Organisation for Economic Co-operation and Development

OLS – Ordinary Least Squares

P&C – Parts and Components

PPML – Poisson Pseudo-Maximum-Likelihood

PTA – Preferential Trade Agreements

ROW – Rest of the World

SITC – Standard International Trade Classification

TiVA – Trade in Value Added

TRAINS – Trade Analysis and Information System

UN Comtrade – United Nations Commodity Trade Statistics Database

UNCTAD – United Nations Conference on Trade and Development

VAX – Value Added to Gross Exports

WIOD – World Input-Output Database

WITS – World Integrated Trade Solution

WTO – World Trade Organization

ABSTRACT

This Ph.D. dissertation is composed of a collection of five essays, fruit of the research effort during my studies in the Graduate School of Economics, Keio University. The main topic that connects each chapter is the recently established way of organizing the manufacturing production, referred as production networks. A consequence of the production fragmentation, or the second unbundling, the international production networks are considered as one of the main causes of the international trade boost in the last decades. It promoted a reduction in the production costs, taking advantage of different locations comparative advantages. Besides this, it opened new possibilities to developing countries, allowing their engagement on some steps of the production of goods they could not produce before. In other words, international production networks is a topic of extreme relevance in the international trade and development economics field.

The emphasis on machinery is explained by the fact that this is the industry that employs the highest number of parts and components, being naturally the most prone to and developed one in terms of production fragmentation. Consequently, the machinery industry is the most appropriate to the study of this type of manufacturing organization.

Despite the reductions in trade and service link costs promoted by the Industrial and the Information and Communication Technology (ICT) revolutions, the core of production networks are still localized inside geographical regions. Therefore, many articles were produced to evaluate the machinery production networks inside three main blocs: East Asia, European Union, and NAFTA. In general, these articles revealed the production structure characteristics of each bloc and contrasted their specificities. During my studies, I identified a scarcity of research related to Latin America and its role in

machinery production networks evolution. The essays in this dissertation are part of an effort to contribute to the international trade and development economics literature, aiming complement the incipient studies comprising Latin America. In fact, to facilitate the comprehension of Latin America's condition, the aggregate of the chapters provides a contrast between the situation in Latin America and East Asia. The choice for East Asia was grounded in three main reasons: East Asia is considered the state-of-the-art in terms of machinery production fragmentation; different from European Union and North America, East Asia configuration is more similar to the Latin American one, being composed mainly of developing economies; the existence of many previous studies in the economics field comparing both regions and their development patterns, makes it a natural choice.

The objective of this dissertation's first chapter is double-fold: update machinery production fragmentation evolution, providing the general scenery of international production networks in the globe, and identify the new tendencies promoted by East Asia's increase in trade of parts and components. Based on data restrictions, UN Comtrade machinery trade data for the period 1996–2011 was collected and classified in parts and components or final products. In the first part of the chapter, trade values and extensive margins were analyzed, providing the general panorama of machinery production networks. In the latter half, a gravity model framework was used to test the hypothesis that the East Asian region has an increasing role supplying production networks in other regions of the globe. Evidences confirmed East Asian role in the development of these inter-regional relations concomitant with a reinforcement of intra-regional production networks. These exercises were also performed for the two main types of machinery, electric machinery and transport equipment, aiming to reveal the differences in their trade patterns. The results indicated that electric machinery has lower transport costs being more prone to fragmented productions networks. Besides this, it was also verified that transport equipment trade cost is lower for final products, while electric machinery trade cost is lower for parts and components, another sign that the latter is more prone to production fragmentation.

Once that the first chapter concentrated more on East Asian trade patterns, the second chapter provides a descriptive analysis of Latin American countries evolution in machinery trade values and extensive margins along the same period (1996–2011). In the first half of the chapter, trade data classified in parts and components or final products revealed an important difference from East Asia: the predominance of final products imports. This information indicates a lower engagement of Latin America in production networks. However, the data also offered evidences of an increase in parts and components imports during the studied period, demonstrating a slow engagement of Latin America in machinery production networks. A quantitative analysis employing a graviy model framework confirmed the findings from the descriptive part.

As Latin America is a heterogeneous region, in the second half of the chapter the analysis focus on the performance of its main economies: Brazil and Mexico. Although both countries maintain developed machinery industrial parks, the adoption of different trade policies led to different levels of engagement on production networks. Mexico participates actively in machinery production networks with higher import values of parts and components and higher export values of final products. On the opposite side, Brazil trade is more concentrated in final products. Another important aspect is the fact that although the Brazilian economy is bigger than the Mexican one, Brazil's machinery trade values are less than half of the Mexican ones. The lack of free trade agreements (FTA) and the protectionist tendency of the Brazilian market are possible reasons for the low level of use of imported parts and components in the domestic machinery industry. Furthermore, the lack of competitiveness of Brazilian products and the domestic oriented production of Brazilian machinery industries are possible explanations for the low level of exports in this sector. These evidences demonstrate that Brazil is not exploring all of its potentials as a participant of machinery production networks.

In the third chapter, international Input-Output (IO) tables were used to estimate indicators that provide evidences of the East Asian and Latin American production fragmentation structure that could not be captured using trade data. The use of this different source of data has the advantage of capturing features like the level of integration in vertically fragmented production networks, the length of these production networks and the distance to the final demand, allowing a comparison between East Asian and Latin American countries. The results obtained supported the discoveries of the previous chapters, confirming the dissimilarities relative to both regions production fragmentation patterns. It was also possible to observe the heterogeneity among the countries that compose each region. In general, the indicators demonstrated a greater participation of East Asian countries in production fragmentation. The East Asian countries exported products that contained less domestic value added than Latin American ones and they participated more in fragmented productions, presenting higher shares in the indices of vertical specialization than Latin American countries. Furthermore, East Asian countries engaged in production networks with a higher number of stages. All these characteristics corroborate the idea that East Asia has higher levels of engagement in production networks.

The fourth chapter investigates the effects that the increase in the importation of machinery parts and components and the changes in the supplier composition had in the trade of final products and parts and components inside Latin America. In other words, given that the first chapter showed an increase in East Asian role supplying production networks in third regions and that the second chapter revealed an increase in Latin American countries imports of parts and components, the fourth chapter investigates the effects that parts and components imports from third regions had in the machinery trade inside Latin America. The first part of the chapter provides a more detailed descriptive analysis, including changes in the intensive and extensive margins. The data revealed a considerable increase in imports from East Asia.

From the perspective of production fragmentation logic, a country purchases more parts and components from a given region if these products have some comparative advantage. The existing literature highlights two channels through which access to inputs can benefit a country: an efficiency gain in the production process by the acquisition of cheaper and/or higher quality inputs, and the possibility of having access to inputs that previously could not be produced domestically or obtained from a third country. In both cases, a gain in productivity and changes in production pattern are expected. Based on this fact, we consider the hypothesis that the increase in import of parts and components, especially from East Asia, should be beneficial to Latin American machinery production networks.

In the second part, a gravity model framework was employed to test these effects according to two dimensions: a quantity one that captures whether an intensification of trade exists and a quality one that captures changes in the sophistication of the traded goods inside Latin America. Evidence was found that an increase in the importation of parts and components from Latin America had positive impacts on both the quantity and quality dimensions. Subregional heterogeneities revealed that, in general, imports from East Asia had positive effects on the quantity dimension, nurturing the expansion of machinery production networks inside Latin America, and on the quality dimension, increasing the sophistication of the products traded inside Latin America, especially for Mercosur member's exports. Imports from North America had positive quantity effects, especially for exports of countries from the Andean Community, Central America, Chile, and Mexico.

The first four chapters use descriptive and quantitative analysis to reveal the evolution of machinery production networks. We identify an enhance of East Asian role in fomenting production networks inside third regions, while Latin American region is slowly engaging in this production organization. We also provide evidences of East Asian countries importance in the promotion of the development of machinery production networks inside Latin America.

The fifth chapter approaches the production networks theme from a totally new perspective. Unifying the tariff evasion literature with the production networks literature, this chapter objective is to confirm if production networks trade are less, equally, or more prone to import tariff evasion than non-production networks trade. Production networks trade relations are, in general, more intensive and stable, increasing the number of times given products are traded in a given period, facilitating the identification of the correct unit value of the traded product. Besides this, the engagement of a country in this type of production organization presupposes a standard of rule of law stability, efficiency dealing with products and competitive prices. Consequently, it is expected that products traded inside production networks would be less prone to tariff evasion. To test this hypothesis we use East Asian intra and inter-regional import data, since this region is considered the state-of-the-art in terms of machinery production networks. Quantitative exercises provide evidences that confirm our hypothesis. Although production networks does not aim curbing import tariff evasion, one of its side effects is the reduction of this practice.

As a robustness check exercise, we compare the import tariff evasion patterns of East Asian intra and inter-regional machinery trade with Latin America's import tariff evasion patterns for intra and inter-regional machinery imports. Although both regions have developed industrial parks, it is known from the previous chapters that Latin America's engagement in production networks is still incipient. Consequently, we compare both regions import tariff evasion patterns expecting that if our hypothesis is correct, Latin American import tariff evasion should present different patterns. It is also expected that Latin American intra and inter-regional import tariff evasion patterns should be similar. Our results reveal no clear differences between Latin American intra and inter-regional import tariff evasion. Furthermore, an examination of the channels employed to evade import tariff reveals that in the Latin American case product quantity underreport, unit price underreport, and product mislabeling were all used in intra and inter-regional trade, while in the East Asian case the quantity under-report was used mainly in the intra-regional trade, while unit price misreport was a practice more common on inter-regional trade. The prevalence of dissimilitude among the two regions tariff evasion patterns endorse the hypothesis that the patterns found in the East Asian case are specific of production networks.

To sum up, the essays in this Ph.D. dissertation provide a rich panorama of machinery production networks development in the period 1996–2011. It contributes to the literature highlighting the increasing importance of East Asian role as a supplier of parts and components to third regions, the slow engagement of Latin American countries on this type of production organization and the quantity and quality impacts that imports of parts and components from the different regions of the world have on Latin American intra-regional machinery trade. Besides these contributions, this Ph.D. dissertation reveals another dimension of production networks effects that is less trivial. It discloses that production networks indirectly contribute to the decrease in machinery import tariff evasion and restrict the channels available for this practice.

CHAPTER 1 – The Evolution of Machinery Production Networks in the World

In this chapter, disaggregated import data from the United Nations Commodity Trade Statistics Database (UN Comtrade) were employed to analyze the evolution of machinery industry trade in the world. In order to test the hypothesis that the East Asian region has an increasing role supplying production networks in other regions of the globe, machinery data were split into final products or parts and components and both, trade values and extensive margins, were examined. Evidence was found that these inter-regional relations were developed simultaneously with the reinforcement of intra-regional production networks. A gravity model framework was also employed to contrast the evolution of the two main machinery sectors: electric machinery and transport equipment.

1.1 Introduction

The production fragmentation was one of the elements that boosted the development of the international trade in the last decades. To be more competitive, many firms expanded their plants to foreign countries and split their activities aiming have access to cheaper factors of production. There were also cases in which a firm outsourced some steps of the production process to third firms localized in different regions and countries. The result was the creation of a web of economical interactions called the international production networks.

According to Baldwin (2011), this labor international division was driven by two unbundlings. Initially, production and consumption was geographically bundled given the cost and time constraints imposed by the available transport. The first Industrial Revolution allowed the invention and diffusion of the railroads and steamships, promoting a considerable decrease in the transport cost that made possible the first unbundling. The machineries and know-how necessary to produce a given a product, as well as, the consumption of the final products were dispersed internationally. However, the production process was still clustered locally. Geographical proximity lowered not just the physical transport cost, but also a new distance-linked cost that was called "coordination glue". In other words, even though some production steps could be performed in different plants, these plants had to be located inside a geographical range that allowed the coordination of the entire production activities. Besides this, scale economies assumed an increasing important role to compete in the international market, reinforcing the importance of a local clusters.

The second unbundling was possible given the Information and Communication Technology (ICT) Revolution that made cheaper, easier, faster and safer the coordination of complex activities at distance. The production process that once was locally clustered could be broken in blocks or production stages, leading to the creation of production networks. According to Fujita, Krugman and Venables (2001), another force that also pushed for the decentralization was the congestion costs that resulted from the excessive concentration of production in one region.

The second unbundling is a relatively new event that started at the end of the 1980s and the beginning of the 1990s. Therefore, production networks are still developing and deserves an analysis of how it has evolved in the last decades. Provided that machinery industry presents a high level of complexity and use of parts and components, it is one of the most suitable for the production networks study. Furthermore, according to Athukorala (2011), the machinery and transport equipment sector concentrates 90.0% of parts and components traded in the world. Hence, the present chapter focuses on the machinery industry international trade, analyzing the spatial structure of production networks in this industry.

The chapter will be organized as follows: section 2 provides a descriptive analysis of the international machinery trade data, classifying the trade according to origin and destiny regions, final products or parts and components, and machinery sector. Both, trade values and extensive margins, are examined in order to assess intra and inter-regional links. Section 3 employs a gravity model framework to check the machinery international trade in general. Next, we investigate the performance of two different machinery sectors, electric machinery and transport equipment. Based on the characteristics of each machinery sector, we expect that transport equipment production networks develop slowly and by regional agglomerations, while electric machinery production networks tend to spread faster and across the regions. Section 4 presents the final considerations.

1.2 The machinery trade in the world

To better understand the evolution of machinery industry global trade and the creation of production networks, machinery bilateral import data of 1996 and 2011 was analyzed in terms of US-dollar deflated values[1] and extensive margins.

1.2.1 Data

We employ international trade data classified according to the Harmonized System (HS), disaggregated to the six-digit level based on its first version (HS1992), obtained from the UN Comtrade. The analysis focused on two points in time, the year 1996 and the year 2011, and the trade data are restricted to the machinery industry and the countries that had an import value equivalent to at least 0.01% of the world machinery imports in 2011. The machinery industry is comprised of all the goods classified as

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[1] The base year of the deflated values is 1996.

general machinery (HS84), electric machinery (HS85), transport equipment (HS86-89), and precision machinery (HS90-92). The use of import data instead of export data is a practice well known in the international trade field, being justified by the fact that the former is more reliable than the latter.[2] The classification of the data into parts and components or final products was performed based on the classification presented by Kimura and Obashi (2010).[3]

Countries in the dataset were classified into five main regions to facilitate a comparison of the trade patterns among these blocs. The blocs are composed of countries from East Asia (EA),[4] countries from the European Union (EU),[5] countries that are members of the North American Free Trade Agreement (NAFTA), countries from Latin America (LA),[6] and the rest of the world (ROW).

1.2.2 Descriptive analysis

Observing the total exports and imports deflated value (in million US$) per region we identify the contribution of each area in the machinery international trade. The first evidence from the data is that traded machinery values presented a sharp increase in the period from 1996 to 2011. Figure 1.1 shows that international machinery trade was mainly concentrated in three regions: EA, EU, and NAFTA. Exports from these regions accounted for more than 88% of world exports in both periods, while the imports

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[2] In general, it is expected that a country's customs tend to be more strict in the control of imported products data than exported ones given that it has to collect import tariff and also screen what is entering the borders.

[3] The classification is available in the Appendix Table A.1.1.

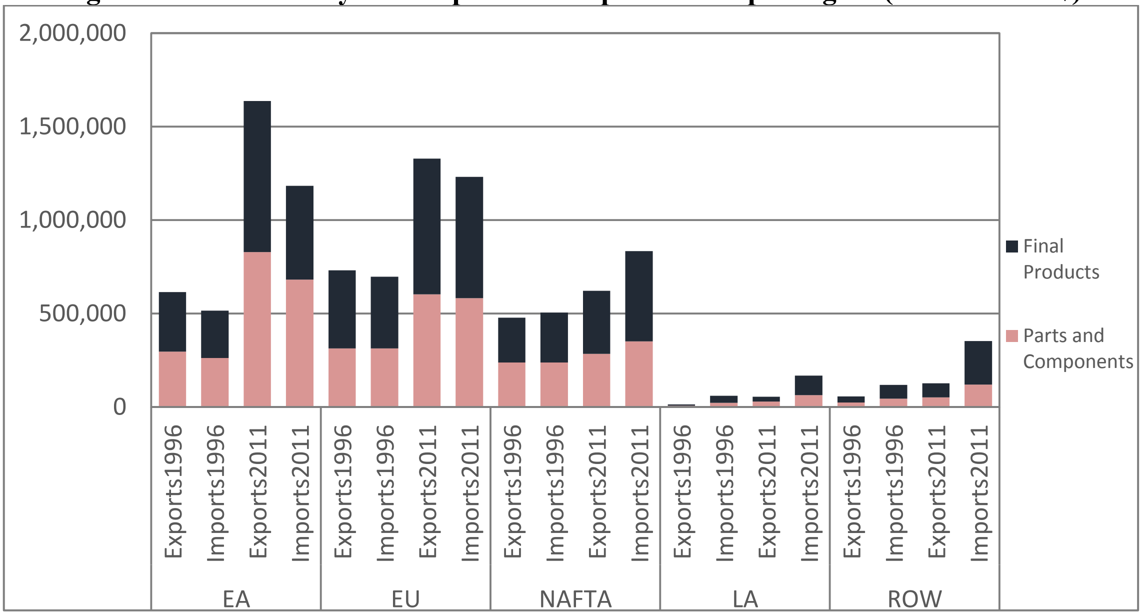
[4] East Asia is composed of the ASEAN (Association of Southeast Asian Nations) countries plus Australia, China, Hong Kong, India, Japan, New Zealand, and Republic of Korea. Given a lack of data Brunei, Cambodia, Laos, Myanmar, and Vietnam were not included in the analysis. On the other hand, according to UN Comtrade's definition, Hong Kong and China were considered as different trading economies.

[5] Given the fact that in 1996 Belgium and Luxembourg data were treated as Benelux, while in 2011 they were treated as individual countries, these two countries were not included in the analysis.

[6] As Mexico is part of the NAFTA, it is not counted again in the LA bloc.

accounted for more than 79%. Consequently, LA and the ROW were almost marginalized from the machinery trade.

Figure 1.1 – Machinery total export and import values per region (in million US$)



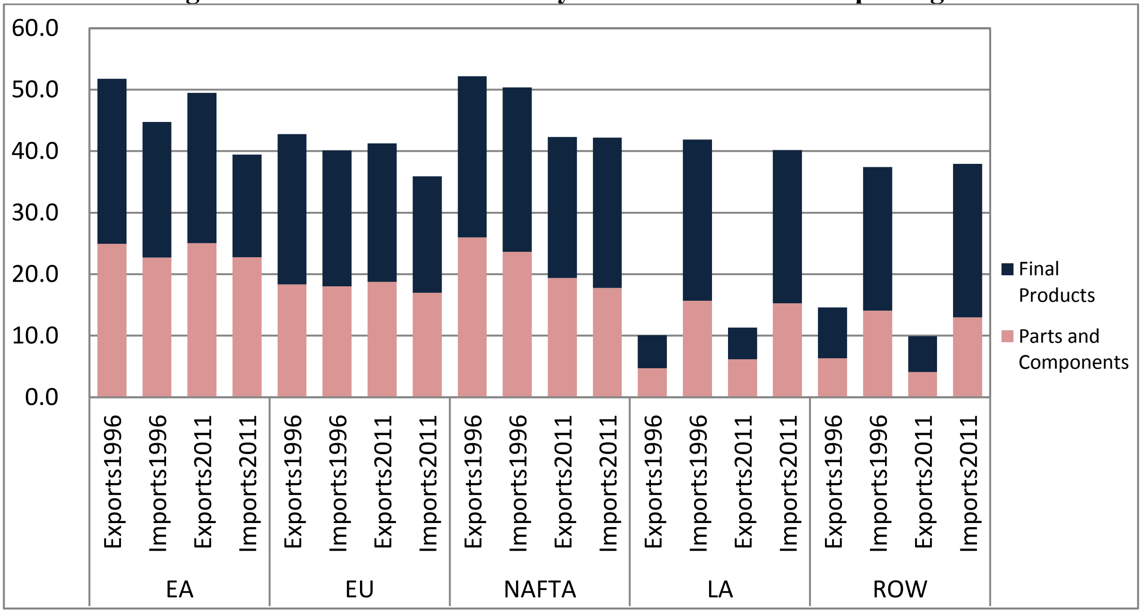
Source: Author's calculation using data from the UN Comtrade.

Figure 1.1 also shows that in 2011 EA and EU were respectively the first and second biggest traders of machinery in the world. EU import value was almost US$50,000 million higher than EA one. On the other hand, EA exported almost US$310,000 million more than EU. Besides this, EA and EU were the only regions with higher export values, while the others had higher import values. In other words, EA and EU were the only regions with positive trade balance in machineries, being mainly exporters to the other areas of the globe.

Considering that the machinery trade can be divided into machinery final goods or machinery parts and components, another important remark from Figure 1.1 is that in 1996 all the regions presented higher final products trade values, with EA imports being the only exception. Although in 2011 LA presented a slightly higher value of exports for parts and components (a surplus around US$4,700 million), the EA was the only region in the world that presented considerable higher values of trade in parts and components (a surplus around US$22,800 million in the exports and US$182,000 million in the imports). The preponderance of trade in parts and components indicates that EA has a predisposition to supply production networks, participating in production processes inside and outside its own region.

Figure 1.2 illustrates the shares of machinery trade over total merchandise trade, providing several interesting findings. First, with the exception of machinery exports in LA and imports in ROW, in all the other regions machinery trade shares declined from 1996 to 2011. There are two possible reasons for this fact. The first one is the increase in the commodities prices that occurred in the 2000s leaded by the Chinese economy growth and its necessity of importing food, energy, and materials from regions other than EA. A second cause is the International Financial Crisis that resulted in a decrease in the demand and volume of traded products in the developed countries, especially within the US and European Union.

Figure 1.2 – Shares of machinery trade over total trade per region



Source: Author's calculation using data from the UN Comtrade.

Second, the figure shows that in LA and ROW the machinery participation in exports is very low, being higher in imports. This configures both regions as importers of machinery products.

In 1996 NAFTA was the region that had the biggest share of machinery trade over the total trade. Though in 2011 NAFTA still had the highest share of machinery imports, EA presented the highest share of machinery exports, around 50% of total exports, a participation almost 10 percentage points higher than the one in the second highest region.

Although there was a decrease in the share of total trade for almost all regions, a closer analysis reveals that trade shares of final products decreased more than parts and components for the majority of the cases. Actually, for EA exports and imports, EU exports, and LA exports, there were increases in the parts and components traded shares. This increase in the importance of machinery parts and components trade reflects an increasing tendency of production fragmentation.

The previous data indicated that EA, EU, and NAFTA were the three main players in the machinery international trade. It also showed the relative increase in parts and components trade, suggesting a trend of machinery production fragmentation. According to Ando and Kimura (2014), the fragmentation process in these three regions occurs in different levels. NAFTA had the simplest type of production fragmentation until recently, mostly a back-and-forth intra-firm trade, a cross-border production that does not deeply integrate the region's economies. The EU also had a simple cross-border integration with the Central and Eastern Europe (CEE) countries that changed to a more integrated one after their accession in 2004 to the European Union. The EA has the most sophisticated production networks where many countries combine fine-tuned intra-firm and inter-firm transactions, resulting in the creation of a regional industrial agglomeration.

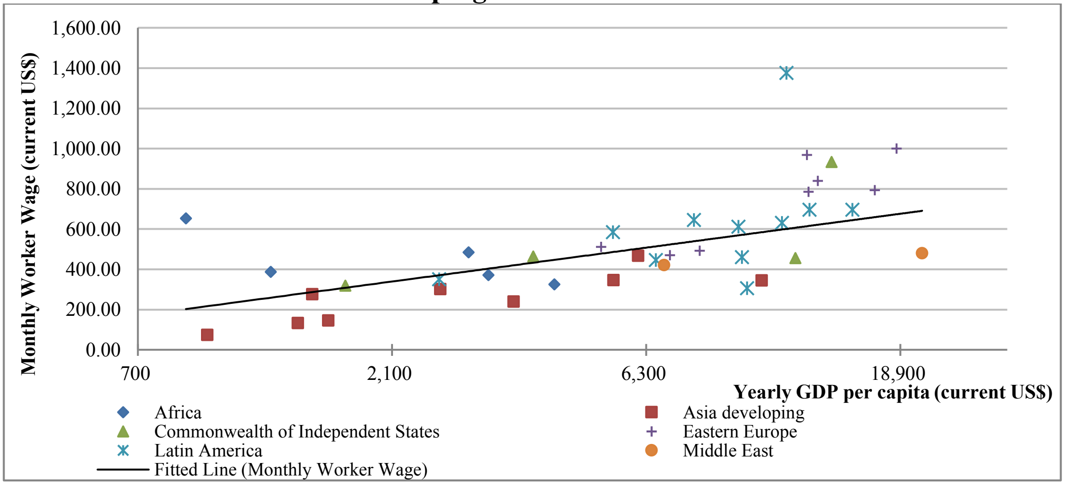
Considering the concentration of the trade and the existence of different patterns of production networks development in each region, we present a brief analysis based on the three main regions' data.

1.2.2.1 The machinery trade in East Asia

The East Asian region is the most developed in terms of production networks. The integration process started in the 1960s with Japan commanding the famous flying geese model. At that time, Japan realized that given the existence of certain comparative advantages in other Asian countries, cheaper labor force for example, it would be profitable keeping in Japanese soil the production of the parts and components with more value added, while dislocating the rest of the production to Taiwan, Korea, Hong Kong or Singapore. Gradually these areas developed their economy and technology, achieving a considerable integration with Japan's production. As the first four economies went up a few steps in the industrialization ladder, other countries from Southeast Asia and China were integrated in this process to substitute the first ones in the lower levels of the production. Consequently, in the first decade of the 21st century almost the whole East Asian region was already part of the process of production integration aiming export final products to the world.

One of the main comparative advantages of East Asia is the abundance of labor force that keeps the region wages in a lower level than the rest of the world. Observing Figure 1.3 that presents the correlation between the worker wage and the logarithm of the gross domestic product (GDP) for developing countries in 2012, we identify that the worker wages in almost all countries in developing East Asian region are lower than the Latin American and Eastern European ones. In fact, it is even lower than the worker wages in Africa. Low worker wages in East Asia are due to relatively smooth labor movements from informal to formal, from rural to urban, and from non-manufacturing to manufacturing sectors.

Figure 1.3 – Correlation between monthly worker wage and GDP per capita for developing countries in 2012[7]



Source: Author's calculation using data from JETRO and the World Bank Database.

On the other hand, Figure 1.4 presents the correlation between the logistic performance index (LPI) and the logarithm of the GDP in 2012. Considering the LPI as a proxy for the service link cost, the figure indicates that, with the exception of Cambodia and Lao, the countries in developing East Asian have LPI values above the conditional average. In other words, they present better logistic performance that results in lower service link cost. These advantages enabled the East Asian region to fragment its production, reduce the prices, and improve its competitiveness in the international market.

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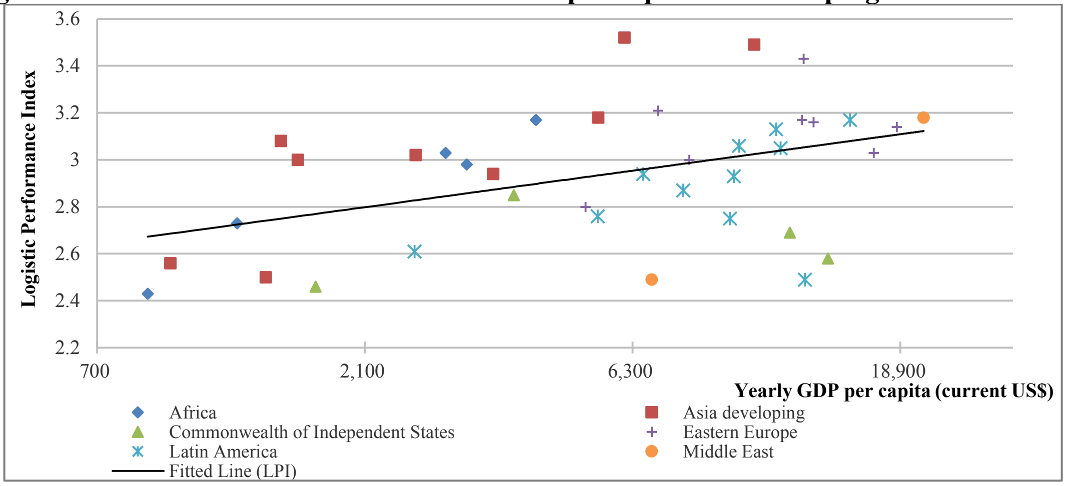
[7] List of the cities per region: Africa – Nairobi (Kenya), Casablanca (Morocco), Abidjan (Ivory Coast), Cairo (Egypt), and Tunis (Tunisia);
Asia developing – Beijing (China), Bangkok (Thailand), Kuala Lumpur (Malaysia), Manila (Philippines), New Delhi (India), Jakarta (Indonesia), Hanoi (Vietnam), Vientiane (Lao), and Phnom Penh (Cambodia);
Commonwealth of Independent States – Moscow (Russia), Kiev (Ukraine), Almaty (Kazakhstan), and Tashkent (Uzbekistan);
Eastern Europe – Prague (Czech Republic), Budapest (Hungary), Zagreb (Croatia), Bratislava (Slovakia), Warsaw (Poland), Belgrado (Serbia), Bucharest (Romania), and Sofia (Bulgaria);
Latin America – Buenos Aires (Argentina), Caracas (Venezuela), Santiago (Chile), Bogota (Colombia), São Paulo (Brazil), San Jose (Costa Rica), Guayaquil (Ecuador), Panama City (Panama), Lima (Peru), La Paz (Bolivia) , and Mexico City (Mexico);
Middle East – Riyadh (Saudi Arabia) and Tehran (Iran).

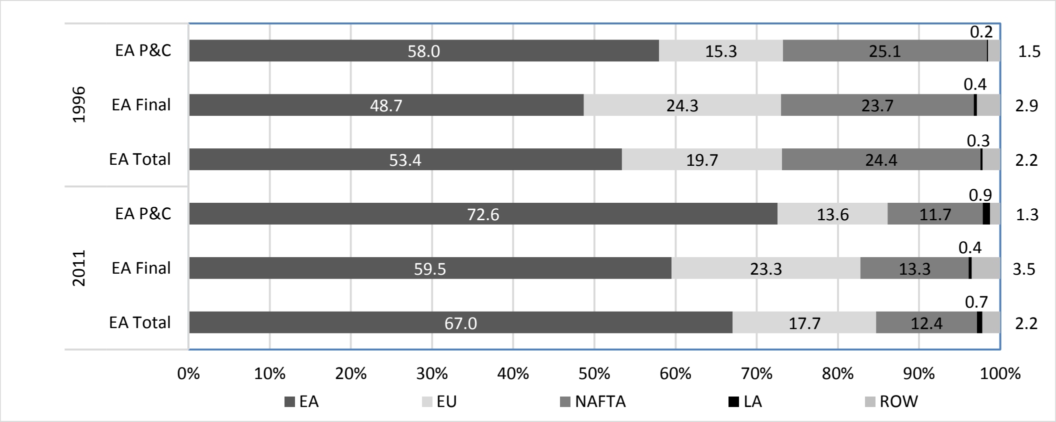
Figure 1.4 – Correlation between LPI and GDP per capita for developing countries in 2012



Source: Author’s calculation using data from JETRO and the World Bank Database.

To visualize the enhancement of EA competitiveness in the machinery international trade, we first present the evolution of the share of machinery imports from 1996 to 2011, having EA as the importer region. Figure 1.5 shows that 53.4% of EA machinery imports in 1996 were intra-regional trade. The EU and NAFTA were responsible for 24.4% and 19.7%, respectively. In 2011 these shares changed with NAFTA decreasing its participation by 12 percentage points, while EU lost 2 percentage points. On the other hand, EA increased its intra-regional trade by 13.6 percentage points achieving a share of 67.0%. This indicates that intra-regional trade increasingly dominated EA machinery imports. In order to check if this trade is a result of the fragmentation process, we also analyze the share for final products (Final) and parts and components (P&C). In 1996 the intra-regional trade in EA was responsible for 58.0% of the parts and components trade and 48.7% of the machinery final goods trade. In 2011 these shares increased by 13.6 percentage points and 10.8 percentage points, respectively. The trade of parts and components inside EA achieved 72.6%, indicating that production networks in EA was stimulated mainly by intra-regional trade.

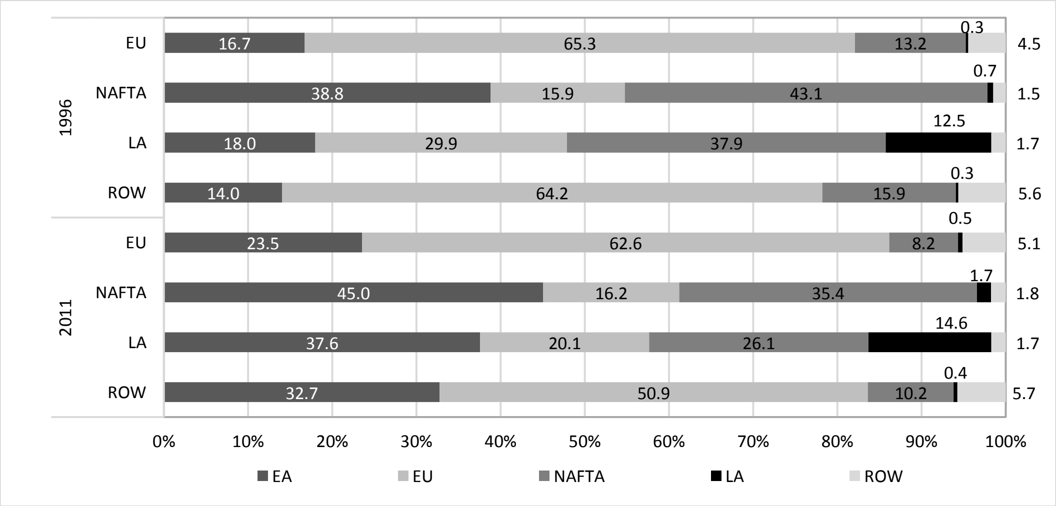
Figure 1.5 – Share of EA machinery imports by region



Source: Author's calculation using data from the UN Comtrade.

Figure 1.6 shows the evolution of EA shares in other regions. The major finding of this figure is that from 1996 to 2011 the EA increased its share in all regions. In 1996, imports from EA were dominant just in NAFTA. In 2011, EA consolidated its participation in NAFTA and became the main supplier to LA. Although the intra-regional trade is prevalent in EU, the EA increased its share by 6.8 percentage points. A similar situation happened in ROW: EU is still the biggest exporter to ROW, but EA took an important portion of EU's share, with an increase by 18.7 percentage points while EU decreased its participation by 13.3 percentage points. These facts reveal an expansion of EA participation on machinery exports all over the globe during the studied period.

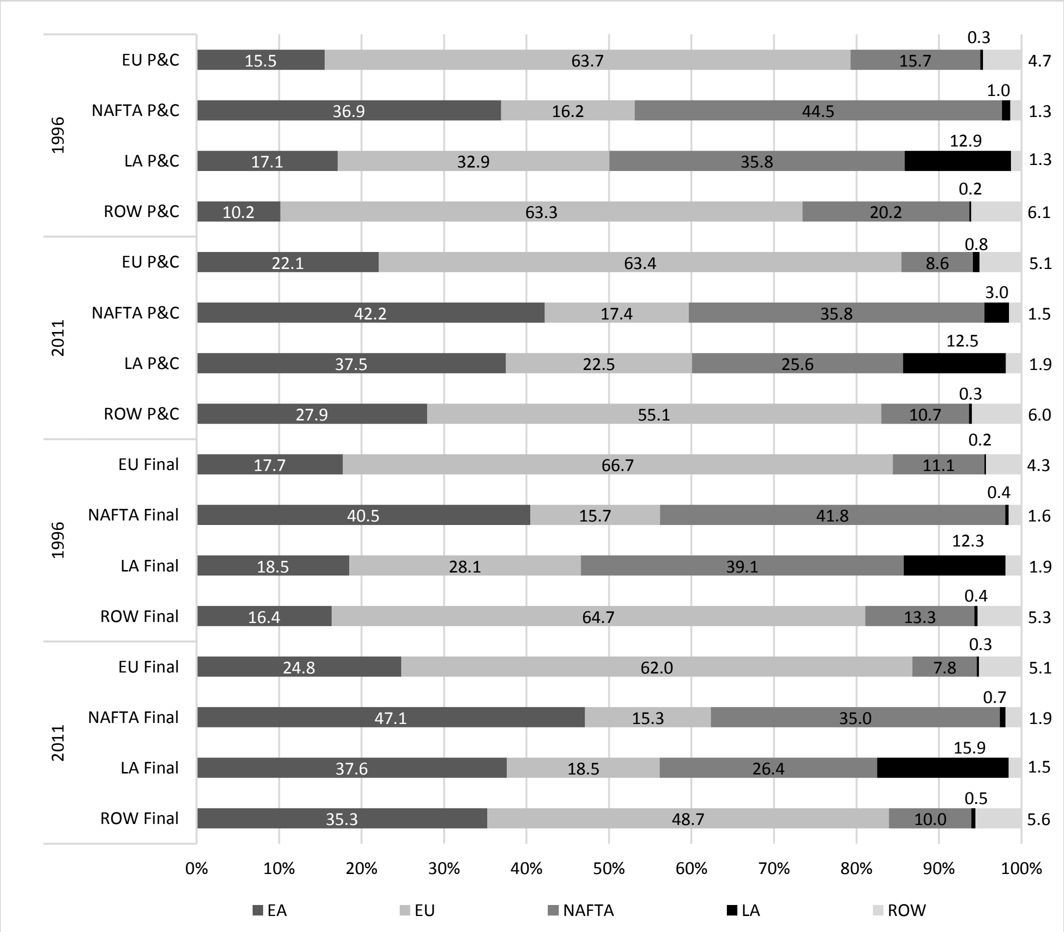
Figure 1.6 - Share of total machinery imports by region



Source: Author's calculation using data from the UN Comtrade.

Figure 1.7 illustrates the imports of final products and parts and components. The objective is to check if the expansion of EA machinery exports to other regions of the world resulted from an expansion in final products or an expansion of trade in parts and components, what could be an evidence of an expansion of EA's role as machinery production networks supplier to other areas of the globe. The figure shows that from 1996 to 2011 there were increases in EA export share of both, final products and parts and components, for all regions. Although, in absolute terms, the difference from EA share in 1996 and 2011 for parts and components and final products did not change much, in terms of growth rate the parts and components share grew faster for two regions, notably ROW and LA, while it presented almost the same pace of final products in EU and NAFTA.

Figure 1.7 - Share of machinery imports by region and type



Source: Author's calculation using data from the UN Comtrade.

As the machinery industry is a heterogeneous one, to capture the characteristic of different machinery sectors, Table 1.1 covers the exports and imports value data of all machinery sectors, electric machinery, and transport equipment, having EA as the base region. The first interesting finding is that in the analyzed period, for all machinery sectors the trade inside the EA increased faster than the average trade with the whole world, especially for parts and components. On the other side, NAFTA presented the slowest growth from the three main regions.

Observing the data for the electric machinery and the transport equipment sector, we can identify different trade patterns for each sector. The parts and components dominate the trade in the electric machinery sector for the whole period, while the transport equipment sector presents the opposite pattern with higher trade values for final products. This indicates that for the EA region the electric machinery sector is more prone to be associated with international production networks, given that parts and components trade value is bigger, while the transport equipment sector seems less prone to the development of international production networks, once the trade value of final products is bigger.

Observing the electric machinery trade growth pace, the intra-regional trade is the one that grew faster, while trade with NAFTA is the slowest one. Considering part and components and final products, the growth in parts and components imports was faster than in final products for all regions, while for exports it was faster just for EA. Nonetheless, the parts and components growth rate for exports was bigger than the imports one.

Table 1.1 – EA machinery trade by region and sector

East Asia			Imports			Exports		
	Year	Origin/Destination	Total	P&C	Final	Total	P&C	Final
(a)All machinery sectors								
Value (millions US$)	1996	World	515,689	261,711	253,978	615,972	296,580	319,392
	2011	World	1,182,883	682,464	500,419	1,637,463	829,738	807,725
Value Index (1996=1)	2011	World	2.3	2.6	2.0	2.7	2.8	2.5
	2011	EU	2.1	2.3	1.9	2.5	2.6	2.4
	2011	EA	2.9	3.3	2.4	2.9	3.3	2.4
	2011	NAFTA	1.2	1.2	1.1	1.9	1.7	2.1
Share (in total (%))	1996	EU	19.7	15.3	24.3	18.9	16.4	21.3
	1996	EA	53.4	58.0	48.7	44.7	51.1	38.7
	1996	NAFTA	24.4	25.1	23.7	31.9	29.6	34.0
	2011	EU	17.7	13.6	23.3	17.7	15.5	20.0
	2011	EA	67.0	72.6	59.5	48.4	59.7	36.9
	2011	NAFTA	12.4	11.7	13.3	23.0	17.9	28.2
(b)Electric machinery sector								
Value (millions US$)	1996	World	213,886	146,379	67,507	264,152	168,987	95,166
	2011	World	532,540	387,751	144,789	771,543	467,781	303,762
Value Index (1996=1)	2011	World	2.5	2.6	2.1	2.9	2.8	3.2
	2011	EU	1.7	1.8	1.6	2.9	2.6	3.3
	2011	EA	3.1	3.4	2.7	3.1	3.4	2.7
	2011	NAFTA	1.0	1.0	0.9	2.1	1.4	3.2
Share (in total (%))	1996	EU	13.0	11.5	16.2	16.8	15.0	20.1
	1996	EA	63.6	64.1	62.6	51.5	55.5	44.4
	1996	NAFTA	22.3	23.4	20.0	28.4	27.2	30.5
	2011	EU	8.9	7.7	12.1	16.7	14.1	20.7
	2011	EA	80.3	81.0	78.1	55.4	67.2	37.2
	2011	NAFTA	8.9	9.0	8.7	20.3	13.7	30.5
(c)Transport equipment sector								
Value (millions US$)	1996	World	70,920	19,440	51,479	92,606	24,031	68,575
	2011	World	152,602	47,772	104,830	214,178	68,354	145,824
Value Index (1996=1)	2011	World	2.2	2.5	2.0	2.3	2.8	2.1
	2011	EU	2.6	3.4	2.4	1.8	2.9	1.5
	2011	EA	2.5	2.7	2.3	2.5	2.7	2.3
	2011	NAFTA	1.4	1.4	1.3	1.6	2.3	1.4
Share (in total (%))	1996	EU	30.7	21.2	34.2	22.1	15.2	24.5
	1996	EA	37.2	49.5	32.6	28.5	40.0	24.5
	1996	NAFTA	28.9	26.9	29.7	39.2	40.0	38.9
	2011	EU	37.4	29.1	41.1	16.8	15.5	17.4
	2011	EA	42.7	54.2	37.4	30.4	37.9	26.9
	2011	NAFTA	18.2	15.6	19.4	27.8	32.1	25.8

Source: Author’s calculation using data from the UN Comtrade.

The transport equipment trade growth rate reveals that imports from EU had the fastest growth, while EA had the fastest growth for exports, with the exception of parts and components that was headed by EU. For both, imports and exports, growth in parts and components was faster than in final products for all regions.

In terms of share, EA detained the biggest ones in all cases, with the exception of final transport equipment imports, which was headed by EU, and transport equipment exports in 1996 that was led by NAFTA.

Although the final products presented the highest value of trade for transport equipment machinery, parts and components presented the fastest growth, indicating a change in EA trade pattern in the direction of fragmentation.

1.2.2.2 The machinery trade in European Union

According to Ando and Kimura (2013b), the development of production networks in Europe started with the Western Europe and the CEE countries nexus. The Western European countries realized that the wages in the Central and Eastern European countries were lower than inside the European Union, providing a comparative advantage to manufacture the labor intensive steps of the production in that region. Like in the NAFTA case, they started from a simplistic back-and-forth division of labor and after 2004, with the accession of some CEE countries to the EU, it evolved to industrial agglomerations, especially in the automobile sector.

Table 1.2 presents the machinery exports and imports value having EU as the base region. Considering all machineries, the trade value in EU was bigger for final products in both years. The trade was mainly focused inside the EU region, with a slightly decrease in this concentration along the years. Although these concentrations exceeded 50.0%, the imports and exports to EA presented a growth rate higher than the other regions, especially for the trade of parts and components, indicating a tendency of production networks development between EU and EA.

As for all machineries, the transport equipment data revealed that final products trade values were higher than parts and components ones. Besides this, except for the imports of final products, the trade with EA had the greatest increases. In terms of the share, the intra-regional trade of transport equipment dominated both periods with a participation of more than 78.0% for imports and 59.0% for exports. The highest import and export shares were for parts and components, 81.1% and 71.1%, respectively. As already mentioned, the development of production networks inside the EU was enhanced by the automobile sector. Therefore, we observe a concentration of intra-regional transport equipment trade, particularly for parts and components.

Table 1.2 – EU machinery trade by region and sector

EU	Year	Origin/Destination	Imports			Exports		
			Total	P&C	Final	Total	P&C	Final
(a)All machinery sectors								
Value (millions US$)	1996	World	696,545	313,400	383,145	731,745	313,881	417,865
	2011	World	1,231,682	581,969	649,713	1,328,631	603,511	725,120
Value Index (1996=1)	2011	World	1.8	1.9	1.7	1.8	1.9	1.7
	2011	EU	1.7	1.8	1.6	1.7	1.8	1.6
	2011	EA	2.5	2.6	2.4	2.1	2.3	1.9
	2011	NAFTA	1.1	1.0	1.2	1.7	1.6	1.7
Share (in total (%))	1996	EU	65.3	63.7	66.7	62.2	63.6	61.1
	1996	EA	16.7	15.5	17.7	13.9	12.7	14.8
	1996	NAFTA	13.2	15.7	11.1	11.0	12.3	10.1
	2011	EU	62.6	63.4	62.0	58.1	61.1	55.5
	2011	EA	23.5	22.1	24.8	15.7	15.3	16.1
	2011	NAFTA	8.2	8.6	7.8	10.2	10.1	10.2
(b)Electric machinery sector								
Value (millions US$)	1996	World	184,493	108,450	76,043	168,136	98,935	69,201
	2011	World	363,356	195,793	167,563	309,459	170,761	138,698
Value Index (1996=1)	2011	World	2.0	1.8	2.2	1.8	1.7	2.0
	2011	EU	1.8	1.7	2.0	1.8	1.7	2.0
	2011	EA	2.9	2.6	3.3	1.7	1.8	1.6
	2011	NAFTA	0.8	0.7	1.0	1.5	1.2	2.1
Share (in total (%))	1996	EU	57.3	56.9	57.8	62.9	62.4	63.5
	1996	EA	24.1	23.3	25.2	16.5	17.0	15.8
	1996	NAFTA	13.7	14.8	12.1	8.2	9.5	6.3
	2011	EU	53.7	54.3	53.1	63.1	62.2	64.1
	2011	EA	35.4	33.6	37.5	15.4	17.6	12.6
	2011	NAFTA	5.5	5.7	5.3	6.7	6.8	6.6
(c)Transport equipment sector								
Value (millions US$)	1996	World	196,341	57,232	139,110	228,112	63,339	164,773
	2011	World	355,083	122,859	232,224	445,169	140,210	304,959
Value Index (1996=1)	2011	World	1.8	2.1	1.7	2.0	2.2	1.9
	2011	EU	1.8	2.1	1.6	1.8	2.1	1.6
	2011	EA	1.8	2.9	1.5	2.6	3.4	2.4
	2011	NAFTA	2.0	1.5	2.3	1.8	1.8	1.8
Share (in total (%))	1996	EU	81.6	82.6	81.2	70.3	74.7	68.6
	1996	EA	10.4	6.4	12.1	9.5	6.5	10.7
	1996	NAFTA	6.0	8.6	5.0	9.8	9.7	9.9
	2011	EU	79.1	81.1	78.1	63.1	71.1	59.4
	2011	EA	10.1	8.6	10.9	12.8	9.9	14.1
	2011	NAFTA	6.6	6.2	6.8	9.1	7.7	9.8

Source: Author’s calculation using data from the UN Comtrade.

Different from the transport equipment results, electric machinery trade values were bigger for parts and components. The intra-regional trade still prevailed, with concentrations higher than 50.0% for imports and 60.0% for exports. However, imports from EA grew at a faster pace than imports from other regions, achieving participations over 30.0% in 2011. Although the electric machinery intra-regional trade is very strong in EU, the EA increased its participation, especially in EU imports.

1.2.2.3 The machinery trade in NAFTA

In the end of the 1980s, Canada and the United States signed a free trade agreement that a few years later would be joined by Mexico. This agreement allowed the development of the trade in the region, stimulating specially the development of the *maquiladoras* in Mexico. In other words, the labor wage in Mexico was substantially cheaper than in the US so that the multinationals considered this comparative advantage, sending parts and components that were produced in the US to be assembled in factories in Mexico and then sent back to the American market. These back-and-forth transactions have characterized the cross-border production process in NAFTA.

Table 1.3 presents the machinery exports and imports data having NAFTA as the base region. For machineries in general the final products trade value was higher than the parts and components one. The share data show that despite the intra-regional trade dominance in the 1996, there was a change in 2011 and EA became the region from where the NAFTA imported the most.

Considering the electric and transport equipment sectors, the first one presented higher trade values in parts and components, with the exception of imports in 2011, while the second presented higher final products trade values. The electric machinery share indicates that in 1996 EA was already the main provider of products to NAFTA. In 2011, EA consolidated even more its position, increasing its exports at a higher growth rate than the other regions. On the other hand, intra-regional exports represented the biggest share of electric machinery exports, with an exception for parts and components exports in 2011 that was slightly higher for EA.

Table 1.3 – NAFTA machinery trade by region and sector

NAFTA	Year	Origin/Destination	Imports			Exports		
			Total	P&C	Final	Total	P&C	Final
(a)All machinery sectors								
Value (millions US$)	1996	World	506,084	237,672	268,412	477,928	238,008	239,920
	2011	World	834,603	351,085	483,517	622,574	285,334	337,240
Value Index (1996=1)	2011	World	1.6	1.5	1.8	1.3	1.2	1.4
	2011	EU	1.7	1.6	1.7	1.1	1.0	1.2
	2011	EA	1.9	1.7	2.1	1.2	1.2	1.1
	2011	NAFTA	1.4	1.2	1.5	1.4	1.2	1.5
Share (in total (%))	1996	EU	15.9	16.2	15.7	19.2	20.7	17.7
	1996	EA	38.8	36.9	40.5	26.4	27.6	25.1
	1996	NAFTA	43.1	44.5	41.8	45.6	44.5	46.8
	2011	EU	16.2	17.4	15.3	16.2	17.6	15.0
	2011	EA	45.0	42.2	47.1	23.6	28.0	19.8
	2011	NAFTA	35.4	35.8	35.0	47.4	44.1	50.2
(b)Electric machinery sector								
Value (millions US$)	1996	World	149,909	95,045	54,864	142,244	93,475	48,769
	2011	World	261,795	119,014	142,782	157,704	87,649	70,056
Value Index (1996=1)	2011	World	1.7	1.3	2.6	1.1	0.9	1.4
	2011	EU	1.5	1.2	2.1	0.8	0.7	1.0
	2011	EA	2.1	1.4	3.2	1.0	1.0	0.9
	2011	NAFTA	1.3	0.9	1.9	1.3	0.9	1.9
Share (in total (%))	1996	EU	9.2	9.9	8.0	17.8	17.2	18.9
	1996	EA	50.0	48.3	52.9	33.5	36.6	27.6
	1996	NAFTA	39.2	40.3	37.2	41.3	41.0	41.9
	2011	EU	7.9	9.7	6.4	12.7	12.7	12.8
	2011	EA	59.9	53.9	64.9	30.2	39.9	17.9
	2011	NAFTA	28.2	28.9	27.5	46.7	39.3	56.1
(c)Transport equipment sector								
Value (millions US$)	1996	World	155,870	47,626	108,244	137,614	43,952	93,662
	2011	World	226,634	73,818	152,815	199,394	59,183	140,211
Value Index (1996=1)	2011	World	1.5	1.5	1.4	1.4	1.3	1.5
	2011	EU	1.8	1.8	1.8	2.0	1.5	2.3
	2011	EA	1.6	2.3	1.4	1.4	1.4	1.3
	2011	NAFTA	1.3	1.3	1.3	1.3	1.3	1.3
Share (in total (%))	1996	EU	14.4	12.9	15.0	8.6	11.3	7.4
	1996	EA	23.3	20.2	24.7	14.9	11.9	16.3
	1996	NAFTA	61.3	64.7	59.8	69.5	70.1	69.2
	2011	EU	17.9	14.7	19.5	11.8	12.8	11.3
	2011	EA	26.3	29.7	24.6	13.9	12.6	14.5
	2011	NAFTA	54.0	53.6	54.2	61.4	66.8	59.1

Source: Author's calculation using data from the UN Comtrade.

Transport equipment data show that NAFTA holds the highest exports and imports shares in both periods, being considerably larger than the second highest share, EA. However, the interesting detail is the fact that trade with EA grew faster than intra-regional trade, especially for the imports of parts and components from EA.

These results indicate that NAFTA participates in electric machinery global production networks, acquiring more than 50.0% of its parts and components imports from EA. Conversely, the whole transport equipment trade was concentrated inside the region. Indeed, after the establishment of the NAFTA, the automobile sector enhanced the development of production networks involving US and Mexico. Naturally, a transport equipment back-and-forth trade inside the NAFTA was already expected.

1.2.3 Extensive margin analysis

The increase in machinery trade value during the analyzed period can be a consequence of an intensive margin growth, that is the change in the value traded in already existent country-product relations, and/or a consequence of an extensive margin, a change in trade value resultant from the establishment of new country-product relations or the extinction of old ones. According to Kehoe and Ruhl (2013) and Hummels and Klenow (2005), considerable large trade growths are, in general, related to changes in the extensive margin. Given the sharp increase in the machinery traded value, an analysis of the evolution of the extensive margin from 1996 to 2011 is necessary and can help identifying the trade pattern of machinery products. The expansion of the parts and components trade also offers clues of the extent and depth of the production networks.

To capture the extensive margin we identified the number of total possible country-product import relations per region and the number of active relations in 1996 and 2011. To avoid possible miscounts, the product-country pair definition has to be the same across the period analyzed. With the aim of ensuring this condition, from a total of 1124 machinery product codes, we choose 955. In other words, approximately 15.0% of the total codes had to be discharged (equivalent of approximately 26.7% of the total value). The reason for the adoption of this measure is that although UN Comtrade provides HS1992 data for the studied period, the UN Comtrade database is constructed based on the data received from the government of each country that not necessarily provided data classified according to the HS1992 version.[8] Consequently, before making the data available to the public, the UN Comtrade had to convert it. In this process, there are four

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[8] In order to improve its use, the HS classification was updated a few times, having the following different versions: HS1992, HS1996, HS2002, HS2007, and HS2012.

possible types of data: 1- the subheading that is correlated with one and only one subheading in the HS1992 classification (referred as a 1:1 relationship); 2- the subheading that is a result of a split of one subheading in the HS1992 classification (referred as a n:1 relationship); 3- the subheading that is a result of merging several subheadings in the HS1992 classification (referred as a 1:n relationship); and 4- the subheading that is the result of a split and merge of several subheadings in the HS1992 classification (referred as a n:n relationship). Therefore, just in the first and second case the data from different versions of HS classification can be properly tracked back to one HS1992 subheading. Consequently, only subheadings that fit these cases are analyzed.[9]

Table 1.4 presents the results in percentage of active relations. Having EA, EU, and NAFTA as the base regions, it shows the percentage for total, final products, and parts and components import relations per region in both years, for all machineries, electric machinery, and transport equipment.

The first finding from Table 1.4 is that for all base regions the electric machinery is the one that had the biggest percentage of active country-product links. In other words, the establishment of trade links in the electric machinery sector is easier than in the transport equipment. The second finding is that the percentage of active parts and components links is higher than the final products one. These findings indicate that trade in parts and components achieves a bigger range of partners than final products. Thus, the electric machinery sector, especially for parts and components, should have some characteristics that make it more tradable than transport equipment. According to Ando and Kimura (2014), the transport equipment sector deals with a large portion of bulky parts and components that have high transport costs, being sensitive to geographical

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[9] We employed conversion tables from UN Comtrade to sort the codes.

distance. Besides this, other characteristics like unbalanced power balance between assemblers and part producers, weak trust between upstream and downstream firms, and total integration inter-firm architecture interface, leads to the formation of industrial clusters. On the other hand, the electric machinery sector deals with parts and components of smaller volume and weight, contributing to cheaper transport costs. Furthermore, in the electric machinery sector, there is a strong trust and balance between upstream and downstream firms, and inter-firm architecture interface is modular. Consequently, it is easier to trade parts and components of the electric machinery sector to more remote areas than transport equipment parts and components. Hence, we observe a higher percentage of active trade links for electric machinery parts and components.

Considering the heterogeneity of the countries that compose each region, another exercise employed was the analysis of the number of active country-product links for a specific country. To capture the evolution of these changes, it was collected data in four different points of the studied period: 1996, 2001, 2006, and 2011. Given the amount of information, the study focused on the differences between parts and components and final products for transport equipment and electric machinery.

As the three regions studied are composed of 40 countries, these countries were split in subgroups and classified according to different patterns for each region. One country was selected to represent each subgroup.

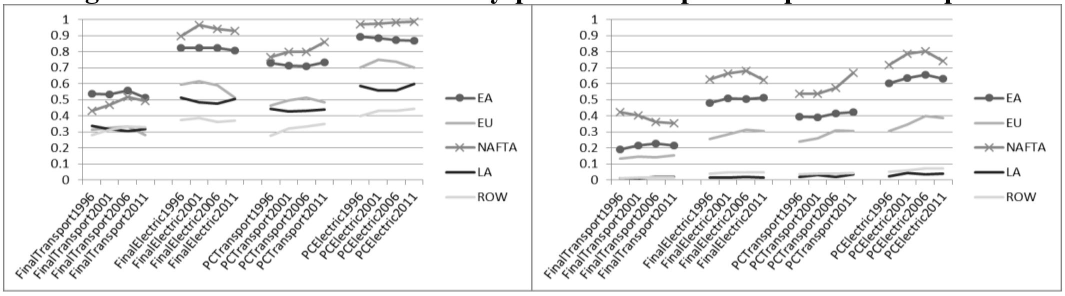
Table 1.4 – Share of active relations per importer region base

Origin	Aggregation	Year	Total	P&C	Final
EA					
EA	All Machineries	1996	44.1	52.7	38.2
		2011	54.6	65.7	47.0
	Electric Machineries	1996	59.2	63.0	54.2
		2011	70.7	74.9	65.0
	Transport Equipment	1996	25.8	39.7	20.1
		2011	35.3	52.3	28.2
EU	All Machineries	1996	17.6	22.2	14.4
		2011	27.2	35.8	21.4
	Electric Machineries	1996	28.7	29.3	27.9
		2011	39.8	44.0	34.3
	Transport Equipment	1996	10.8	18.3	7.7
		2011	17.1	30.1	11.6
NAFTA	All Machineries	1996	38.0	48.5	30.8
		2011	52.1	64.9	43.4
	Electric Machineries	1996	57.2	61.0	52.1
		2011	70.6	76.5	62.9
	Transport Equipment	1996	20.4	40.2	12.2
		2011	31.5	54.8	21.8
EU					
EA	All Machineries	1996	21.5	25.6	18.7
		2011	28.1	36.1	22.7
	Electric Machineries	1996	27.0	28.7	24.9
		2011	37.9	41.9	32.6
	Transport Equipment	1996	11.5	17.7	8.9
		2011	17.3	29.1	12.3
EU	All Machineries	1996	30.0	34.1	27.1
		2011	36.2	42.8	31.7
	Electric Machineries	1996	36.5	37.5	35.2
		2011	46.8	48.8	44.0
	Transport Equipment	1996	22.7	30.5	19.4
		2011	29.3	39.4	25.0
NAFTA	All Machineries	1996	29.4	35.8	25.0
		2011	40.3	49.8	33.8
	Electric Machineries	1996	35.9	39.4	31.2
		2011	52.2	56.9	45.9
	Transport Equipment	1996	16.9	29.3	11.7
		2011	25.5	41.8	18.7
NAFTA					
EA	All Machineries	1996	46.1	53.2	41.3
		2011	54.3	65.5	46.6
	Electric Machineries	1996	57.1	60.3	52.8
		2011	69.9	75.1	62.9
	Transport Equipment	1996	32.6	43.1	28.3
		2011	40.1	58.7	32.3
EU	All Machineries	1996	34.6	40.5	30.5
		2011	41.1	51.2	34.2
	Electric Machineries	1996	43.3	45.3	40.7
		2011	54.5	59.3	48.1
	Transport Equipment	1996	27.8	34.3	25.0
		2011	32.0	46.7	25.9
NAFTA	All Machineries	1996	80.7	87.6	76.1
		2011	85.3	90.7	81.5
	Electric Machineries	1996	91.7	94.5	87.9
		2011	94.4	95.5	93.0
	Transport Equipment	1996	70.4	84.3	64.7
		2011	80.5	93.3	75.2

Source: Author’s calculation using data from the UN Comtrade.

The East Asian region is the most heterogeneous case. Figure 1.8 shows that Japan has higher export shares. Although there were no big changes in the patterns, in general, there was a small decrease in the shares of this country, in special for the final electric machinery exports. One reason should be the tendency of offshoring the final products assembly to places with labor-intensive workers lower wage.

Figure 1.8 – Share of active country-pair links: Japan's exports and imports



Source: Author's calculation using data from the UN Comtrade.

A second subgroup is composed of China and India, two economies that grew at a fast pace during the analyzed period. Both of them present higher export shares. They also have the steepest rising curves in trade with all countries, demonstrating that the high growth of their economies was attached to an integration with the international trade. An interesting detail is that for the Chinese case the integration with EU, considering the exports of electric machineries, achieved approximately the same level as the intra-regional one. Compared to other countries, the curves of final products export in China are in general very steep, especially in the electric products case, reflecting the fact that many companies assemble their final products there and then export them to other regions of the world. Figure 1.9 illustrates the curves for China.[10]

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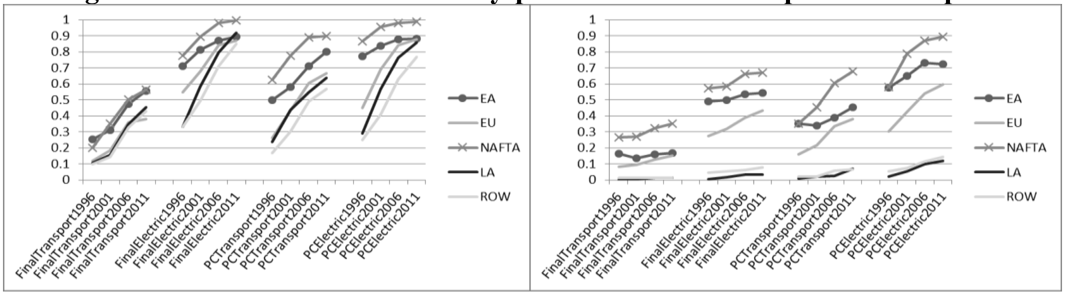
[10] Figures for the complementary countries of each subgroup and subgroups with a secondary importance are available in the Appendix from Figure A.1.1 to A.1.10.

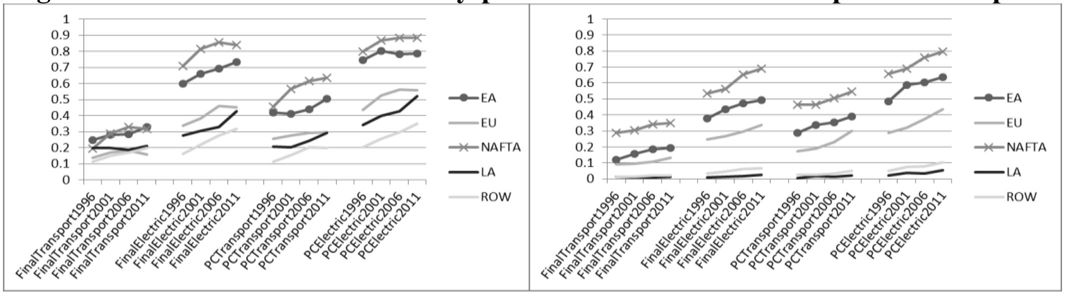
Figure 1.9 – Share of active country-pair links: China's exports and imports



Source: Author's calculation using data from the UN Comtrade.

Another subgroup is the Asian Tigers (Hong Kong, Korea and Singapore).[11] This subgroup presents a more stable pattern than the previous one and share values that are not as high as the Japanese ones. Another peculiarity of this subgroup is that the final electric machineries' shares are higher than the parts and components for transport equipment, reflecting the importance of the electric sector. Figure 1.10 presents the results for South Korea.

Figure 1.10 – Share of active country-pair links: South Korea's exports and imports



Source: Author's calculation using data from the UN Comtrade.

A fourth subgroup is formed by the other ASEAN countries (Indonesia, Malaysia, the Philippines, and Thailand). In this case the export and import shares present a growth pattern (not as strong as in the Chinese and Indian case), with a strong presence of intra-regional imports. This reflects the integration of these economies in the region. Another important aspect is that, as in the case of the Asian Tigers, the final electric machineries shares are higher than the parts and components for transport equipment, demonstrating

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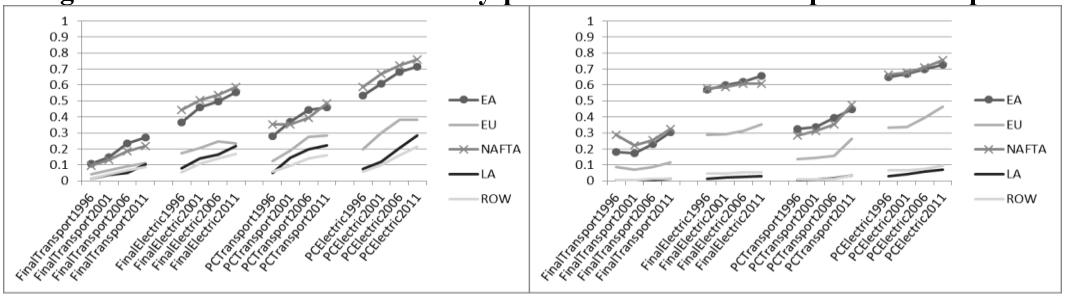
[11] Given a lack of information, the Taiwanese case could not be analyzed.

the importance of this sector for these countries. Figure 1.11 presents the curves for Thailand.

Figure 1.11 – Share of active country-pair links: Thailand's exports and imports

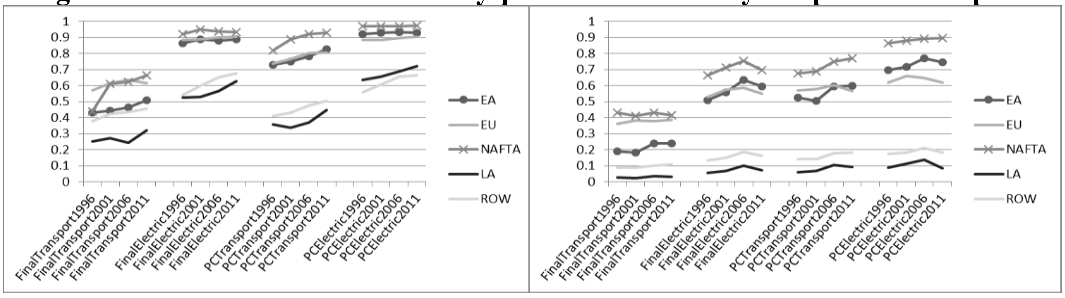


Source: Author's calculation using data from the UN Comtrade.

The last subgroup is composed of the countries from Oceania: Australia and New Zealand. In this case, the special feature is the higher import shares, especially for electronic products. The result reflects the difficulties in participating in the production networks, attributed to the geographical isolation.

In the case of EU, the countries were separated in two groups: a first group with the countries that were already members of EU in 1996 and a second group with the countries that joined EU after 1996. Inside the first group, the four biggest economies (France, Germany, Italy, and United Kingdom) present similar patterns. Figure 1.12 represents the share of active links in Germany and illustrates some common characteristics of these four countries. The shares of active links are higher than in other European countries, and the exports are, in general, at least 10 percentage points higher than the imports, showing a preponderance in these economies. A second feature is that the transport equipment shares of active links are smaller than the electric machineries ones, while the parts and components achieve higher shares of active links than the final products. In general, the shares of active links in the trade with EA are higher than the ones with EU or when EU has higher active links the gaps between the shares are in general small (the exception is the trade of final transport machineries) with a trend of reduction. This difference is more evident for electric products.

Figure 1.12 – Share of active country-pair links: Germany's exports and imports



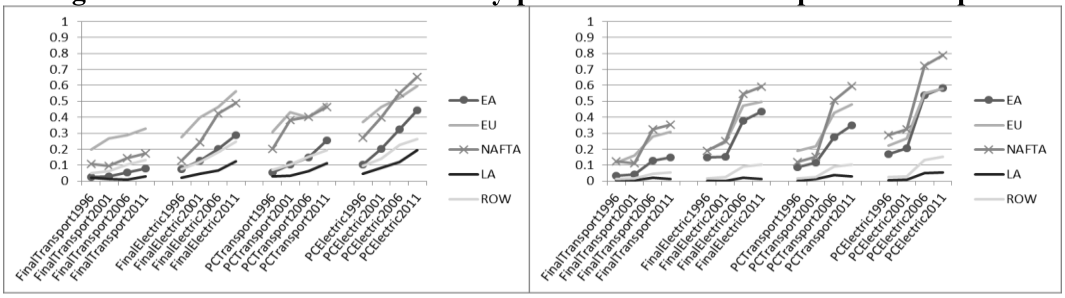
Source: Author's calculation using data from the UN Comtrade.

Another subgroup is composed of other mature economies (Austria, Denmark, Finland, Netherlands, Spain, and Sweden). The basic difference from this subgroup and the previous one is that, in general, the share of active links in intraregional exports and imports are higher than the ones for EA, especially for trade in transport equipment. The gap is larger for the exports, while the import curves of trade with EA present, in general, a steeper increase, indicating a trend of integration with this area. The fastest increases are in imports of parts and components indicating integration with the production networks. Another important difference from the countries in the previous subgroup is that the percentages of active shares are smaller for both, imports and exports, a consequence of the difference in the size of the economies. Finally, in this subgroup the differences in the active link shares for imports and exports, excluding Sweden, are not as clear as it is in the first subgroup.

A third subgroup is formed by smaller economies (Greece, Ireland, and Portugal). The countries in this subgroup present higher active shares for imports. Furthermore, the shares are smaller than the ones in the previous two subgroups, indicating that these economies are not as integrated in the international trade and production network as the previous ones. In general, the percentage of active trade links with EU is higher than the ones with EA.

The twelve other countries that accessed to EU more recently were separated in two subgroups. The first one is composed of countries that, in general, present steep export and import curves (Bulgaria, Czech Republic, Hungary, Lithuania, Poland, Romania, Slovakia, and Slovenia). This indicates that the preparation period and the effective accession to EU brought benefits for these economies, suggesting an inclusion in the production networks. Another feature is that, in general, the shares of import active links are higher than the export ones. Figure 1.13 illustrates the changes in Poland.

Figure 1.13 – Share of active country-pair links: Poland's exports and imports

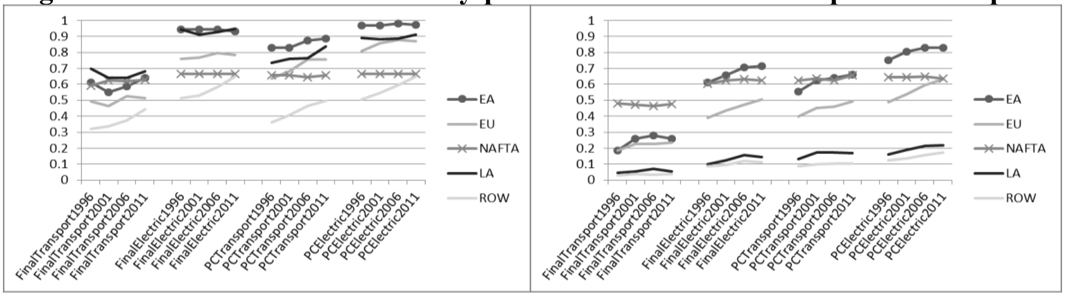


Source: Author's calculation using data from the UN Comtrade

The second subgroup is composed of economies with smaller shares of active links (Cyprus, Estonia, Latvia, and Malta), indicating that these countries are still not integrated in the production networks.

The NAFTA members also have higher shares of active links in electric machinery than in transport equipment. We also observe that parts and components shares are higher than final products ones, but these differences are not as accentuated as in the previous subgroups. Figure 1.14 shows that the United States present higher values for exports and imports from EA, with exports and imports of final transport equipment being the exception. This demonstrates a strong link of United States with EA. Besides this, export shares are higher than import ones. Another important feature is the fact that shares of active links of exports to third regions are higher than the intra-regional ones (exports to the rest of the world and exports of final transport equipment are the exceptions). This indicates the great presence of United States exports in the international trade.

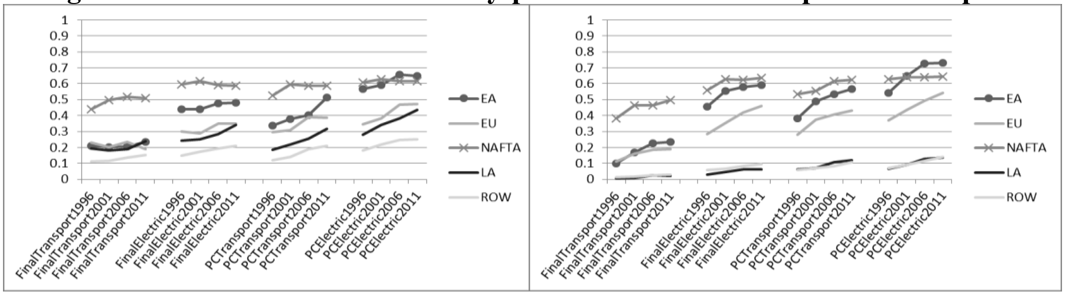
Figure 1.14 – Share of active country-pair links: United States' exports and imports



Source: Author's calculation using data from the UN Comtrade.

Canada and Mexico are in the second subgroup. Their share of active links for imports are higher than for exports. Another feature is that their changes in the curves are more accentuated than the American ones. The curves of trade with EA are steep, indicating an increase in the integration with this region. In general, the curves of electric machinery parts and components are higher for imports from EA, while it is catching up with the NAFTA one in the transport equipment sector. The exception is the trade of final transport equipment, where the gap between the NAFTA curve and the EA curve is still big. Figure 1.15 shows the curves for Canada.

Figure 1.15 – Share of active country-pair links: Canada's exports and imports



Source: Author's calculation using data from the UN Comtrade.

The analysis of the evolution of country-product active link by country showed that the three big regions are very heterogeneous. Given this heterogeneity, it is possible to verify bigger changes in the extensive margins for the countries that joined more recently a regional trade agreement or presented structural changes, like high economic growths. On the opposite hand, changes in the extensive margin are smaller for the most developed countries, since they have more stable economies. These evidences are in accordance with the discoveries from Kehoe and Ruhl (2013) and Hummels and Klenow (2005). Besides this, we identified an increase in EA's participation in third regions' imports, indicating a deeper integration of EA as a supplier to other region's production networks.

1.3 Gravity model analysis

As observed in the previous section, the machinery trade was concentrated in three main regions. This trade incorporates the final products and the parts and components that are used in fragmented productions. The data also showed that the trade in these three regions was mainly confined to the intra-regional level. However, recently the EA increased considerably its participation in production networks inside and outside its region. Additionally, the data also indicated a proportionally higher increase in the parts and components trade.

Given this scenario, we employ the gravity model, using disaggregated import data from the UN Comtrade, to analyze the evolution of machinery sector trade. Based on the trade in final products and parts and components, we try to capture the evolution of production networks from a regional structure to a global one. We consider the hypothesis that production networks extrapolated the East Asian region, with this region supplying parts and components to countries in other regions that use them to produce final products and other parts and components that will be traded inside their own regions.

Furthermore, using the gravity model we test the evolution of two different categories of machinery, electric machineries and transport equipment, aiming identify the existence or not of dissimilarities in their production networks expansion behavior. We expect that transport equipment expansion occur slowly and by regional agglomerations, while electric machineries dissipate faster and smoother across the world.

1.3.1 Estimation methodology and data

The augmented gravity model estimation for bilateral machinery imports has the following equation as its base:

$$\ln T_{ij} = \alpha + \beta_1 lnDist_{ij} + \beta_2 lnGDP_i + \beta_3 lnGDP_j + \beta_4 lnGAP_{ij} + \beta_5 cont_{ij} + \beta_6 lang_{ij} + \varepsilon \qquad (1)$$

where T_{ij} denotes the total value of imports of country *i* from country *j*, $Dist_{ij}$ the geographical distance between capitals of country *i* and country *j*, GDP_i the gross domestic product (GDP) of the importer country *i* while GDP_j denotes the GDP of the exporter country *j*, GAP_{ij} represents the absolute value of the difference in GDP per capita between country *i* and country *j*, $cont_{ij}$ is a dummy that assumes value of 1 if there is contiguity for country *i* and country *j* or 0 otherwise, and $lang_{ij}$ is a dummy that assumes value of 1 for common official primary language for country *i* and country *j* or 0 otherwise.

Regarded as a transport cost or service link cost, the distance is supposed to have a negative coefficient. On the opposite hand, the GDP is a proxy for the market size and is expected to present a positive coefficient. The absolute difference between the GDP per capita is interpreted as a measure of factor endowment differences. Consequently, it is expected to present a positive coefficient given that the difference in the factor endowments was one of the determinants for production fragmentation. Nevertheless, the expansion of production networks contributed to a recent increase in south-south trade of parts and components. As a result, the differences in factor endowments may not be sufficient to be captured in the overall trade pattern. The coefficients for language and contiguity are expected to present positive values, since common language and proximity are characteristics that are expected to enhance the trade.

Some dummies were added in the previous equation to capture EA's impact as an exporter region. Thus, we have the following two equations:

$$\ln T_{ij} = \alpha + \beta_1 lnDist_{ij} + \beta_2 lnGDP_i + \beta_3 lnGDP_j + \beta_4 lnGAP_{ij} + \beta_5 cont_{ij} + \beta_6 lang_{ij} + \beta_7 EA + \varepsilon_{ij} \qquad (2)$$

$$\ln T_{ij} = \alpha + \beta_1 lnDist_{ij} + \beta_2 lnGDP_i + \beta_3 lnGDP_j + \beta_4 lnGAP_{ij} + \beta_5 cont_{ij} + \beta_6 lang_{ij} + \beta_7 EAROW + \beta_8 EAEU + \beta_9 EA2 + \beta_{10} EALA + \beta_{11} EANAFTA + \varepsilon_{ij} \qquad (3)$$

where *EA* is a dummy that assumes value of 1 if the exporter country is one of the EA countries, *EAROW* is a dummy that assumes value of 1 if the exporter country belongs to EA and the importer country belongs to ROW, *EAEU* is a dummy that assumes value of 1 if the exporter country belongs to EA and the importer country belongs to EU, *EA2* is a dummy that assumes value of 1 if the exporter and importer countries belong to EA, *EALA* is a dummy that assumes value of 1 if the exporter country belongs to EA and the importer country belongs to LA, *EANAFTA* is a dummy that assumes value of 1 if the exporter country belongs to EA and the importer country belongs to NAFTA.

The dummy in equation (2) captures the performance of the EA exports compared to the world exports. This dummy will be positive if imports from EA are greater than the levels predicted by the model for the reference region. In equation (3) the dummies capture EA exports performance to each of the five regions compared to the world exports. The coefficients will reveal with each region EA has stronger export relations.

To check the evolution along the time, the two equations are estimated for four different years: 1996, 2001, 2006, and 2011. We estimate separate equations just for transport equipment and electric machinery products to capture their trade pattern differences. Finally, to capture the differences in final products and parts and components, the equations are estimated for final products or parts and components.

We used 89 countries[12] in the gravity model estimations. These countries are the ones with more than 0.01% market share in the world machinery imports in 2011 and that had the distance, GDP, and GDP per capita data available for the four years. Data on trade values in US dollars were obtained from UN Comtrade, the geographical distance are from CEPII database, and GDP and GDP per capita are from The World Bank database.

The trade data contains zero value inputs. The gravity model literature regards as a major issue the treatment of the zero-valued trade. One of the reasons is the fact that the gravity model employs the natural logarithm of the traded value. Since the natural logarithm of zero does not exist, proceeding with this method of estimation results in the drop of zero-valued trade that may contain important information from the trade pattern. These dropped data would not be accounted in the estimation, possibly leading to a bias in the regression results. To avoid this problem, we estimate the regressions using the Poisson pseudo-maximum-likelihood (PPML) method (Santos Silva & Tenreyro, 2006). Thus, we estimate the following equations:

$$T_{ij} = \exp[\alpha + \beta_1 lnDist_{ij} + \beta_2 lnGDP_i + \beta_3 lnGDP_j + \beta_4 lnGAP_{ij} + \beta_5 cont_{ij} + \beta_6 lang_{ij} + \beta_7 EA] + \varepsilon_{ij} \tag{4}$$

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[12] A list of the 89 countries is available in the Appendix, Table A.1.2.

$$T_{ij} = [\alpha + \beta_1 lnDist_{ij} + \beta_2 lnGDP_i + \beta_3 lnGDP_j + \beta_4 lnGAP_{ij} + \beta_5 cont_{ij} + \beta_6 lang_{ij} + \beta_7 EAROW + \beta_8 EAEU + \beta_9 EA2 + \beta_{10} EALA + \beta_{11} EANAFTA] + \varepsilon_{ij} \quad (5)$$

Finally, to check if the results are still similar after controlling for time and countries specific characteristics, we pooled the data of the four periods and estimated the gravity regressions. According to the Cheng and Wall (2005), "standard cross-section estimates of the gravity model yield biased estimates of the volume of bilateral trade because there is no heterogeneity allowed for in the regression equations" (p. 54). Consequently, when estimating a gravity model with panel or pooled data, fixed effect dummies should be included to control for all sources of unobserved heterogeneity that are constant for each period of time or individual. Given this fact, we use importer, exporter, and year dummies, estimating three different kinds of fixed effect regressions: year fixed effect regressions, exporter and importer fixed effect regressions and year, exporter and importer fixed effect regressions. These dummies account for the characteristics that are constant for each importer, each exporter, and the invariant characteristics of each year. In other words, the exporter and importer fixed effect dummies will control for the time-varying multilateral resistance terms, while time effects will control for the specificity of each year, being an indicator of the globalization extent.

1.3.2 Estimation results

The first estimation was based on equation (4) and aims capturing the performance of EA exports. The first finding from Table 1.5 is that the coefficient for the logarithm of the distance slightly increased in absolute values along the period. This change indicates an increase in the service link costs. However, as the descriptive analysis showed a sharp increase in the traded values along the period, this result indicates that despite the rise in the long-distance trade, the growth in short-distance trade was bigger. In other words, inter-regional trade increased, but intra-regional trade increased in an even faster pace.

Table 1.5 – Gravity model estimation for machinery imports with EA dummy

	1996		2001		2006		2011	
	Final	P&C	Final	P&C	Final	P&C	Final	P&C
lnDist	-0.53^{***}	-0.54^{***}	-0.56^{***}	-0.59^{***}	-0.59^{***}	-0.72^{***}	-0.60^{***}	-0.78^{***}
	(0.05)	(0.06)	(0.05)	(0.05)	(0.04)	(0.06)	(0.04)	(0.06)
lnGAP	-0.02	-0.01	0.00	0.04	0.08^{**}	0.09^{**}	0.06	0.05
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)	(0.04)
EA	0.82^{***}	0.96^{***}	0.85^{***}	1.03^{***}	1.17^{***}	1.54^{***}	0.90^{***}	1.32^{***}
	(0.11)	(0.12)	(0.11)	(0.11)	(0.11)	(0.14)	(0.10)	(0.15)
Observations	23496	23496	23496	23496	23496	23496	23496	23496
R^2	0.503	0.578	0.534	0.579	0.465	0.431	0.421	0.365

Given a restriction of space, the coefficients of secondary variables are omitted. Robust standard errors in parentheses: $^{*} p < 0.10$, $^{**} p < 0.05$, $^{***} p < 0.01$.

Regarding the differences in final products and parts and components, the distance coefficients of the latter presented higher absolute values. Moreover, the amplitude of the difference just increased along the period, demonstrating that parts and components trade increased faster for short-distance trade. This reflects a faster increase in the production networks density inside each region. This result is similar to the one achieved by Johnson and Noguera (2012a) using input-output tables. According to them, though the production fragmentation increases on both local and global scale, the intra-regional trade is more fragmentation intensive than the trade with outside regions.

The second finding is that the impact of the absolute difference in the importer exporter GDP per capita was almost zero along the period, showing that factor endowments had almost no impact in the trade, given the increase in south-south trade enhanced by the production networks. Finally, the EA dummy, which captured the performance of EA exports compared to the world exports, presented positive values in all years, showing that imports from EA were greater than the level predicted by the model for the reference region. In other words, EA region is more active in exports than the rest of world. Another interest finding is that the difference between the final products and the parts and components coefficients just increased along the period, indicating that EA exports of parts and components became more conspicuous than the final products.

Given that the results characterized EA as an exporter region, the next estimations employed dummies for EA exports to the five regions in the globe. The objective is to capture the relation of EA with these other regions. Tables 1.6 and 1.7 present the results for electric machinery and transport equipment sector, respectively.

The distance coefficient in Table 1.6 shows an increase in the absolute value along the time, reflecting a higher increase in short-distance than long-distance exports of electric machinery products. As for final products and parts and components, in 1996, 2001, and 2006, the absolute value of final products distance coefficients were higher, but the parts and components one increased steadily, surpassing the final products in 2011. This change captures the fast development of production networks inside the EA region since the end of the 1980s and beginning of the 1990s. Another reason for the increase in the coefficients is the Chinese economy growth and its consequent integration in the intra-regional production networks, especially after its accession to the World Trade Organization (WTO) in 2001.

Table 1.6 – Gravity model estimation for electric machinery imports with dummies for EA exports to the five regions

	1996		2001		2006		2011	
	Final	P&C	Final	P&C	Final	P&C	Final	P&C
lnDist	-0.33**	-0.31**	-0.47***	-0.37***	-0.62***	-0.53***	-0.64***	-0.69***
	(0.14)	(0.13)	(0.12)	(0.10)	(0.12)	(0.11)	(0.11)	(0.11)
EA2	1.62***	1.94***	1.43***	2.00***	1.83***	2.64***	1.57***	2.46***
	(0.30)	(0.19)	(0.31)	(0.16)	(0.30)	(0.18)	(0.29)	(0.21)
EAEU	0.77***	0.51**	1.03***	0.66***	1.80***	1.17***	1.53***	1.40***
	(0.19)	(0.24)	(0.16)	(0.19)	(0.22)	(0.20)	(0.20)	(0.23)
EANAFTA	1.73***	1.77***	1.94***	1.58***	2.59***	2.05***	2.62***	2.17***
	(0.31)	(0.30)	(0.30)	(0.25)	(0.42)	(0.30)	(0.38)	(0.33)
EALA	0.08	-0.35	0.15	-0.27	1.37***	0.77**	1.54***	1.19***
	(0.21)	(0.37)	(0.20)	(0.35)	(0.28)	(0.37)	(0.28)	(0.40)
EAROW	-0.14	-1.35***	-0.03	-1.32***	0.96***	-0.41*	1.02***	0.17
	(0.17)	(0.22)	(0.15)	(0.19)	(0.20)	(0.22)	(0.21)	(0.23)
Observations	7832	7832	7832	7832	7832	7832	7832	7832
R^2	0.466	0.534	0.523	0.533	0.472	0.488	0.587	0.437

Given a restriction of space, the coefficients of secondary variables are omitted. Robust standard errors in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

In general, the coefficients for EA exports to the other five regions are positive and present an increasing trend along the period. Intra-regional trade has the strongest ties for the parts and components trade, while exports to NAFTA has the strongest ties for the final products. On the other hand, exports to ROW had the weakest bonds. In the electric machinery case, the parts and components coefficients are bigger than the final products just in the intra-regional trade case. This information confirms the development of intra-regional production networks that led to an increase in the absolute value of the distance coefficient.

Although for the other regions the coefficients for final products were higher than the ones for parts and components, the general trend shows a decrease in the difference between them, with the exception of NAFTA, revealing an increase in East Asian parts and components exports to other regions.

Table 1.7 contains the results for the transport equipment estimation. One major difference between the electric machinery sector and the transport equipment sector is that for 1996 the absolute values for transport equipment distance coefficients were approximately two times as high as the coefficients for the electric machinery sector. Even though the difference decreases along the period, this fact indicates that the costs to trade transport equipment are higher than the electric machinery ones. Additionally, compared to the electric machinery sector there are no significant changes in the coefficients along the period, what indicates that the trade in transport equipment increased maintaining a similar pattern. Besides this, the absolute values for final products are smaller than parts and components ones, indicating that for this sector the trade in long-distance happened more for final products, while the trade in parts and components was more limited to short-distances. Considering the dummies for the EA exports to the five regions, just the trade with NAFTA had coefficients that were statistically significant. An analysis of the final products and parts and components coefficients reveal that the former had higher coefficients for the trade with NAFTA until 2006.

Table 1.7 – Gravity model estimation for transport equipment imports with dummies for EA exports to the five regions

	1996		2001		2006		2011	
	Final	P&C	Final	P&C	Final	P&C	Final	P&C
lnDist	-0.65***	-0.66***	-0.71***	-0.72***	-0.68***	-0.75***	-0.71***	-0.78***
	(0.10)	(0.11)	(0.09)	(0.07)	(0.08)	(0.07)	(0.08)	(0.08)
EA2	0.08	0.37	-0.51	-0.09	-0.25	0.26	-0.31	0.08
	(0.32)	(0.39)	(0.37)	(0.25)	(0.29)	(0.20)	(0.24)	(0.23)
EAEU	0.22	-0.46*	0.28	-0.29	0.44**	-0.12	-0.12	-0.06
	(0.22)	(0.24)	(0.18)	(0.21)	(0.18)	(0.14)	(0.19)	(0.17)
EANAFTA	0.98**	0.96***	1.06***	0.95***	1.32***	1.26***	0.72	1.16***
	(0.40)	(0.29)	(0.36)	(0.24)	(0.43)	(0.22)	(0.48)	(0.26)
EALA	0.51	-0.80***	0.74**	0.05	0.76***	0.47*	0.86***	0.48**
	(0.38)	(0.25)	(0.32)	(0.24)	(0.29)	(0.25)	(0.26)	(0.21)
EAROW	0.44	-0.78**	0.91***	-0.67***	0.98***	0.1	0.72***	0.09
	(0.28)	(0.31)	(0.29)	(0.26)	(0.25)	(0.27)	(0.27)	(0.30)
Observations	7832	7832	7832	7832	7832	7832	7832	7832
R^2	0.627	0.785	0.732	0.870	0.672	0.803	0.622	0.639

Given a restriction of space, the coefficients of secondary variables are omitted. Robust standard errors in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Next, we estimate the same regression for electric machinery and transport equipment using the four years pooled data to test if the results are still similar after controlling for time and countries specific characteristics. Following the literature, we employ fixed effect dummies to control for the time, exporter, and importer specificities, estimating three versions of the regression: just with year fixed effect, with importer and exporter fixed effect, and a third version with year, importer, and exporter fixed effect. Tables 1.8 and 1.9 present the results.

Comparing the absolute values of the distance coefficients between electric machinery and transport equipment, the first one has smaller values, indicating smaller trade costs for electric machineries. Considering the coefficients for final products and parts and components, the absolute values were clearer smaller for parts and components in the electric machinery sector. On the other hand, transport equipment had a smaller coefficient for final products, when we control for year fixed effects, and smaller for parts and components coefficients when we control for exporter and importer characteristics or year, importer and exporter characteristics. However, this was a difference of just 0.01. The results confirmed that the electric machinery sector is more prone to the trade in parts and components, and consequently the development of production networks, while the transport equipment sector does not show this characteristic.

Table 1.8 – Gravity model estimation for electric machinery imports with dummies for EA exports to the five regions and fixed effects

	Year Fixed Effect		Importer and Exporter Fixed Effect		Year, Importer and Exporter Fixed Effect	
	Final	P&C	Final	P&C	Final	P&C
lnDist	-0.55^{***}	-0.52^{***}	-0.64^{***}	-0.54^{***}	-0.64^{***}	-0.54^{***}
	(0.06)	(0.06)	(0.03)	(0.05)	(0.03)	(0.04)
EA2	1.61^{***}	2.31^{***}	1.08^{***}	1.25^{***}	1.95^{***}	2.45^{***}
	(0.16)	(0.11)	(0.28)	(0.35)	(0.35)	(0.42)
EAEU	1.41^{***}	1.02^{***}	1.27^{***}	0.90^{***}	2.14^{***}	2.11^{***}
	(0.12)	(0.12)	(0.27)	(0.34)	(0.35)	(0.41)
EANAFTA	2.35^{***}	1.93^{***}	1.96^{***}	1.37^{***}	2.84^{***}	2.58^{***}
	(0.22)	(0.16)	(0.25)	(0.35)	(0.37)	(0.42)
EALA	1.09^{***}	0.57^{**}	1.15^{***}	1.16^{***}	2.00^{***}	2.34^{***}
	(0.18)	(0.23)	(0.28)	(0.37)	(0.35)	(0.43)
EAROW	0.74^{***}	-0.44^{***}	0.97^{***}	0.32	1.82^{***}	1.51^{***}
	(0.12)	(0.13)	(0.28)	(0.34)	(0.35)	(0.41)
Observations	31328	31328	31328	31328	31328	31328
R^2	0.483	0.437	0.905	0.804	0.918	0.817

Given a restriction of space, the coefficients of secondary variables are omitted. Robust standard errors in parentheses: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 1.9 – Gravity model estimation for transport equipment imports with dummies for EA exports to the five regions and fixed effects

	Year Fixed Effect		Importer and Exporter Fixed Effect		Year, Importer and Exporter Fixed Effect	
	Final	P&C	Final	P&C	Final	P&C
lndist	-0.69^{***}	-0.74^{***}	-0.85^{***}	-0.84^{***}	-0.85^{***}	-0.84^{***}
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
EA2	-0.27^{*}	0.13	2.35^{***}	2.07^{***}	2.31^{***}	2.08^{***}
	(0.15)	(0.14)	(0.59)	(0.43)	(0.59)	(0.43)
EAEU	0.19^{*}	-0.19^{**}	3.45^{***}	1.98^{***}	3.40^{***}	1.99^{***}
	(0.10)	(0.09)	(0.57)	(0.42)	(0.57)	(0.41)
EANAFTA	1.02^{***}	1.11^{***}	3.90^{***}	2.99^{***}	3.84^{***}	3.00^{***}
	(0.24)	(0.13)	(0.58)	(0.41)	(0.58)	(0.41)
EALA	0.79^{***}	0.25^{*}	3.79^{***}	2.42^{***}	3.74^{***}	2.43^{***}
	(0.17)	(0.14)	(0.59)	(0.43)	(0.59)	(0.43)
EAROW	0.80^{***}	-0.08	3.97^{***}	2.52^{***}	3.92^{***}	2.53^{***}
	(0.17)	(0.18)	(0.57)	(0.44)	(0.57)	(0.44)
Observations	31328	31328	31328	31328	31328	31328
R^2	0.634	0.725	0.889	0.853	0.896	0.856

Given a restriction of space, the coefficients of secondary variables are omitted. Robust standard errors in parentheses: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Considering the dummies for the EA exports of electric products, all of them are positive, with the exception of the coefficient for EA parts and components exports to ROW in the time fixed effects estimation. This indicates that EA exports more than is expected from the other regions of the world. Besides this, the coefficient for intra-regional exports of parts and components is higher than the one for final products. On the other hand, the coefficient for final products is bigger for all the other regions in the model estimated with time fixed effects. In the model with exporter and importer fixed effects and the one with exporter, importer, and time fixed effects, the same happens, with the exception of exports to Latin America. As expected, in general, the results from Table 1.8 are very similar to the ones in Table 1.6.

Considering the dummies for the EA exports of transport equipment, the statistically significant ones have positive values, indicating that EA exports more than the expected exports of the rest of the world. Analyzing the parts and components and final products coefficients, in general, final products ones are bigger, indicating that EA exports more final products than parts and components. In general, the results from Table 1.9 are also similar to the ones in Table 1.7.

1.4 Final considerations

This chapter investigated the development of the machinery trade in the world. The descriptive analyses showed that the machinery trade was concentrated inside three main regions: EA, EU, and NAFTA. It also revealed that in the studied period the traded values increased for all regions. Nevertheless, machinery exports from EA increased faster than exports from the other regions, leading to an increase in its export shares in all five regions.

We analyzed the composition of the machinery exports to identify what boosted this growth. Sorting out the traded products in final goods or parts and components, the extensive margin analysis demonstrated that, in general, trade in parts and components achieved a bigger range of partners than trade in final products. The descriptive analysis also revealed that the EA machinery exports growth was driven more by the expansion of parts and components than final products export values. This tendency to increase the trade in parts and components indicates an EA's predisposition to participate in production networks, both inside and outside its own region. This happens because the parts and components exported to third countries are used to produce final products or other parts and components that will be regionally re-exported.

The country level extensive margin analysis indicated that the three main regions are composed of countries in different stages of integration in the machinery production networks. It was possible to verify the increases in the extensive margins for countries that joined more recently a regional free trade agreement or that presented structural changes, like high economic growths.

The quantitative analyses revealed differences in the trade patterns according to the machinery sector. Evidences were provided that electric machinery has lower trade costs than the transport equipment. Besides this, transport equipment trade cost is lower for final products, while for the electric machinery it is the opposite. This is in accordance with Ando and Kimura (2014) that stated that the transport equipment sector deals with bulky parts and components, having higher transport costs that lead to the formation of industrial clusters nearby, while the electric machinery sector deals with parts and components of smaller volume and weight that contributes to cheaper transport costs.

Another interest finding is that along the period the coefficient for the trade cost of electric machinery increased and in 2011 the parts and components presented a higher service link cost than final products. This fact can be attributed to a higher growth of short-distance trade, resulting from the evolution of intra-regional production networks. In other words, the long-distance trade increased, but the short-distance one increased in a faster pace leading to an increase in the absolute value of the distance coefficients, especially for the parts and components trade. Considering the EA exports dummy, they were positive revealing that EA exports more than the expected for the world trade, suggesting that EA has an increasing role as a supplier. Considering the dummies for EA exports by regions, the coefficients for parts and components trade increased in a faster pace than the final products ones, indicating the development of production networks.

The evidences collected in this chapter suggest that the East Asian region through the expansion of the trade in parts and components is fomenting the development of production networks in other regions of the globe. However, the data also reveal that the concentration of regional trade and production networks also increased along the period. Intra-regional production networks developed in a faster pace, especially inside EA and EU, leading to even denser intra-regional economic ties.

CHAPTER 2 – Latin America and the Machinery Production Networks

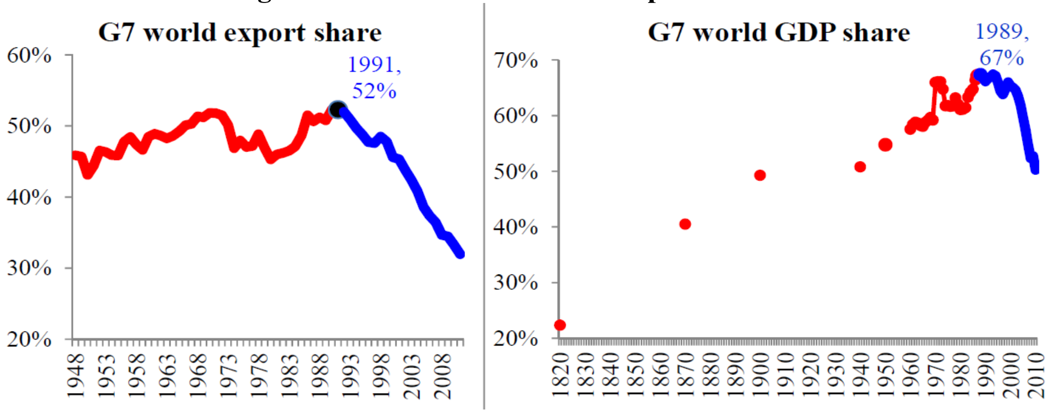
Employing disaggregated trade data obtained from the UN Comtrade, the present chapter analyzes the evolution of the machinery industry trade in Latin America. Classifying the machinery data in final products or parts and components, it compares the evolution of Latin American trade pattern with the one in other regions of the world. The objective is to verify whether the development of production networks in Latin America follows a trend similar to other regions or not. As Latin America is a heterogeneous area, some descriptive data of this region countries were provided and then a deeper analysis of the performance of its main economies, Brazil and Mexico, was realized. Although both countries have a developed industrial park, we attest that Mexico's one is more integrated in the machinery production networks than the Brazilian one.

2.1 Introduction

The production fragmentation was one of the elements that boosted the development of the international trade in the last decades. To be more competitive, many firms expanded their plants to third countries, offshoring their activities, or transferred some production steps to third firms, outsourcing their activities, to have access to cheaper factors of production. This fragmentation process promoted an increase in global integration, driven by what Grossman and Rossi-Hansberg (2008) called "trade in tasks", and the creation of the so-called international production networks.

In a first moment, this movement involved mostly the trade among rich nations, but the real "revolution started when supply chain trade gained importance between high-tech and low-wage nations between 1985 and 1990" (Baldwin & Lopez-Gonzalez, 2015, p. 2). In other words, the production fragmentation caused a revolution, because it opened new possibilities to the developing countries, allowing their participation in the production process of manufactured goods that they did not produce before. As showed in Figure 2.1, this fact promoted a big change in the distribution of the world export and GDP shares, resulting in a fast decrease in the shares of the developed countries in the international trade and world GDP, a reflection of the fast increase in the developing countries' shares.

Figure 2.1 – G7 share of world export and GDP



Source: Baldwin and Lopez-Gonzalez (2015).

The expansion of production networks changed the rules of the economic development game, facilitating the developing countries' access to networks, global markets, capital, knowledge, and technology (OECD, 2013). Previously, a country had to climb every single step in the industrial development ladder, but the advent of the production networks offered the possibility of skipping steps in the catch-up process through the acquisition of knowledge and technology from third countries or the specialization in one or few steps of the production process. Thus, for the developing countries the understanding of these changes and its implications is especially important to draw efficient policies aiming benefit from these new opportunities and promote a sustainable economic growth.

Bearing in mind this context, the purpose of this chapter is to analyze how the Latin American countries are dealing with this new dynamics. We compare the performance of machinery trade in Latin America with other regions, in special the East Asia, since this region is also composed of developing countries. As Latin America is a heterogeneous region, we also study the performance of its main economies, Brazil and Mexico, in order to understand their stances and the results of their policies.

This chapter will be organized as follows. Section 2 includes a descriptive analysis of the international machinery trade data, classifying the trade according to origin and destiny region, if it is final product or parts and components, and machinery sector. In section 3 the study will focus in the Brazilian and Mexican cases. Section 4 presents the final considerations of the chapter.

2.2 The machinery trade in Latin America

According to Baldwin (2011), the labor international division was driven by the globalization process that can be separated in two unbundlings. Before the first Industrial Revolution, production and consumption was geographically bundled given the cost and time constraints imposed by the available transport. At the end of 19th century, the invention and diffusion of the railroads and steamships allowed for the first time a considerable decrease in the transport cost, leading to the first unbundling. For that reason, the consumption and production of a given product was dispersed internationally, but the production process was still clustered locally. The Information and Communication Technology (ICT) Revolution made cheaper, easier, faster and safer the coordination of complex activities at distance, allowing for the second unbundling. The production process, that once was locally clustered, could be broken in production stages, leading to the creation of production networks.

The fragmentation of the production process brought new possibilities for all players, especially for the developing countries that increased their participation in the world exports and GDP, promoting a considerable change in the global economy. Given that the machinery industry presents a high level of complexity and use of parts and components, in this chapter we analyze machinery production networks in Latin America.

2.2.1 Data

It is employed international trade data classified according to the Harmonized System (HS), disaggregated to the six-digit level, obtained from the UN Comtrade. The machinery industry is comprised by all the goods classified as general machinery (HS84), electric machinery (HS85), transport equipment (HS86-89), and precision machinery sectors (HS90-92). The machinery data are grouped into parts and components or final products, using the classification presented in Kimura and Obashi (2010).

The countries are classified in five main regions in order to facilitate a comparison of the trade patterns among these blocs. As in the previous chapter, the blocs are composed of: countries from the East Asian region (EA); countries from the European Union (EU), countries that are members of North American Free Trade Agreement (NAFTA), countries from Latin America (LA)[13], and the rest of the world (ROW).

2.2.2 Descriptive analysis

To evaluate the evolution of production fragmentation in the machinery sector, in the first chapter we observed the total exports and imports deflated value (in million US$) per region. Given a restriction imposed by the availability of data, this first exercise was

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[13] As Mexico is part of the NAFTA it is not counted again in the LA bloc. This bloc is composed of: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador,Guatemala, Honduras, Nicaragua, Panama, Paraguay, Peru, Uruguay, and Venezuela.

restricted to two points in time: the year 1996 and the year 2011. Figure 1.1 showed that the machinery trade in the world was basically concentrated in three regions: EA, EU, and NAFTA. The exports from these regions accounted for more than 88% of world's exports in both periods, while the imports accounted for more than 79%. The LA was almost marginalized from the international machinery trade, a first sign of the region's lack of integration in the machinery production network.

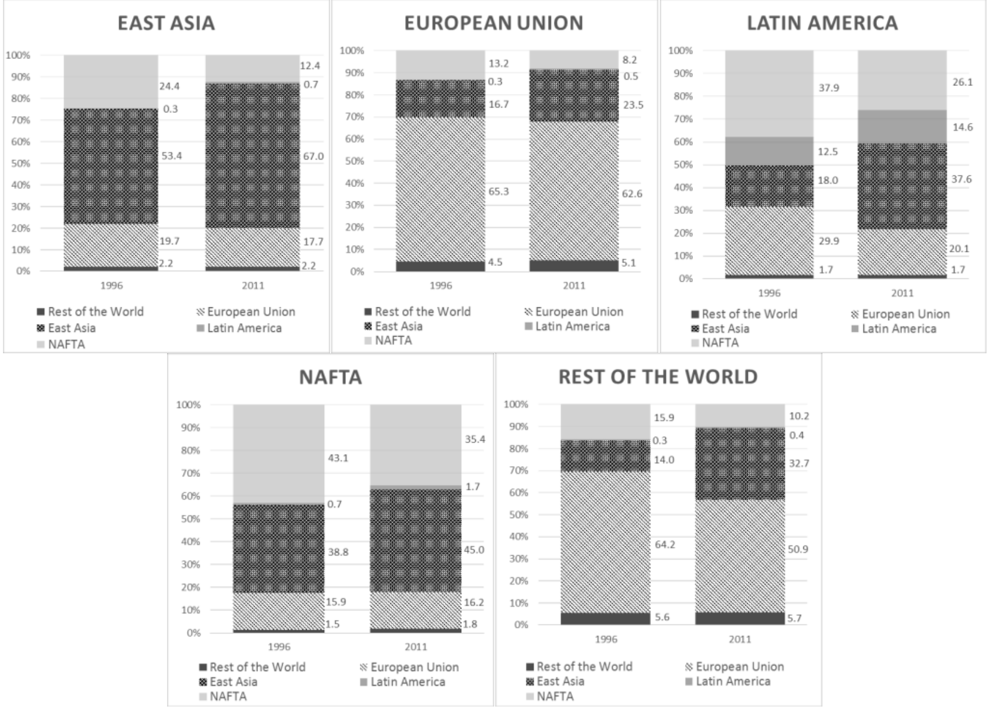
From the same figure, we verified that LA's import values were higher than the export ones and this amplitude increased from 1996 to 2011. On the opposite hand, EA presented a contrasting pattern, with exports prevailing over the imports. Once again, the amplitude increased.

Figure 1.2 illustrated per region share of the machinery trade over total trade. Differently from the three main regions where the global machinery trade was concentrated, in LA the participation of machinery in total exports was very low. The share of machinery imports in LA total imports was similar to the other regions. However, the difference between parts and components and final products, revealed that imports of final products was predominant and there were almost no changes in the proportion observed in the beginning and ending of the analyzed period. These results corroborated with the idea that LA is an exporter of commodity products and importer of final machinery products. The low import share of machinery parts and components, around 15%, supported the idea that LA is still not well integrated in machinery production networks.

EA data presented a different pattern. Machinery import and export shares were both higher than LA ones, demonstrating the importance of machinery trade in this region. Although we verified a small decrease in the machinery trade share along the period, the parts and components shares increased proportionally to final products, indicating a deepening in the production networks participation.

In Figure 2.2 it is displayed the shares attributed to each of the five regions in the machinery imports of a base region, in order to verify the evolution of EA and LA’s participation. The figure reveals that EA increased its export shares in all the regions, becoming the main exporter in three of them: NAFTA, LA, and EA. On the opposite side, despite a tiny increase of LA participation in all regions, LA still detained the smallest shares in all areas, but LA. In other words, the data exposed that LA machinery exports to other regions were almost irrelevant, characterizing LA as a machinery importer region. It also confirmed that the export-oriented industrialization policy in East Asian region has generated fruits, with higher trade flows and an increase in the region’s participation in machinery production networks.

Figure 2.2 – Shares of machinery import by region



Source: Author's calculation using data from the UN Comtrade.

Next, we analyze Latin American machinery trade by sectors. Defining Latin America as the base region, Table 2.1 captures the characteristics of different machinery sectors, covering the export and import values of all machinery, electric machinery, and transport equipment. The first interesting finding is that for all machinery the trade with EA increased in a faster pace than the average trade with the whole world, especially for parts and components. In 1996, the main exporter to the region was NAFTA, but in 2011, the import share from EA more than doubled, becoming LA's main provider of machinery products. On the export side, with the exception of exports of parts and components in 2011, the main receiver of LA machinery products was the LA region. Given that the Latin American production was mainly consumed inside the region and that the region imports was still dominated by the products from EA, EU, and NAFTA, one can assume that the regional machinery production was small and/or not competitive in the international market.

Table 2.1 – Latin America machinery trade by destination

LA		Origin/ Destination	Imports			Exports		
	Year		Total	P&C	Final	Total	P&C	Final
(a)All machinery sectors								
Value (millions US$)	1996	World	61,090	22,869	38,221	14,956	6,971	7,984
	2011	World	167,809	63,662	104,147	54,593	29,683	24,910
Value Index (1996=1)	2011	World	2.7	2.8	2.7	3.7	4.3	3.1
	2011	EU	1.8	1.9	1.8	3.5	4.4	2.3
	2011	EA	5.7	6.1	5.5	5.4	14.1	1.8
	2011	NAFTA	1.9	2.0	1.8	3.9	4.4	2.9
Share (in total (%))	1996	EU	29.9	32.9	28.1	12.8	15.7	10.2
	1996	EA	18.0	17.1	18.5	9.8	6.2	12.9
	1996	NAFTA	37.9	35.8	39.1	23.7	34.4	14.3
	2011	EU	20.1	22.5	18.5	12.2	16.2	7.5
	2011	EA	37.6	37.5	37.6	14.6	20.5	7.6
	2011	NAFTA	26.1	25.6	26.4	25.4	35.3	13.6
(b)Electric machinery sector								
Value (millions US$)	1996	World	16,184	7,927	8,257	2,168	1,158	1,010
	2011	World	44,932	21,800	23,132	16,982	14,829	2,153
Value Index (1996=1)	2011	World	2.8	2.7	2.8	7.8	12.8	2.1
	2011	EU	1.4	1.5	1.3	3.0	3.1	2.8
	2011	EA	5.5	4.9	6.4	60.0	120.7	2.5
	2011	NAFTA	1.8	1.7	1.8	10.6	19.9	1.3
Share (in total (%))	1996	EU	26.8	28.1	25.6	11.4	14.9	7.3
	1996	EA	26.7	30.0	23.5	3.9	3.6	4.3
	1996	NAFTA	38.5	33.7	43.1	33.6	31.4	36.1
	2011	EU	13.3	15.2	11.5	4.4	3.6	9.5
	2011	EA	53.3	52.9	53.7	29.9	33.5	4.9
	2011	NAFTA	24.7	21.0	28.1	45.4	48.8	22.4
(c)Transport equipment sector								
Value (millions US$)	1996	World	15,833	3,962	11,871	6,889	2,299	4,590
	2011	World	51,977	11,601	40,376	20,505	4,571	15,933
Value Index (1996=1)	2011	World	3.3	2.9	3.4	3.0	2.0	3.5
	2011	EU	2.5	2.0	2.9	2.5	3.0	2.3
	2011	EA	4.8	8.3	4.4	1.5	0.6	1.7
	2011	NAFTA	2.6	2.8	2.5	2.1	1.1	4.5
Share (in total (%))	1996	EU	24.3	42.5	18.2	9.7	7.0	11.0
	1996	EA	20.5	9.4	24.2	14.6	9.1	17.3
	1996	NAFTA	28.9	17.4	32.7	14.1	30.2	6.0
	2011	EU	18.4	28.4	15.5	8.1	10.4	7.4
	2011	EA	30.1	26.7	31.1	7.1	2.6	8.4
	2011	NAFTA	22.5	16.6	24.2	10.0	17.3	7.9

Source: Author's calculation using data from the UN Comtrade.

To capture different machinery sector patterns, we separate the data for electric machinery and transport equipment. Results for the electric machinery sector indicate that the main exporter to LA in 1996 was the NAFTA, however during the period analyzed the EA exports to LA presented a growth rate superior to the NAFTA one. Consequently, in 2011 the EA controlled more than 50% of LA parts and components and final products imports, consolidating the position of main provider of electric products. Observing the export side, in 1996 the intraregional exports were dominant, but in 2011 NAFTA became the main receptor of parts and components produced in the LA, being followed by EA, with 48.8% and 33.5%, respectively. Although the total value of trade was not as high as in the three main regions, these evidences are a first sign of a movement towards an integration in production networks.

Data for the transport equipment reveal a more balanced import pattern. Though the LA was not the main provider of transport equipment, it retains the second biggest share in almost all categories for 1996 and 2011. Other important feature is the entry of the EA's transport equipment parts and components in LA market, ascending from a share of 9.4% in 1996 to 26.8 % in 2011. Considering the export side, the main destiny of the transport equipment produced in LA was the internal market, with export shares higher than 50% in 1996 and higher than 67% in 2011.

An additional relevant feature is that in term of values the transport equipment trade was bigger than the electric machinery, reflecting the importance of this sector to the Latin American economy. The opposite was true for the East Asian case: electric machinery trade values were more than two times higher than the transport equipment ones.

2.2.3 Quantitative analysis

In this subsection we perform an exercise similar to the one in the first chapter, but this time we add a LA dummy to compare the evolution of EA and LA performances in machinery trade. We employ the following two equations:

$$\ln E_{ij} = \alpha + \beta_1 lnDist_{ij} + \beta_2 lnGDP_i + \beta_3 lnGDP_j + \beta_4 lnGAP_{ij} + \beta_5 cont_{ij} + \beta_6 lang_{ij} + \beta_7 EA + \beta_8 LA + \varepsilon_{ij} \quad (1)$$

$$\ln I_{ij} = \alpha + \beta_1 lnDist_{ij} + \beta_2 lnGDP_i + \beta_3 lnGDP_j + \beta_4 lnGAP_{ij} + \beta_5 cont_{ij} + \beta_6 lang_{ij} + \beta_7 EA + \beta_8 LA + \varepsilon_{ij} \quad (2)$$

where E_{ij} represents the exports from country *i* to country *j*, I_{ij} represents the imports of country *i* from country *j*, *EA* is a dummy that assumes value of 1 if country *i* is one of the EA countries, and *LA* is a dummy that assumes value of 1 if country *i* is one of the LA countries. We still control for characteristics such as geographical distance between capitals of country *i* and country *j* ($Dist_{ij}$), the gross domestic product of country *i* (GDP_i) and country *j* (GDP_j), the absolute value of the difference in GDP per capita between country *i* and country *j* (GAP_{ij}), if country *i* and country *j* have common borders ($cont_{ij}$), and if they have a common language ($lang_{ij}$).

As in the previous chapter, we estimate the gravity model using the Poisson pseudo-maximum-likelihood (PPML) method to account for the zero-value and missing trade flows. Thus, we estimate the following equations:

$$E_{ij} = \exp[\alpha + \beta_1 lnDist_{ij} + \beta_2 lnGDP_i + \beta_3 lnGDP_j + \beta_4 lnGAP_{ij} + \beta_5 cont_{ij} + \beta_6 lang_{ij} + \beta_7 EA + \beta_8 LA] + \varepsilon_{ij} \tag{3}$$

$$I_{ij} = \exp[\alpha + \beta_1 lnDist_{ij} + \beta_2 lnGDP_i + \beta_3 lnGDP_j + \beta_4 lnGAP_{ij} + \beta_5 cont_{ij} + \beta_6 lang_{ij} + \beta_7 EA + \beta_8 LA] + \varepsilon_{ij} \tag{4}$$

Table 2.2 reports the results for the estimations considering all machinery trade data. In the upper part of the table, the coefficients are attributed to equation (3), where EA and LA dummies capture these regions exports, while in the lower part the import flows are examined with EA and LA coefficients capturing the effects of these regions as importers. As expected, the EA dummy coefficients are positive in almost all cases, while the LA ones are negative in almost all cases. This indicates that EA exported and imported more than the expected from the reference group (the combination of the other three regions), while the LA trade flows were under the levels expected from the reference group. A second feature that can be captured from LA dummies is the fact that import coefficients are, in general, less negative than export coefficients, signalizing that LA imports are closer to the predicted levels for the reference group, while the exports are more distant from the predicted levels. A third interesting feature is observed comparing the evolution of the coefficients for final products and parts and components imports. We observe that the LA region coefficient for imports of parts and components is more negative than the final products one in 1996. The amplitude of the coefficients decreased along the period and in 2006 the difference was of just 0.02 percentage points. In 2011 the coefficients became statistically insignificant, indicating that for both cases the imports achieved a level similar to the one predict for the reference group. Finally, EA import coefficients reveal that this region imports more parts and components than final products.

Table 2.2 – Gravity model estimation for machinery trade with EA and LA dummies

	1996		2001		2006		2011	
	Final	P&C	Final	P&C	Final	P&C	Final	P&C
				Exports				
EA	0.75***	0.90***	0.79***	0.98***	1.13***	1.51***	0.84***	1.29***
	(0.12)	(0.13)	(0.11)	(0.11)	(0.11)	(0.14)	(0.10)	(0.15)
LA	-1.46***	-1.30***	-1.10***	-1.27***	-0.72***	-0.51***	-1.12***	-0.60***
	(0.20)	(0.20)	(0.23)	(0.15)	(0.17)	(0.17)	(0.26)	(0.23)
Observations	23496	23496	23496	23496	23496	23496	23496	23496
R^2	0.508	0.58	0.541	0.585	0.47	0.431	0.427	0.365
				Imports				
EA	0.41***	0.68***	0.02	0.72***	0.11	1.15***	0.12	0.94***
	(0.14)	(0.15)	(0.13)	(0.13)	(0.14)	(0.16)	(0.16)	(0.18)
LA	-0.20*	-0.57***	-0.36***	-0.53***	-0.28***	-0.30**	-0.07	-0.18
	(0.11)	(0.12)	(0.10)	(0.12)	(0.11)	(0.13)	(0.12)	(0.14)
Observations	23496	23496	23496	23496	23496	23496	23496	23496
R^2	0.444	0.513	0.495	0.538	0.385	0.371	0.364	0.31

Given a restriction of space, the coefficients of secondary variables are omitted. Robust standard errors in parentheses: $^{*}\ p < 0.10$, $^{**}\ p < 0.05$, $^{***}\ p < 0.01$.

Next, the same exercise was performed for the electric machinery sector.[14] Table 2.3 reveals that once again LA dummy coefficients are negative, confirming the results obtained in the descriptive analysis. Still in accordance with the descriptive subsection,

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[14] As observed in the previous chapter, the coefficients for transport equipment are mainly statistically insignificant, so we do not report neither analyze this sector. However, a table with the results is available in the Appendix.

the export coefficients are lower than the import coefficients, indicating that LA tends to import more than export. Another interesting feature is the decrease in the coefficient values along the period. Especially in the case of parts and components imports, the coefficients became statistically insignificant in the last two years analyzed, revealing that the region is catching up with the reference group import levels, signalizing a slowly engagement in production networks.

Table 2.3 – Gravity model estimation for electric machinery trade with EA and LA dummies

	1996		2001		2006		2011	
	Final	P&C	Final	P&C	Final	P&C	Final	P&C
				Exports				
EA	1.21***	1.34***	1.28***	1.42***	1.82***	2.17***	1.54***	2.14***
	(0.23)	(0.22)	(0.21)	(0.18)	(0.21)	(0.23)	(0.20)	(0.24)
LA	-2.11***	-2.26***	-1.51***	-1.61***	-1.04***	-0.61**	-1.99***	-0.12
	(0.26)	(0.26)	(0.45)	(0.24)	(0.33)	(0.30)	(0.25)	(0.40)
Observations	7832	7832	7832	7832	7832	7832	7832	7832
R^2	0.412	0.455	0.487	0.449	0.405	0.393	0.429	0.399
				Imports				
EA	0.58**	1.04***	0.25	1.24***	0.23	1.84***	0.12	1.62***
	(0.30)	(0.26)	(0.28)	(0.20)	(0.33)	(0.26)	(0.39)	(0.29)
LA	-0.35**	-0.81***	-0.41***	-0.67***	-0.32	-0.29	-0.39*	-0.19
	(0.15)	(0.21)	(0.13)	(0.21)	(0.20)	(0.24)	(0.23)	(0.28)
Observations	7832	7832	7832	7832	7832	7832	7832	7832
R^2	0.328	0.381	0.388	0.415	0.224	0.33	0.273	0.307

Given a restriction of space, the coefficients of secondary variables are omitted. Robust standard errors in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

2.3 The Brazilian and the Mexican case

The aggregated data for LA indicated that its participation in the international machinery trade is very small and LA is predominantly an importer of final products. However, as the LA region is composed of countries that are very heterogeneous, there is a possibility that some countries are more prone to participate in machinery production networks while others are not. To test this hypothesis, Figure 2.3 shows the machinery trade value by country[15] for 1996 and 2011, while Figure 2.4 shows the share of final

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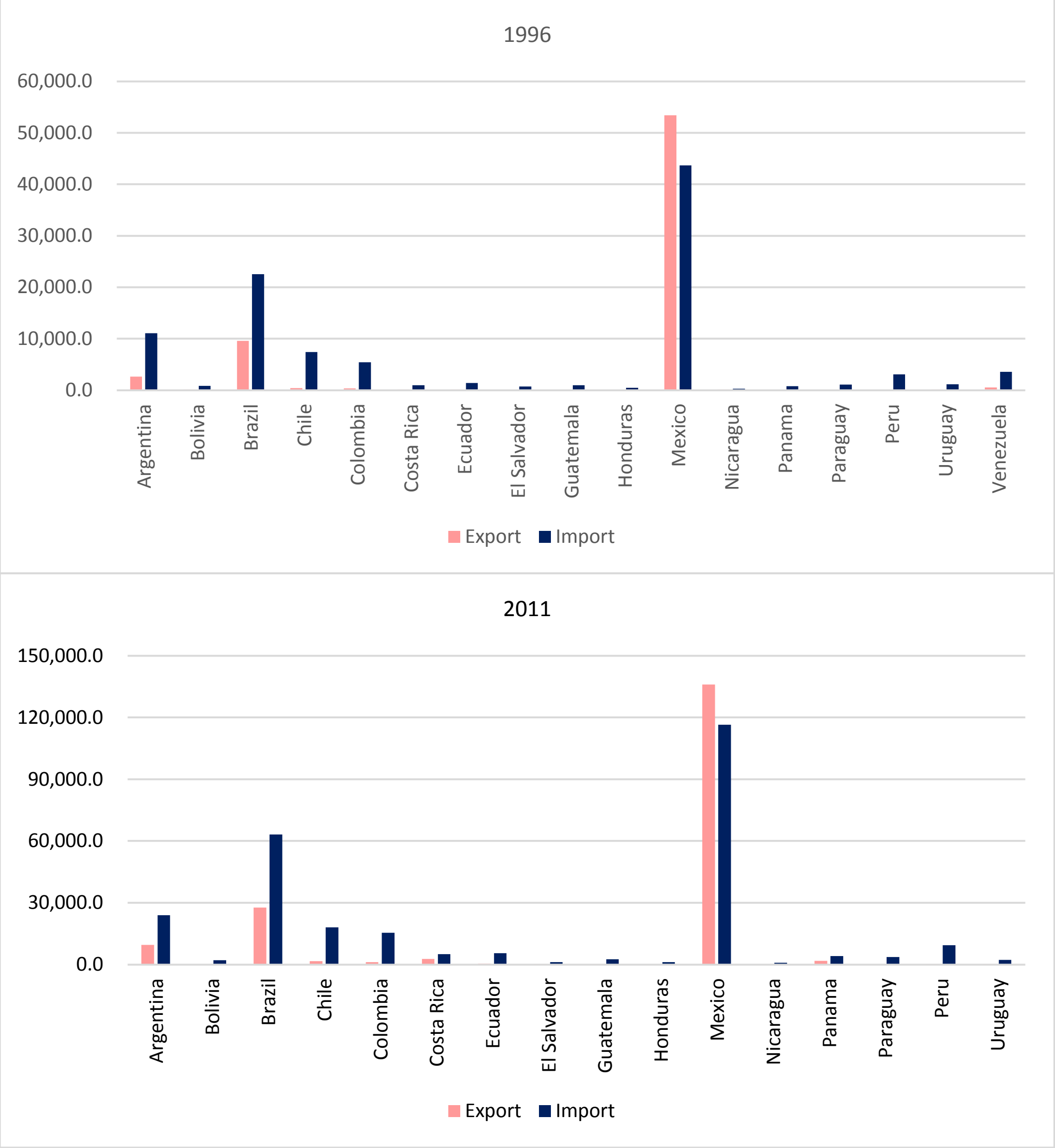
[15] Although in the previous subsections Mexico data was included in the NAFTA bloc, Mexico is also a Latin American country. As Venezuelan data is just available for the year 1996, no data could be plotted for the year 2011.

machinery and parts and components over the total trade of each country for the same years.

Figure 2.3 – Total machinery export and import values per country (in US$ million)



Source: Author’s calculation using data from the UN Comtrade.

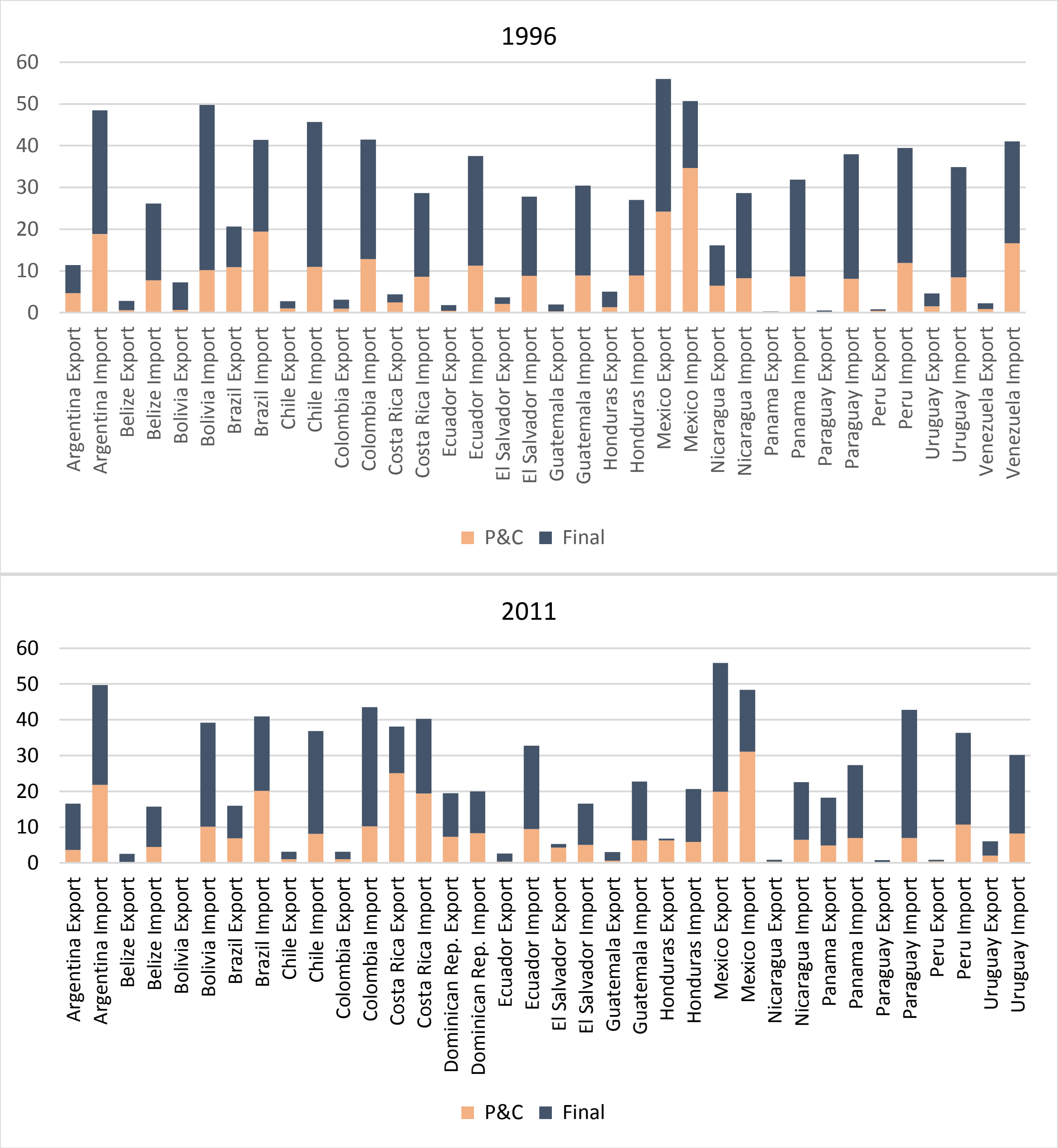
Figure 2.3 reveals that machinery trade values for the majority of Latin American countries are very low. As expected, the two biggest economies in the region have the highest machinery trade values. Nonetheless, Mexican trade values in both periods are approximately three times higher than the Brazilian ones. Mexico also contrast with the other Latin American countries being the only one to present a machinery trade surplus.

In other words, Mexico was the only country exporting more machinery products than importing.

Considering a 20% share of machinery parts and components trade flow as a threshold to the establishment of production networks, Figure 2.4 shows that in 1996 Mexico was the only country where machinery parts and components trade share was higher than this threshold. In 2011, machinery parts and components import shares of Brazil and Argentina were a little bit higher than 20%, indicating that these countries were slowly engaging in production networks. Costa Rica's imports and exports also surpassed or were close to the threshold of 20%. In the Costa Rican case, Intel made heavy investments in the country, opening plants that received parts and components and assembled processors to be sent back to United States. For the same period, Mexico's export share was a little bit lower than 20%, while the import share was higher than 35%. As already observed in the first chapter, Mexico has back-and-forth transactions with US, receiving parts and components to be assembled and sent back to the American market. The rest of the Latin American countries presented percentages far from this threshold.

As Brazil and Mexico are the biggest economies and main traders of machinery products in the region, it is expected that they exercise some influence in the other countries, or through their economic power or providing examples of economic policies that should or should not be adopted. Therefore, we study what kind of policies they adopted and if they strategically promoted or not the integration in production networks.

Figure 2.4 – Shares of machinery trade over total trade per country



Source: Author's calculation using data from the UN Comtrade.

2.3.1 Descriptive analysis

Aiming an increase in its participation in the international trade, in the end of the 1980s the Mexican government decided to open the country's market by join the NAFTA. This agreement allowed the expansion of the trade in the region, stimulating specially the development of the *maquiladoras*. Bearing in mind that the labor wage in Mexico was lower than in the US, companies in American soil opted for offshoring the production of some components, as well as the task of assembling the final products, to plants localized in Mexican territory. The idea was to use the NAFTA agreement to benefit from the Mexican comparative advantages, assembling final products in Mexican territory and dispatching them back to the American market. These back-and-forth transactions promoted the development of an agglomeration of plants along the Mexican border with US, especially the ones related to the transport equipment sector.

Also in the end of the 1980s beginning of the 1990s, the transition from a military government to a democratic one, brought a change in Brazil's economic policy, ending a period of economic isolation. The new government started a process of economic liberalization that was driven by the creation of the Mercosur, a customs union composed of Argentina, Brazil, Paraguay, and Uruguay.[16] Although in the first years the Mercosur promoted an increase in the intrabloc trade, a series of political and economic crisis affected its members, undermining the effectiveness of the economic bloc. Furthermore, the creation of the Mercosur bonded Brazil to the other members in a way that new FTAs just could be negotiated with the concordance of all members. Indeed, Brazil adopted a political stance of avoiding FTA negotiations, favoring multilateral negotiations in the WTO. This strategy was based in the belief that negotiations in a multilateral forum would bring more symmetry between developed and developing countries, leading to more equilibrated negotiations. Nevertheless, contradicting Brazilian expectations, the last decades have witnessed a series of fails in the multilateral negotiations conducted in the WTO, while the implementation of FTAs increased all over the globe. Therefore, the maintenance of this political posture, allied to an emphasis in the development of the domestic market, has driven the country to a position of relative protectionism. If we

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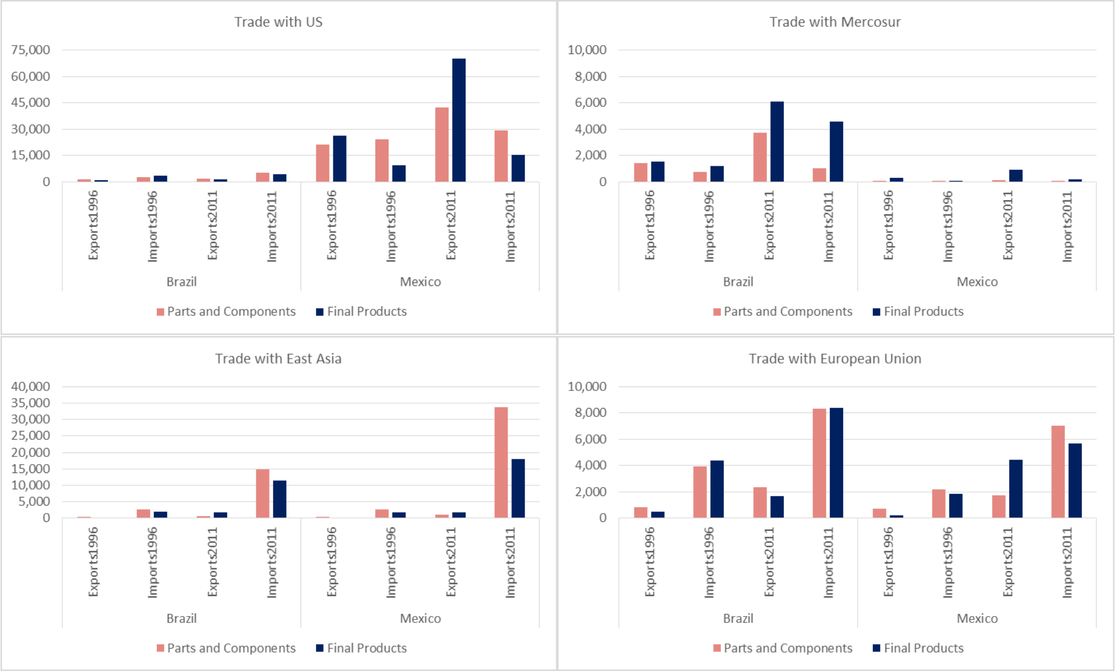
[16] Venezuela participation as a full member became effective just in 2012.

consider Brazil and Mexico's merchandise share in world total trade in 2013, Mexican shares were higher than Brazilian ones, despite the fact that Brazil's GDP is bigger than the Mexican one. Brazilian share in world total exports in 2013 was 1.29% while Mexican was 2.02%. Considering the imports, the situation is similar, with shares of 1.33% and 2.07% respectively.[17]

To infer how the policies adopted by each country affected the machinery sector, Figure 2.5 shows the machinery total trade values by selected regions. First, we observe that the value traded by both countries increased from 1996 to 2011. As expected, the main importer of Mexican machinery products was the US, while Brazil's equivalent was the Mercosur. In 1996, the main exporter of machinery to the Mexican market was the US, while in the Brazilian case it was the European Union. Nevertheless, in 2011 the East Asia consolidated the position of main exporter for both countries.

Figure 2.5 – Brazil and Mexico's machinery trade values per region (in million US$)



Source: Author's calculation using data from the UN Comtrade.

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[17] Data obtained in World Trade Organization Statistics Base.

As already mentioned, although Brazil's economy is approximately two times bigger than the Mexican one,[18] regarding machinery traded values Mexico traded considerably more than Brazil, what per se indicates a Brazilian lack of trade openness and participation in global machinery production networks.

Mexico's trade pattern with its main partner, the US, was characterized by higher values of parts and components imports and higher values of final products exports, reflecting the back-and-forth transactions. Conversely, the Brazilian trade with its preferential partner, the Mercosur, was characterized by higher import and export values of final products, reflecting a lack of production integration with the Mercosur's partners.

Figure 2.6 illustrates the weight of machinery trade over the total trade with selected regions. Once again, considering that shares of 20% for parts and components trade is the minimum threshold to the development of production networks, we identify that Mexico could possibly integrate production networks with EA, EU, and US. Nonetheless, the existence of production networks is also conditioned on the traded values, since high shares of parts and components in small trade flows cannot be taken as a sign of production networks development. Observing both information, Mexico could integrate production networks with US and EA. Machinery parts and components weight in Brazilian imports, signalize the possibility of the existence of production networks with EA, EU, and US, since they are bigger than 20%. However, when we observe the traded values, they are very small, reducing the possibility of the existence of production networks. The exception are the imports from EA in 2011. These findings are supported by Fung, Hwang, Ng, & Seade (2015) that highlighted the increasing role of China

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[18] Brazilian GDP in 2012 was 2,248,780 US$ millions, while Mexican was 1,186,460 US$ millions.

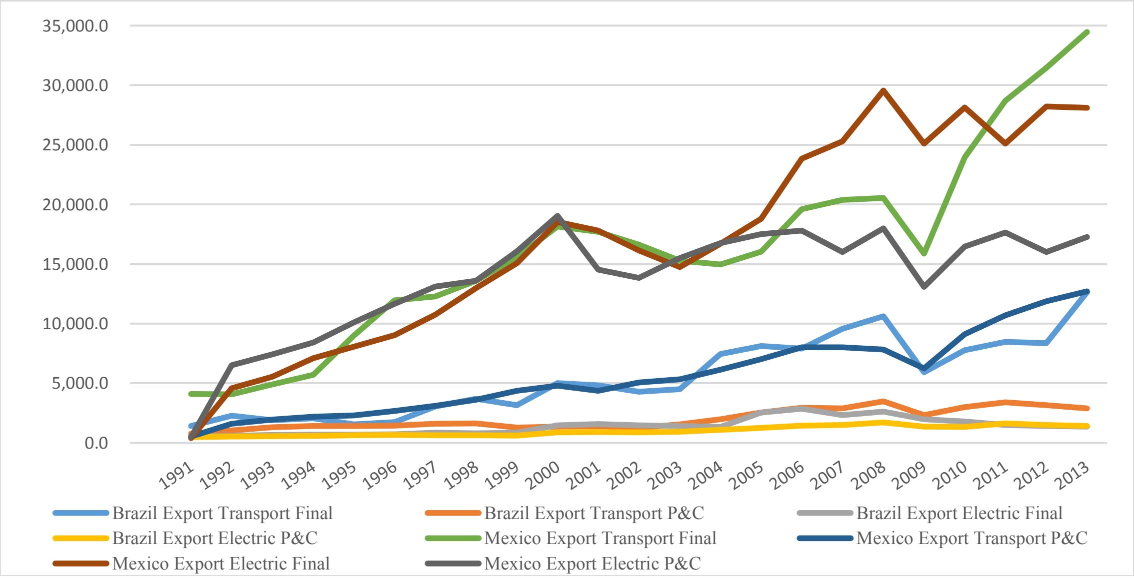
supplying parts and components for both countries and the possible creation of a China-Brazil-Mexico production networks.

Figure 2.6 – Brazil and Mexico’s shares of machinery trade over total trade per region

Source: Author’s calculation using data from the UN Comtrade.

Figure 2.7 presents the evolution of transport equipment and electric machinery exports splitting the data in parts and components or final products. In the beginning of the period, Mexico’s final transport equipment export values were slightly higher than Brazilian ones, while for other categories the values were smaller or similar. As the time passed the Mexican export values increased at higher rates than the Brazilian ones. In the end of the period, Mexico was exporting almost three times more final transport equipment than Brazil, while the amplitude in the other categories were even higher. The figure also shows that final transport equipment exports were the most important machinery trade flow for Mexico and Brazil in the end of the period. In fact, in the Brazilian case it was the most important trade flow since the beginning of the period, but in Mexico’s it was surpassed by the electric machinery in the years 2000. Final transport equipment started a recovery in 2009, regaining the first position in 2011. Another important detail is that Brazilian exports of transport equipment parts and components and electric machinery were very small and stable along the whole period, demonstrating that the country either ignored or failed in the adoption of policies to promote these products exports.

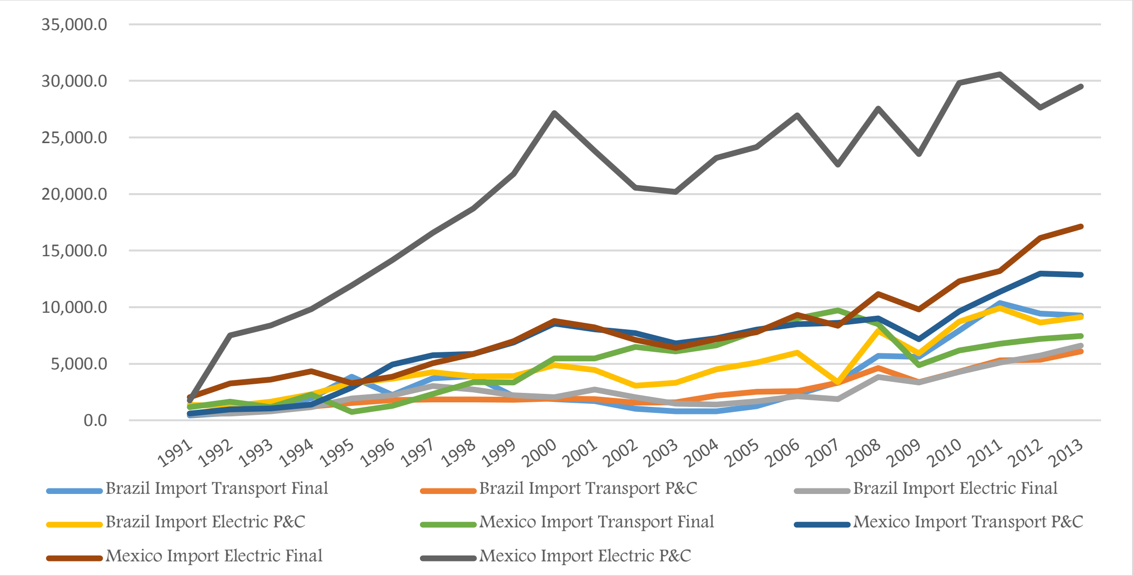
Figure 2.7 – Brazil and Mexico's export values by machinery sector (in US$ million)



Source: Author's calculation using data from the UN Comtrade.

Figure 2.8 presents the same type of data, but considering the import side. Once again, both countries presented similar values in the beginning, but along the period there was a faster increase in Mexico's values. Mexico's electric machinery parts and components values, followed by electric machinery final products and transport equipment parts and components, were higher than the Brazilian ones. It is interesting to notice that Mexico exported higher values of final products and imported higher values of parts and components for both types of machineries, indicating its participation in back-and-forth production networks. In other words, Mexico received more parts and components that were used in the production of final products and then were exported. However, in Brazil's case the higher values of export and import in the most important machinery sector, the transport equipment, were concentrated in final products. Indeed, compared to Mexico, Brazilian parts and components imports were very low for both machinery sectors. A cautious analysis of the data reveals that Brazilian exports of electric machineries were stable during the period, while the imports of electric machinery parts and components increased, revealing the possibility that Brazil is increasingly using these parts and components to produce final electric machineries for the domestic market.

Figure 2.8 – Brazil and Mexico's import values by machinery sector (in US$ million)



Source: Author's calculation using data from the UN Comtrade.

Finally, given the well-known importance and strength of the transport equipment industrial park in both countries, we analyze the vehicle data to recognize more specific differences between Brazil and Mexico. Figure 2.9 illustrates each country's vehicle production, sales, exports and imports per year.[19] Observing the curves, we detect that Brazil produced more vehicles than Mexico. It also consumed more vehicles than Mexico. However, Mexico exported more than two times the number of vehicles exported from Brazil. Brazil was the fourth biggest consumer of vehicles and its production was mainly consumed in the domestic market. On the other hand, one third of the Mexican production

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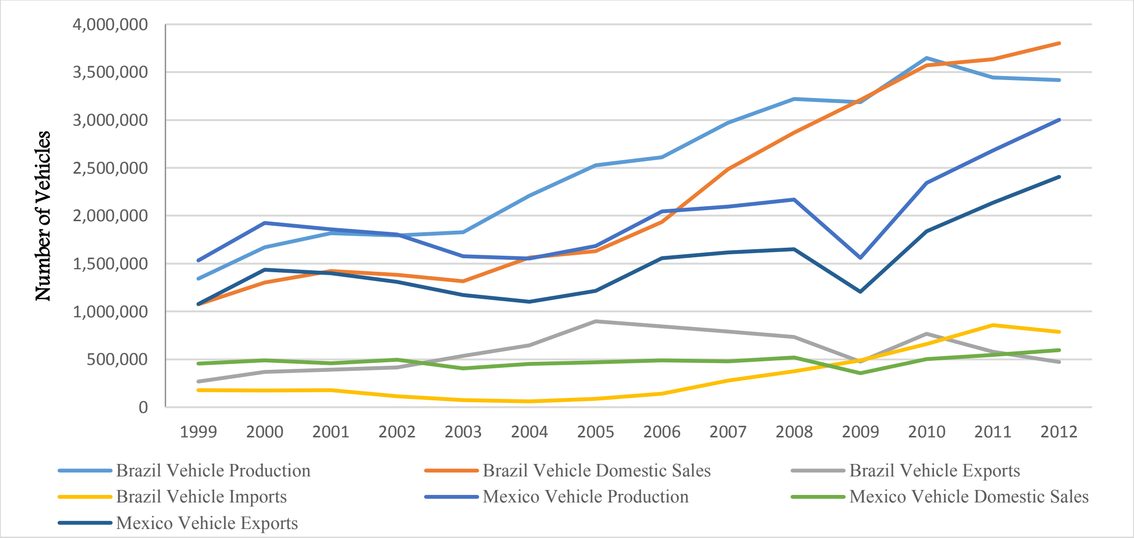
[19] Given a lack of data it was not possible to identify the number of vehicles imported by Mexico.

was exported to other markets, reflecting Mexico's back-and-forth production with the United States. Although the vehicle production is important for both economies, we identify a clear different pattern with Mexico's proactive engagement in production networks, while Brazilian production and consumption was more constrained to the domestic market.

Figure 2.9 – Brazil and Mexico's vehicle production, sales, exports, and imports per year



Source: Author's calculation using data from the Ward's automotive yearbook and JAMA.

2.3.2 Extensive and intensive margin analysis

As observed in Figure 2.3, during the analyzed period there was an increase in both countries machinery trade values. The increase in the trade flow can be a consequence of an intensive margin growth, that is the change in the value traded in already existent country-product relations, and/or a consequence of an extensive margin, that is the change of trade value resultant from the establishment of new country-product relations and the extinction of old ones. An analysis of the evolution of the active country-product trade links during the studied period can indicate how both countries are promoting or not the diversification and integration in machinery international trade. In order to follow these evolutions, two exercises were performed. In the first exercise, both countries machinery trade data were disaggregated in extensive and intensive margins considering the differences between electric machinery, transport equipment, final products and parts and components. In the second exercise, the number of active country-product links were tracked according to the trade partner region of Brazil and Mexico.

As Brazilian and Mexican data were reported in different HS versions along the studied period (HS1996, HS2002, and HS2007), the data was shared in three spans in order to maintain a common classification per span: a first period that goes from 1997 to 2001, a second period from 2002 to 2007, and a third period from 2008 to 2011. For each period, we compare the initial with the final year.

Table 2.4 contains the data relative to Brazil and Mexico's transport equipment and electric machinery changes from 1997 to 2001. The number of existing products is identified inside the parentheses and each country can trade with a maximum of 88 countries. Mexican trade data reveals a better performance than the Brazilian ones, indicating an increase in the trade flows. After 1999, Brazilian economy suffered with a crisis that leaded to a deflation of the national currency, what could be one of the causes for the decrease in the traded values, specially the import ones. Considering the margins, transport equipment data shows that although Mexico exported higher values than Brazil, its exports were, in general, more focused than the Brazilian ones, resulting in a smaller number of active export links. On the other hand, Mexico presented a higher number of import links than Brazil. This indicates that Mexican exports were more focused in the NAFTA market, while imports were more diversified. Electric machinery data presented a similar pattern, with the difference that Mexico had more active product-country links than Brazil for the export of final products. Another important detail from Table 2.4 is the fact that Mexico has more stable country-product links than Brazil. This information is reflected by the fact that the contribution of existing links to trade value change were close to 100%, while the contribution of disappearing and new ones were close to 0%.

Table 2.4 – Margins of Brazil and Mexico's machinery trade: 1997-2001

	Transport Equipment							
	Brazil				Mexico			
	Parts and Components (44)		Final (88)		Parts and Components (44)		Final (88)	
	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports
Average value of trade (million US$)								
1997	1,797.3	**2,102.5**	3,280.8	**4,150.7**	3,574.5	**6,619.0**	**14,033.5**	2,692.1
2001	1,516.8	**2,054.8**	**5,285.1**	1,965.3	5,020.1	**9,272.0**	**20,327.1**	6,148.4
Trade Growth (%) 1997 to 2001								
	-15.6	-2.3	61.1	-52.7	40.4	40.1	44.8	128.4
Number of traded varieties								
1997	**934**	**606**	409	427	543	560	**459**	**443**
Existing	756	469	244	237	393	445	208	319
Disappearing	178	137	165	190	150	115	251	124
New	182	157	221	103	138	212	138	221
2001	**938**	626	**465**	340	531	**657**	346	**540**
% change in number of varieties 1997 to 2001								
	0.4	3.3	13.7	-20.4	-2.2	17.3	-24.6	21.9
% of trade growth contribution of varieties of each category								
Existing	-117.1	-123.3	62.9	-83.3	**98.5**	**98.7**	**101.2**	**94.1**
Disappearing	-7.4	-25.3	-22.6	-25.7	-1.3	-0.4	-3.2	-0.2
New	24.6	48.6	59.7	8.9	2.8	1.7	1.9	6.1

	Electric Machinery							
	Brazil				Mexico			
	Parts and Components (144)		Final (149)		Parts and Components (144)		Final (149)	
	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports
Average value of trade (million US$)								
1997	737.0	**4,856.5**	951.3	**3,486.6**	15,070.9	**18,979.5**	**12,373.5**	5,743.8
2001	1,021.6	**5,094.3**	1,771.2	**3,108.1**	16,701.6	**27,354.3**	**20,466.6**	9,418.4
Trade Growth (%) 1997 to 2001								
	38.6	4.9	86.2	-10.9	10.8	44.1	65.4	64.0
Number of traded varieties								
1997	**2,241**	3,133	1,263	2,293	1,879	**3,174**	**1,511**	**2,501**
Existing	1,734	2,616	918	1,667	1,294	2,690	980	2,013
Disappearing	507	517	345	626	585	484	531	488
New	1,035	688	654	497	781	886	635	715
2001	**2,769**	3,304	1,572	2,164	2,075	**3,576**	**1,615**	**2,728**
% change in number of varieties 1997 to 2001								
	23.6	5.5	24.5	-5.6	10.4	12.7	6.9	9.1
% of trade growth contribution of varieties of each category								
Existing	67.6	79.0	84.4	-138.3	**97.4**	**97.8**	**99.6**	**94.0**
Disappearing	-6.9	-25.8	-4.7	-30.5	-4.6	-0.2	-0.8	-0.7
New	39.3	46.9	20.3	68.8	7.3	2.4	1.3	6.7

Source: Author's calculation using data from the UN Comtrade.

Table 2.5 reveals a change in the trade flow, with an increase in Brazilian traded values. However, Mexico's trade was still considerably larger than the Brazilian one. Mexican data showed a clear trade pattern for both products: high parts and components import values concomitant with even higher final products export values. Considering the margins, the patterns were still similar to the first period, with Mexico having more diversified import active links, while export links were less diversified than Brazilian ones, reflecting the focus on NAFTA market. Furthermore, Mexico trade was, in general, more stable than Brazilian one.

Table 2.5 – Margins of Brazil and Mexico's machinery trade: 2002-2007

Transport Equipment								
	Brazil				Mexico			
	Parts and Components (43)		Final (89)		Parts and Components (43)		Final (89)	
	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports
Average value of trade (million US$)								
2002	1,367.5	**1,723.9**	**4,674.6**	1,183.7	5,836.8	**8,857.2**	**19,100.4**	7,383.1
2007	2,952.9	**3,700.5**	**10,189.4**	3,843.9	9,213.9	**9,910.2**	**23,383.9**	11,154.3
Trade Growth (%) 2002 to 2007								
	115.9	114.7	118.0	224.7	57.9	11.9	22.4	51.1
Number of traded varieties								
2002	**952**	645	**535**	292	497	**665**	359	**543**
Existing	777	506	347	208	416	579	232	389
Disappearing	175	139	188	84	81	86	127	154
New	277	227	422	195	214	325	257	218
2007	**1,054**	733	**769**	403	630	**904**	489	**607**
% change in number of varieties 2002 to 2007								
	10.7	13.6	43.7	38.0	26.8	35.9	36.2	11.8
% of trade growth contribution of varieties of each category								
Existing	96.3	**97.9**	58.7	83.5	**99.1**	**87.2**	**94.0**	**84.6**
Disappearing	-0.7	-1.3	-7.5	-4.3	-0.5	-0.5	-4.6	-5.1
New	4.4	3.4	48.7	20.8	1.4	13.3	10.7	20.5

Electric Machinery								
	Brazil				Mexico			
	Parts and Components (141)		Final (146)		Parts and Components (141)		Final (146)	
	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports
Average value of trade (million US$)								
2002	993.2	**3,495.3**	1,664.6	**2,310.0**	15,913.2	**23,611.7**	**18,572.8**	8,160.0
2007	1,608.3	**3,850.8**	**2,520.5**	2,143.4	18,376.2	**25,901.2**	**29,079.7**	9,575.1
Trade Growth (%) 2002 to 2007								
	61.9	10.2	51.4	-7.2	15.5	9.7	56.6	17.3
Number of traded varieties								
2002	**2,839**	3,228	**1,646**	2,028	1,974	**3,522**	1,584	**2,639**
Existing	2,171	2,574	1,052	1,246	1,459	3,142	1,081	2,022
Disappearing	668	654	594	782	515	380	503	617
New	1,060	766	690	495	957	1,403	771	748
2007	**3,231**	3,340	1,742	1,741	2,416	**4,545**	**1,852**	**2,770**
% change in number of varieties 2002 to 2007								
	13.8	3.5	5.8	-14.2	22.4	29.0	16.9	5.0
% of trade growth contribution of varieties of each category								
Existing	110.3	129.9	**97.8**	53.4	97.6	96.2	99.4	99.7
Disappearing	-25.3	**-48.0**	-10.4	-190.0	**-3.1**	-1.5	-0.6	**-8.5**
New	**15.0**	18.2	**12.6**	**36.7**	5.4	5.2	1.3	8.9

Source: Author's calculation using data from the UN Comtrade.

Table 2.6 presents similar results for the third period. Although the number of products changed according to the analyzed period (in general, in the new HS versions there was a decrease in the number of products), the number of active country-product links increased along the period, revealing a diversification tendency promoted by the globalization.

Table 2.6 – Margins of Brazil and Mexico's machinery trade: 2008-2011

Transport Equipment

	Brazil				Mexico			
	Parts and Components (44)		Final (87)		Parts and Components (44)		Final (87)	
	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports
Average value of trade (million US$)								
2008	3,531.3	**5,167.6**	**11,199.2**	6,529.7	8,981.9	**10,361.9**	**23,603.7**	9,763.0
2011	3,682.1	**6,015.2**	9,048.6	**11,801.8**	12,309.6	**13,038.1**	**32,844.7**	7,766.2
Trade Growth (%) 2008 to 2011								
	4.3	16.4	-19.2	80.7	37.0	25.8	39.2	-20.5
Number of traded varieties								
2008	**1,059**	821	**694**	456	665	**935**	555	**636**
Existing	851	712	385	324	540	775	381	471
Disappearing	208	109	309	132	125	160	174	165
New	150	234	156	225	197	177	296	213
2011	**1,001**	946	541	549	737	**952**	**677**	**684**
% change in number of varieties 2008 to 2011								
	-5.5	15.2	-22.0	20.4	10.8	1.8	22.0	7.5
% of trade growth contribution of varieties of each category								
Existing	123.6	96.4	-53.5	95.5	**99.0**	**99.8**	**94.6**	**-101.0**
Disappearing	-37.0	-2.6	-98.7	-4.3	-0.3	-1.0	-1.4	-13.5
New	13.4	6.2	52.2	8.8	1.3	1.1	6.7	14.5

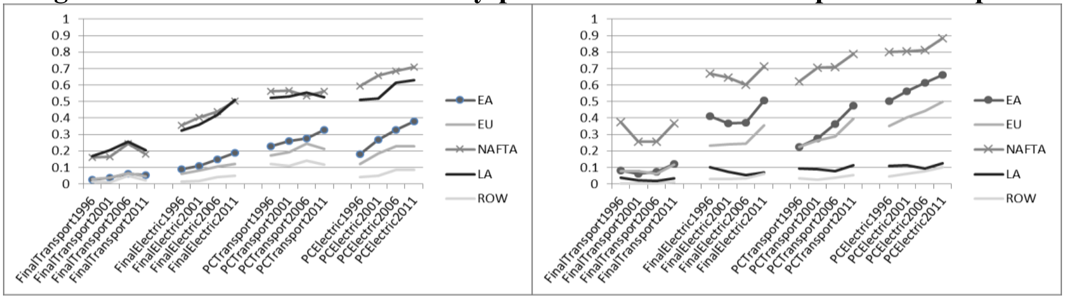
Electric Machinery

	Brazil				Mexico			
	Parts and Components (140)		Final (123)		Parts and Components (140)		Final (123)	
	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports
Average value of trade (million US$)								
2008	1,864.7	**9,057.7**	2,832.4	**4,382.7**	20,588.7	**31,603.0**	**33,914.8**	12,804.4
2011	1,783.8	**11,332.9**	1,582.1	**5,813.2**	20,235.7	**35,109.5**	**28,773.9**	15,125.3
Trade Growth (%) 2008 to 2011								
	-4.3	25.1	-44.1	32.6	-1.7	11.1	-15.2	18.1
Number of traded varieties								
2008	**3,396**	3,715	**2,048**	2,293	2,514	**4,489**	1,994	**2,785**
Existing	2,659	3,235	1,440	1,908	1,966	3,777	1,456	2,271
Disappearing	737	480	608	385	548	712	538	514
New	**813**	725	544	584	802	778	704	554
2011	**3,472**	3,960	1,984	2,492	2,768	**4,555**	**2,160**	**2,825**
% change in number of varieties 2008 to 2011								
	2.2	6.6	-3.1	8.7	10.1	1.5	8.3	1.4
% of trade growth contribution of varieties of each category								
Existing	-86.9	101.5	-94.5	83.9	**-101.8**	**100.3**	**-100.3**	**96.6**
Disappearing	-58.6	-4.1	-9.8	-2.9	-27.6	-1.1	-2.4	-0.9
New	45.5	2.6	4.3	19.0	29.4	0.8	2.7	4.2

Source: Author's calculation using data from the UN Comtrade.

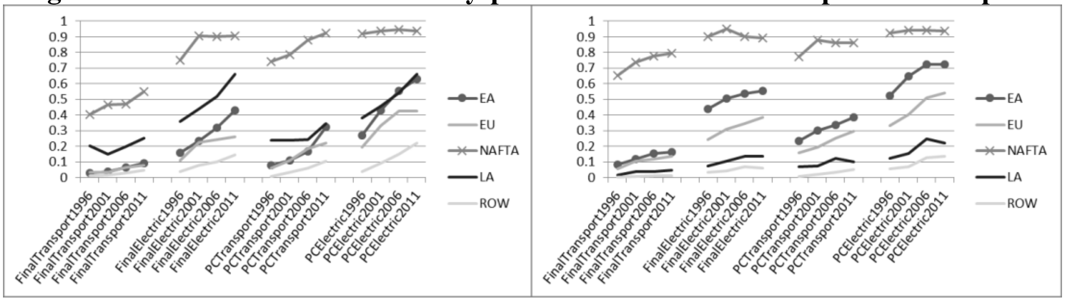
Another way of verifying the margins is analyzing the changes in the number of active links by trading regions. According to Kehoe and Ruhl (2013) and Hummels and Klenow (2005) a growth in trade in general leads to an increase in the extensive margin trade. To check this feature, it was selected four years: 1996, 2001, 2006, and 2011. Given the existence of different HS code revisions, to avoid possible miscounts and guarantee the possibility of comparison, the product-country pair definition has to be the same across the analyzed period. To ensure this condition, from a total of 1124 machinery product codes (HS1992) it was analyzed 955 ones. Figures 2.10 and 2.11 present the active links for Brazil and Mexico's exports and imports.

Figure 2.10 – Share of active country-product links: Brazil's exports and imports



Source: Author's calculation using data from the UN Comtrade.

Figure 2.11 – Share of active country-product links: Mexico's exports and imports



Source: Author's calculation using data from the UN Comtrade.

The first interesting finding is that Mexico had higher active country-product links for exports and imports to NAFTA, indicating the importance of the intraregional trade. In the Brazilian case, import curves and export curves of parts and components to NAFTA were higher than the other ones, although not as high as in the Mexican case, while the export curves of final products to LA were as high or higher than NAFTA ones. Curves for import from Latina America are very low for both countries, while the East Asian ones were the second highest. In general, Mexico had more import active links with LA than Brazil. Comparing the evolution of Brazilian and Mexican export active links, another outstanding feature is that Mexican export curves were steeper than the Brazilian ones. Mexico ended up the period with higher curves than Brazil, being the exports of transport equipment to Latin America, in special parts and components, the only exception. These results indicate that although both countries diversified their trade along the studied period, Mexico still has, in general, a more diversified trade pattern than Brazil. This fact corresponds to the international trade policy promoted by both countries, with Mexico being more proactive in the implementation of FTAs, while Brazil seems to give priority to the protection of its domestic market.

2.3.3 Quantitative analysis

In this subsection we perform a last exercise to confirm the different patterns of Brazilian and Mexican machinery trade. A gravity model framework is used to study the evolution of Brazil and Mexico's machinery trade performance in the period studied. This exercise was based in the following two equations:

$$\ln E_{ij} = \alpha + \beta_1 lnDist_{ij} + \beta_2 lnGDP_i + \beta_3 lnGDP_j + \beta_4 lnGAP_{ij} + \beta_5 cont_{ij} + \beta_6 lang_{ij} + \beta_7 Brazil + \beta_8 Mexico + \varepsilon_{ij} \quad (5)$$

$$\ln I_{ij} = \alpha + \beta_1 lnDist_{ij} + \beta_2 lnGDP_i + \beta_3 lnGDP_j + \beta_4 lnGAP_{ij} + \beta_5 cont_{ij} + \beta_6 lang_{ij} + \beta_7 Brazil + \beta_8 Mexico + \varepsilon_{ij} \quad (6)$$

where E_{ij} represents the exports from country *i* to country *j*, I_{ij} represents the imports of country *i* from country *j*, *Brazil* is a dummy that assumes value of 1 if country *i* is Brazil, and M*exico* is a dummy that assumes value of 1 if country *i* is Mexico. We still control for characteristics such as geographical distance between capitals of country *i* and country *j* ($Dist_{ij}$), the gross domestic product of country *i* (GDP_i) and country *j* (GDP_j), the absolute value of the difference in GDP per capita between country *i* and country *j* (GAP_{ij}), if country *i* and country *j* have common borders ($cont_{ij}$), and if they have a common language ($lang_{ij}$).

To avoid the problems that can arise from the use of OLS, we estimate the gravity model using the PPML method. Thus, we estimate the following equations:

$$E_{ij} = \exp[\alpha + \beta_1 lnDist_{ij} + \beta_2 lnGDP_i + \beta_3 lnGDP_j + \beta_4 lnGAP_{ij} + \beta_5 cont_{ij} + \beta_6 lang_{ij} + \beta_7 Brazil + \beta_8 Mexico] + \varepsilon_{ij} \tag{7}$$

$$I_{ij} = \exp[\alpha + \beta_1 lnDist_{ij} + \beta_2 lnGDP_i + \beta_3 lnGDP_j + \beta_4 lnGAP_{ij} + \beta_5 cont_{ij} + \beta_6 lang_{ij} + \beta_7 Brazil + \beta_8 Mexico] + \varepsilon_{ij} \tag{8}$$

Table 2.7 reports the results for the estimations considering all machinery trade data. In the upper part of the table, the coefficients are attributed to equation (7), while in the lower part the coefficients are relative to equation (8). The negative coefficients in the upper part confirm that Brazil exports were under the predicted level for the reference group (the other 87 countries with available data), while the positive ones indicate that Mexico exports more than the predicted levels. Another interesting evidence from Mexican dummies is related to the fact that final products coefficients are positive and statistically significant, while parts and components ones are, in general, statistically insignificant. This result endorses the existence of *maquiladoras* and the back-and-forth trade with US, with final products being assembled in Mexican territory and sent back to the American market. In the lower part of the table the Brazilian import coefficients are in general negative, while the Mexican ones have a pattern that is the opposite of the observed for exports: coefficients for imports of final products are statistically insignificant, while the coefficients for parts and components are positive. This confirms Mexico's engagement in production networks, through the imports of parts and components that are used in the *maquiladoras*.

Table 2.7 – Gravity model estimation for machinery trade with Brazil and Mexico dummies

	1996		2001		2006		2011	
	Final	P&C	Final	P&C	Final	P&C	Final	P&C
				Exports				
Brazil	-1.65***	-1.26***	-0.62**	-1.01***	-0.68***	-0.90***	-1.30***	-1.33***
	(0.21)	(0.23)	(0.24)	(0.15)	(0.22)	(0.19)	(0.33)	(0.23)
Mexico	0.77**	0.59	0.59***	0.19	0.54**	0.32	1.05***	0.58**
	(0.30)	(0.36)	(0.21)	(0.29)	(0.22)	(0.27)	(0.18)	(0.25)
Observations	23496	23496	23496	23496	23496	23496	23496	23496
R^2	0.474	0.548	0.522	0.569	0.404	0.348	0.408	0.288
				Imports				
Brazil	-0.61***	-0.53***	-0.46**	-0.09	-1.06***	-0.32*	-0.50**	-0.2
	(0.20)	(0.15)	(0.18)	(0.14)	(0.21)	(0.17)	(0.23)	(0.19)
Mexico	-0.31	0.63**	-0.16	0.60***	-0.18	0.65***	-0.06	0.92***
	(0.24)	(0.29)	(0.17)	(0.21)	(0.20)	(0.18)	(0.25)	(0.20)
Observations	23496	23496	23496	23496	23496	23496	23496	23496
R^2	0.461	0.556	0.498	0.585	0.393	0.348	0.374	0.285

Given a restriction of space, the coefficients of secondary variables are omitted. Robust standard errors in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Tables 2.8 and 2.9 provide the results for similar models that employ electric machinery or transport equipment data, respectively. The results in Table 2.8 indicate that after controlling for characteristics like distance, common border and GDP, Brazilian exports of electric machinery are still under the levels expected from the reference group, presenting negative coefficients. On the opposite side, Mexican coefficients are statistically significant just for final products, being statistically insignificant for parts and components. Once again, the results support the existence of back-and-forth trade with US. Observing the imports side, Brazilian coefficients are still negative for final products, while in the parts and components case it was negative in 1996, but became statistically insignificant from 2001, possibly indicating an increase in imports of parts and components in this sector. The Mexican import coefficients present a pattern that is the opposite of the exports ones, with positive and statistically significant coefficients just in the case of final products exports. The value of the coefficients slowly increased along the period, revealing an improvement in Mexico's performance against the rest of world.

Table 2.8 – Gravity model estimation for electric machinery trade with Brazil and Mexico dummies

	1996		2001		2006		2011	
	Final	P&C	Final	P&C	Final	P&C	Final	P&C
				Exports				
Brazil	-2.13^{***}	-2.54^{***}	-0.95^{**}	-1.89^{***}	-1.05^{***}	-1.83^{***}	-2.26^{***}	-2.23^{***}
	(0.27)	(0.32)	(0.39)	(0.22)	(0.39)	(0.23)	(0.28)	(0.36)
Mexico	0.91^{*}	0.59	0.72^{**}	0.25	0.74^{*}	0.4	1.16^{***}	0.52
	(0.48)	(0.50)	(0.36)	(0.40)	(0.41)	(0.48)	(0.33)	(0.45)
Observations	7832	7832	7832	7832	7832	7832	7832	7832
R^2	0.396	0.412	0.473	0.411	0.272	0.171	0.327	0.155
				Imports				
Brazil	-0.76^{***}	-0.69^{***}	-0.39^{*}	-0.24	-1.33^{***}	-0.4	-0.96^{**}	-0.28
	(0.22)	(0.20)	(0.22)	(0.17)	(0.42)	(0.33)	(0.47)	(0.40)
Mexico	-0.11	0.77^{**}	-0.04	0.81^{***}	-0.27	0.87^{***}	0	1.09^{***}
	(0.38)	(0.38)	(0.32)	(0.25)	(0.49)	(0.28)	(0.61)	(0.35)
Observations	7832	7832	7832	7832	7832	7832	7832	7832
R^2	0.345	0.431	0.4	0.462	0.241	0.173	0.287	0.154

Given a restriction of space, the coefficients of secondary variables are omitted. Robust standard errors in parentheses: $^{*}\ p < 0.10$, $^{**}\ p < 0.05$, $^{***}\ p < 0.01$.

Finally, Brazilian coefficients in the upper part of Table 2.9 are all statistically insignificant, while Mexican ones are positive, revealing a better performance of Mexican transport equipment exports. We also observe that final products coefficients are higher than parts and components ones, revealing that Mexico had a better performance in the export of final transport equipment. Brazilian coefficients in the lower part of the table are statistically insignificant or negative, while Mexican ones are negative for the imports of final products, but positive for the imports of parts and components, confirm the existence of strong back-and-forth transactions also in the transport equipment sector.

Table 2.9 – Gravity model estimation for transport equipment trade with Brazil and Mexico dummies

	1996		2001		2006		2011	
	Final	P&C	Final	P&C	Final	P&C	Final	P&C
				Exports				
Brazil	-1.11^{***}	-0.07	0.24	0.04	0.09	0.01	-0.46	-0.54
	(0.42)	(0.37)	(0.24)	(0.21)	(0.32)	(0.28)	(0.48)	(0.52)
Mexico	1.33^{***}	1.01^{***}	0.77^{***}	0.3	0.80^{**}	0.66^{**}	1.39^{***}	1.07^{***}
	(0.37)	(0.39)	(0.29)	(0.26)	(0.32)	(0.27)	(0.26)	(0.30)
Observations	7832	7832	7832	7832	7832	7832	7832	7832
R^2	0.585	0.751	0.674	0.835	0.603	0.785	0.654	0.667
				Imports				
Brazil	-0.86^{**}	0.01	-0.81	0.39	-1.23^{**}	0.05	-0.16	0.13
	(0.43)	(0.43)	(0.60)	(0.31)	(0.49)	(0.27)	(0.42)	(0.23)
Mexico	-1.44^{***}	0.87^{***}	-0.78^{***}	0.73^{***}	-0.36	0.55^{**}	-0.44^{*}	0.95^{***}
	(0.30)	(0.28)	(0.27)	(0.23)	(0.31)	(0.24)	(0.23)	(0.21)
Observations	7832	7832	7832	7832	7832	7832	7832	7832
R^2	0.574	0.763	0.667	0.845	0.597	0.771	0.602	0.638

Given a restriction of space, the coefficients of secondary variables are omitted. Robust standard errors in parentheses: $^{*}\ p < 0.10$, $^{**}\ p < 0.05$, $^{***}\ p < 0.01$.

2.4 Final considerations

Bearing in mind the advent of the production fragmentation and its importance for the developing countries, this chapter investigated the position of Latin America in the global machinery trade. The descriptive analyses showed that the machinery trade concentrates inside three regions: ASEAN, EU, and NAFTA. Additionally to the lower participation in the global machinery trade, the data also revealed that the Latin American share of machinery exports over the total exports is relatively low, while the machinery imports share were similar to the other regions. Considering the difference between parts and components and final products, final products imports were predominant. These results corroborates the idea that the region is still far from being engaged in machinery production networks. The quantitative exercises compared the trade patterns of EA and LA confirming the findings from the descriptive analysis.

Given the heterogeneity of the countries that compose the Latin America, in the second half of the chapter we observed per country machinery trade data and selected the two biggest economies in the region, Brazil and Mexico, for a closer analysis. The data indicated that Mexico was more prone to participate in machinery production networks, revealing a clear pattern of higher values of parts and components imports and higher values of final products exports. On the opposite side, Brazilian trade was more concentrated in final products, especially in the transport equipment sector. Furthermore, although the Brazilian economy was bigger than the Mexican one, Brazil's machinery trade values were less than half of the Mexican ones. The lack of FTAs and the protectionist tendency are possible reasons for the Brazilian relative low level of use of imported parts and components in its machinery industry. The lack of competitiveness of Brazilian products and the domestic oriented production of machinery industries are possible motives for the low level of exports in this industry. These facts demonstrate that Brazil and other Latin American countries are not fully exploring their potentials to engage in machinery production network. On the opposite side, Mexico’s openness to promote FTAs and for engaging in production networks was reflected by the trade diversification and the increasing imports of parts and components allied with increasing exports of final products.

CHAPTER 3 – Machinery Production Networks: an approach from the international input-output tables perspective

Employing international Input-Output (IO) tables obtained from the OECD-WTO Trade in Value Added (TiVA) database, the present chapter reveals the evolution of machinery production networks from a different perspective. Utilizing a range of indicators that measure the value added content of international trade flows and final demand, we obtain specific indices that provide some intuition about machinery production networks in East Asian and Latin American countries. These indexes are calculated based on OECD's Inter-Country Input-Output (ICIO) tables for the years 1996 and 2011. The results support what was observed in the previous chapters, confirming the dissimilar patterns between machinery production fragmentation in East Asia and Latin America. It is also possible to observe the heterogeneity of the countries that compose both regions, through the characterization of their engagement in machinery production networks. In general, compared to the Latin American countries the East Asian ones exported products that contained less domestic value added and participated more in fragmented productions, presenting higher shares in the indices of vertical specialization. Furthermore, East Asian countries engaged in production networks with a higher number of stages. All these characteristics corroborate the idea that East Asia has higher levels of engagement in production networks.

3.1 Introduction

The previous chapters provided an analysis of global machinery production networks evolution along the period 1996–2011, paying special attention to the situation in East Asia and Latin America. Provided that the findings of these chapters were mainly grounded in the use of international trade data reported by the countries, the objective of the present chapter is to complement the previous analysis providing insights that just can be apprehended using a different type of data: international IO tables.

Although the concept and use of IO tables was established in the economics literature many decades ago, it was just recently that researchers and organizations, like the OECD and WTO, started to organize and employ harmonized international IO tables to collect evidences of international trade linkages and production fragmentation. In fact, important efforts and investments have been done in order to standardize the data collection and increase the number of countries with data available to the construction of these databases. Projects like the World Input-Output Database (WIOD), the OECD-WTO Trade in Value Added (TiVA) database, and Eora multi-region input-output (MRIO) data, are examples of efforts to produce and provide international IO tables.

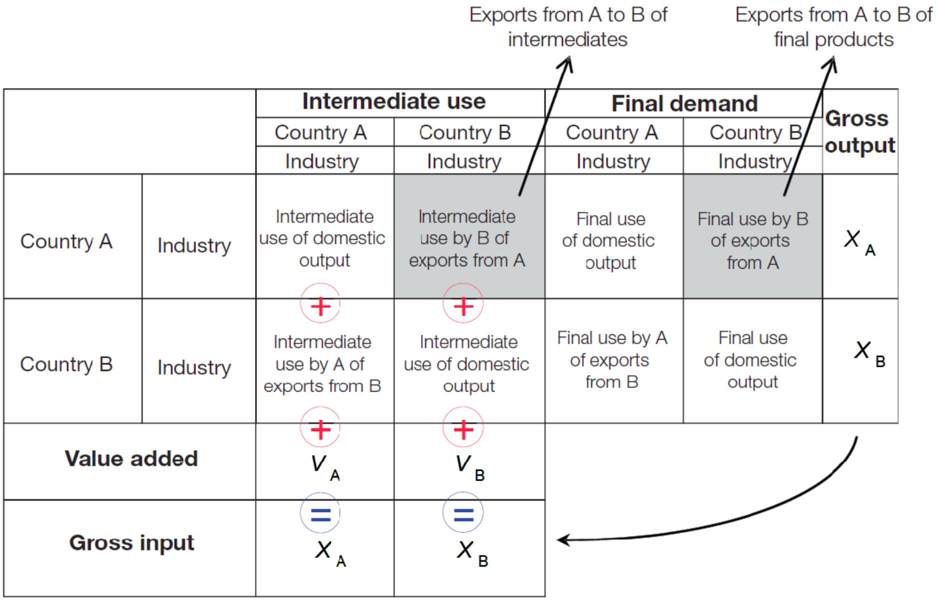
Given the increasing importance that the use of these databases has gained in the international trade literature and the complementary information that can be extracted from this type of data, this chapter explores the international IO tables from TiVA database for the years 1996 and 2011, aiming obtain evidences that confirm and expand the discoveries from the previous two chapters.

This chapter was organized as follows: section 2 describes the employed data providing the advantages and disadvantages in the use of IO tables. Section 3 describes the construction of IO table based indicators. Section 4 disclose the results of the calculated indices and their interpretations, while section 5 reports the final considerations of the chapter.

3.2 The Input-Output tables: a complementary approach

The IO analysis has a long tradition in the economics field, revealing the production and consumption structure of a given country or state. In general, IO tables map the portions of the output of given industries that are utilized as intermediate inputs in the same or third industries, as well as, the portion that will be consumed by the final demand. The International IO tables are extensions of the basic IO table framework that account also for the origin country and industry of imported products and the destiny country and industry of exported products. Figure 3.1 illustrates the basic framework of a simplified international IO table. In this case, a two-country and one-industry world, the IO table reports the intermediate use and final demand of countries A and B considering the outputs produced in both countries. It also reports the gross out of each country that can be calculated as the sum of intermediate and final demand of the outputs produced by a given country or the sum of the intermediate inputs used by this country plus the value added aggregated in the production process.

Figure 3.1 – Example of a basic international Input-Output table structure



		Intermediate use		**Final demand**		**Gross output**
		Country A	Country B	Country A	Country B	
		Industry	Industry	Industry	Industry	
Country A	Industry	Intermediate use of domestic output	Intermediate use by B of exports from A	Final use of domestic output	Final use by B of exports from A	X_A
Country B	Industry	Intermediate use by A of exports from B	Intermediate use of domestic output	Final use by A of exports from B	Final use of domestic output	X_B
Value added		V_A	V_B			
Gross input		X_A	X_B			

Source: UNCTAD (2013).

In one sense, the international IO table approach provides a more accurate level of analysis on intermediate inputs use, discriminating these inputs according to their country and industry of origin. The literature that employs international IO tables commonly use the term Global Value Chain (GVC) instead of production networks. According to Gereffi and Fernandez-Stark (2011, p. 4) a value chain can be defined as the “full range of activities that firms and workers do to bring a product from its conception to its end use and beyond”. In other words, the concept of GVC comprises all steps and inputs used to produce a final product, from the raw material to the final services like logistic and marketing. In this sense, it embraces more intermediate steps than previewed by the concept of production networks that just consider the use of parts and components as intermediate products. Consequently, the use of international IO tables provide a different perspective for production networks, capturing more intermediate steps in the production of machineries than is possible using trade data. The authors in the international IO table literature argue that the use of IO tables provide a superior account of the production fragmentation since production network studies that use trade data require a definition of which parts and components are used in the production of specific products. Therefore, they argue that these definitions are arbitrary, not necessarily comprehending all parts and components used in the production of the product in question.

Despite the aforementioned differences, another interesting feature of international IO tables is the fact that they eliminate the double counting in intermediate products. According to OECD (2013), international IO tables allow for the use of valued added instead of current gross trade flow, avoiding double counting of the intermediate products. In other words, when a country A exports parts and components to country B at a price X, and country B uses it to manufacture a final product that will be traded with country C at a price Y, this price Y incorporates the value of the intermediate good (X) and the value that was added by country B. Considering that a final machinery product is composed of a range of parts and components, the gross trade value of a final product incorporate multiple counting of intermediate goods. Eliminating these multiple counting we can identify the real contribution of each country in the production networks. The importance of this fact was illustrated by a few studies that focused on specific products, like the iPhone case (Kraemer, Linden, & Dedrick, 2011). According to the trade data, China exported the final product iPhone to the rest of the world, giving the impression that the country had a comparative advantage in the production of high-tech goods, while the real value added by this country was relatively low, given that it mainly assembled parts and components imported from other regions of the globe, having comparative advantage in low-skilled assembly tasks. The opposite is true, with countries that provided parts and components with high aggregated value added being overlooked. An advantage of the use of international IO tables is the fact that it allows the calculation of the position and the share of valued added aggregated by each country in a production network.

3.2.1 The TiVA database

The increasing importance of production fragmentation, the difficulties in using pure trade data to track trade in value added flows and the necessity of better understanding them, stimulated the OECD and the WTO to gather efforts in the construction of a new database. Initially, they produced yearly Inter-Country Input-Output (ICIO) models that linked internationally the IO tables of 58 economies, accounting for more than 95% of the global output. Their project prospered and they kept updating the available database. In this research, we employed the latest version of TiVA database that was released in March 2017. In this version, the ICIO tables provide data for 64 economies (all 34 OECD members, 29 non-member countries, and an aggregate of the rest of the world) and 34 industries for all years from 1995 to 2011. Provided that the investigation in the previous two chapters was centered in the years 1996 and 2011, and the fact that the structure of GVCs activities remain remarkably stable over time (Shepherd & Archanskaia, 2014), this chapter examination will be based on ICIO tables for the years 1996 and 2011.

The classification of TiVA data in 34 industries was based on the International Standard Industrial Classification of All Activities (ISIC), revision 3. The machinery products were classified in five industries: machinery and equipment, nec (C29MEQ); computer, electronic and optical equipment (C30T33XCEQ); electrical machinery and apparatus, nec (C31ELQ); motor vehicles, trailers and semi-trailers (C34MTR); and other transport equipment (C35TQR). Even though the ISIC is different from the HS classification, to keep the analysis more tractable and comparable with the one in the previous chapters, we aggregate the data and focus the analysis in two industries that are proxies to the ones studied in the previous chapters: electrical and optical equipment (an aggregation of C30T33XCEQ and C31ELQ) and transport equipment (an aggregation of C34MTR and C35TQR).

As mentioned above, there are other initiatives, like the WIOD and Eora, that also provide international IO tables. Our choice for TiVA in detriment of WIOD was grounded on the fact that TiVA provides data for a higher number of Latin American countries (seven countries against just two in the WIOD database). In addition, TiVA initiative is the only one that "aims developing an internationally recognized 'official' international IO table within a coordinated network of national and international statistics agencies" (Ahmad, Bohn, Mulder, Vaillant, & Zaclicever, 2017, p.19), being more reliable than the other projects. Indeed, the main advantage of TiVA "is the statistical network within which this database was constructed, capitalizing on the OECD's networks of official statistics agencies and its official Committees and Working Parties, omitting countries and industries that lacked sufficiently reliable data" (Ahmad et al., 2017, p. 20).

From the 64 economies represented in TiVA database, we calculate the indicators for the Latin American countries (Argentina, Brazil, Chile, Colombia, Costa Rica, Mexico, and Peru) and the East Asian countries (Brunei Darussalam, Cambodia, China, Indonesia, Japan, Malaysia, South Korea, Chinese Taipei, Thailand, The Philippines, and Vietnam).

3.2.2 Advantages and disadvantages of the use of Input-Output tables

Since IO tables trace the trade flows of value added, the first advantage of using this type of data is the possibility of analyzing production fragmentation identifying where the value was produced. A second advantage is the fact that IO table structure permits the identification of the linkages between the countries, making possible the creation of indices that reveal the relative position of a given country inside GVCs. In other words, we can identify if an industry in a specific country is closer to the upstream or the downstream part of the production. It is also possible to identify the GVC length of a specific industry and country, calculating the production average steps. These features cannot be obtained from the investigation of pure trade data.

The access to these features comes with a loss in other fields. The first loss is attributed to the fact that the indices calculated using IO tables contain value added aggregated by different industries, including services and raw materials, not being in accordance with the production networks definition. Consequently, in the interpretation of the indicators produced in this chapter it is necessary to take this fact in consideration. A second drawback from the IO table data is the fact that some assumptions were required to calculate the TiVA database. Consequently, the data are only estimated and not measured per se. The construction of these tables present many challenges, creating a trade-off between country and time coverage and the degree of reliability, given that certain countries data are of poor quality. Another problem, according to Ahmad (2015), is the difficulty in precisely identifying the links between exports and purchasing industries or final demand in the importing country, given data restrictions and inconsistencies across countries' data collection. Finally, it is assumed that all firms in an industry use the same technology to produce a good that will be sold to the same consumers and markets. In other words, firm heterogeneity is ignored in the construction of IO tables.

Independent of all the drawbacks presented, the IO tables are important sources of information to the study of production fragmentation. Based on this fact, the next section presents the main indicators adopted in the GVC literature.

3.3 Input-Output table based GVC indicators

The intensification of production fragmentation proportionated by the second unbundling highlighted the shortcomings of international trade statistics based on trade data, like the inability of providing an accurate description of the true trade patterns according to where the value was added. Consequently, in the last years there was a proliferation of studies that use IO table to track country linkages and value added flows. This strand of the international trade literature is relatively new and measures of the sequential production and linkages are still under development. In this chapter, we adopt the most used analytical tools available in the international IO table literature. The first index to be investigated is the domestic value added to gross exports (VAX) ratio. According to Johnson and Noguera (2012b), this index can be interpreted as a measure of the intensity of product sharing. This index reveals the proportion of the total gross exports of a given industry in a given country that is accounted by the domestic value added. To calculate this index it is necessary to first calculate the domestic value embodied in gross exports:

$$EXGR\_DVA_{c,p,i} = V_c B_{c,c} EXGR_{c,p,i} \qquad (1)$$

where $EXGR\_DVA_{c,p,i}$ stands for domestic value added in country *c* exports to country *p* of product from industry i. Vc is a row vector with domestic value added shares of output for each industry i, $B_{c,c}$ is a diagonal block matrix of B[20] representing the total domestic gross output required for an one unit increase of country c's demand, and $EXGR_{c,p,i}$ is a vector with all entries equal to zero except the one corresponding to industry *i*, that contains this industry gross exports from country *c* to country *p*.

This data is used to compute the VAX ratio according to the following equation:

$$EXGR\_DVASH_{c,i} = \frac{\sum_p EXGR\_DVA_{c,p,i}}{\sum_p EXGR_{c,p,i}} \times 100 \qquad (2)$$

A lower VAX ratio means that a country uses more imported value added to produce the exported product, indicating a higher probability of participation in GVCs, while countries with higher VAX ratio have a higher probability of being less engaged in GVCs. Although this index can be interpreted as a first sign of engagement in production networks, some caution is necessary, given that many reasons can affect the level of VAX ratio. One example is the fact that this index accounts for raw materials, consequently, it is expected that products exported from countries rich in natural resources will naturally have higher VAX ratios.

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[20] In the IO table literature the matrix *B* represents the Leontief Inverse matrix: $B=(I-A)^{-1}$.

A second type of indicators are the vertical specialization ones. The first index created in the international IO table literature was the vertical specialization (VS) one proposed by Hummels, Ishii, and Yi (2001). Aiming obtain a better understanding of the extent to which countries get involved in vertically fragmented productions, these authors proposed the VS index as a measure of the value of imported inputs in the gross exports of a given country. It was also proposed a VS1 index that calculated the share of exported goods and services from a given country used as import inputs to produce other countries' exports. In other words, the VS index is a backward participation measure that estimates the importance of foreign suppliers in value chain, while the VS1 index is a forward participation measure. Koopman, Powers, Wang, and Wei (2011) suggested a GVC participation index that results from the combination of the VS and VS1 shares, assessing a country participation as a user of foreign inputs and supplier of intermediate goods and services used in third countries' exports.

According to the literature, to derive the VS index it is necessary to first decompose the gross exports into value added share by source country. It is necessary to calculate the following matrix:

$$VBE = V(I - A)^{-1}E \qquad (3)$$

where the V is a diagonal matrix of a vector with value added shares in each country and industry, B is the Leontief Inverse, and E is the diagonal matrix of a vector of gross exports.

After calculating the VBE matrix, a sum of the values in the columns of this matrix (without the contribution of domestic industries) results in the contribution of foreign industries to exports, while a sum over rows (omitting contribution of domestic industries) generates the contribution of domestically produced intermediates to exports in third countries. The participation index is obtained according to the following equation:

$$P_{c,i} = \frac{VS_{c,i}}{E_i} + \frac{VS1_{c,i}}{E_i} \tag{4}$$

More recently, two types of position indicators were developed in the international IO table literature. The first indicator considers the average number of international production stages for a given country and industry. Fally (2012) proposed a measure of the average number of international production stages for a specific industry in a specific country. Differently from the vertical specialization measures that focus on the valued added, this new measure identify how "long" are value chains. In other words, a high VS share can be attributed to the use of one expensive intermediate input in a simple value chain or the use of many intermediate inputs with less value added in a more complex value chain. This difference can be captured by the production length index, that assumes the value of 1 if there is just a single production stage in the final industry and increases as more inputs from the same or other industries are used. The GVC length is computed as:

$$N = u(I - A)^{-1} \tag{5}$$

where N is the length index, u is a row vector of ones, and $(I\text{-}A)^{-1}$ is the Leontief Inverse matrix.

The second indicator aims identifying if a given sector in a country is specialized in relatively upstream or downstream stages of the GVC. Antràs, Chor, Fally, and Hillberry (2012) and Fally (2012) proposed two different approaches to calculate the upstreamness or distance to final demand index. Despite the differences in their approaches, it is proven that the achieved results are the same. This measure indicates the position of a country in the value chain, revealing if it is closer to the final demand and consequently in a downstream position, being responsible for the assembly process or customer service, or if it is farer from the final demand and consequently in a upstream position, producing raw materials or intangibles like research and design of the final product. According to Fally (2012), the upstreamness measure can be computed in the following way:

$$D = u(I - G)^{-1} \tag{6}$$

where D is the length index, u is a row vector of ones, and $(I-G)^{-1}$ is the output inverse or the Ghosh Inverse matrix.

Given the aforementioned measures, the next section presents the result of their calculations for all Latin American and East Asian available countries for the years 1996 and 2011.

3.4 GVC indicators analysis

Using the ICIO tables available for the years 1996 and 2011 in the TiVA database, we start our analysis calculating the VAX ratio for the East Asia (EA) and Latin America (LA) regions.[21] Figure 3.2 reveals the aggregated VAX ratio for both regions, providing some insights on the evolution of each region participation in GVCs. The first feature we observe is that VAX ratios for electrical and optical equipment are lower than transport equipment ones. This fact is in accordance with the findings from the previous two chapters that indicated that electric machineries are more prone to participate in

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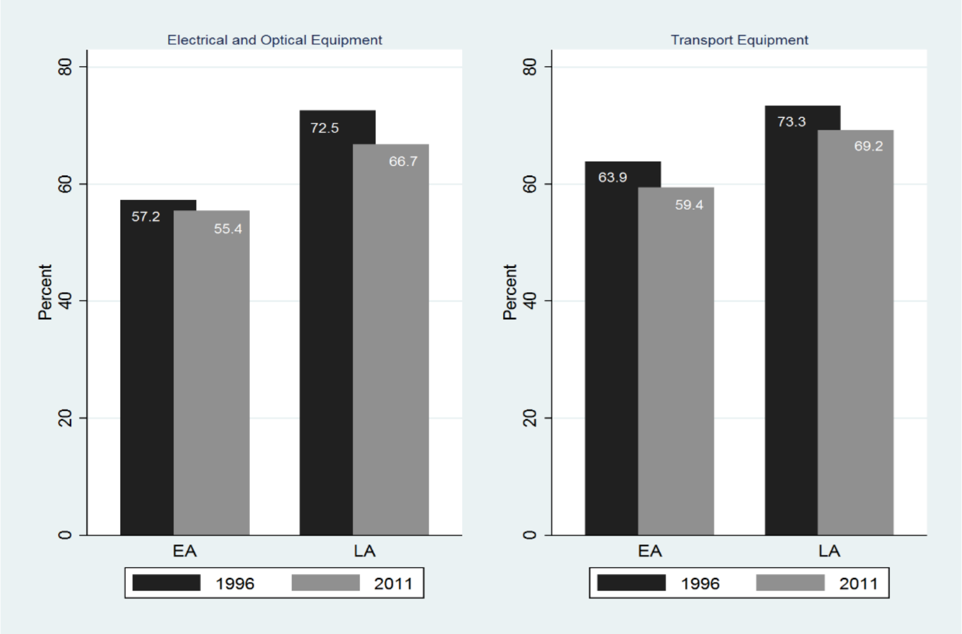
[21] Following the exercise in Shepherd (2015), the indicators for the aggregated region level were calculated by taking the simple average across all economies.

production networks than transport equipment. Next, we observe that EA VAX ratios are considerably lower than LA ones. The amplitude in transport equipment achieves almost 10 percentage points, while for electric and optical equipment it is higher than 11 percentage points. Indeed, the difference decreases from more than 15 percentage point in 1996 to 11.3 percentage points in 2011, revealing an engagement of Latin American countries in electric and optical equipment fragmented production. Another outstanding feature is the decrease in the VAX ratio from 1996 to 2011 for both regions, endorsing the findings from the previous chapters that indicated an increase in production fragmentation along the studied period.

Figure 3.2 – VAX ratio of East Asia and Latin America



Source: Author’s calculation using data from the OECD-TiVA Database.

Based on these initial findings and the fact that both regions are very heterogeneous, being composed of countries of different sizes and levels of development, the next step is to calculate the same index for the economies that compose each region. The upper part of Figure 3.3 contains the VAX ratio data for Latin American countries’ electrical and optical equipment, while the lower part plots the same indicator for East

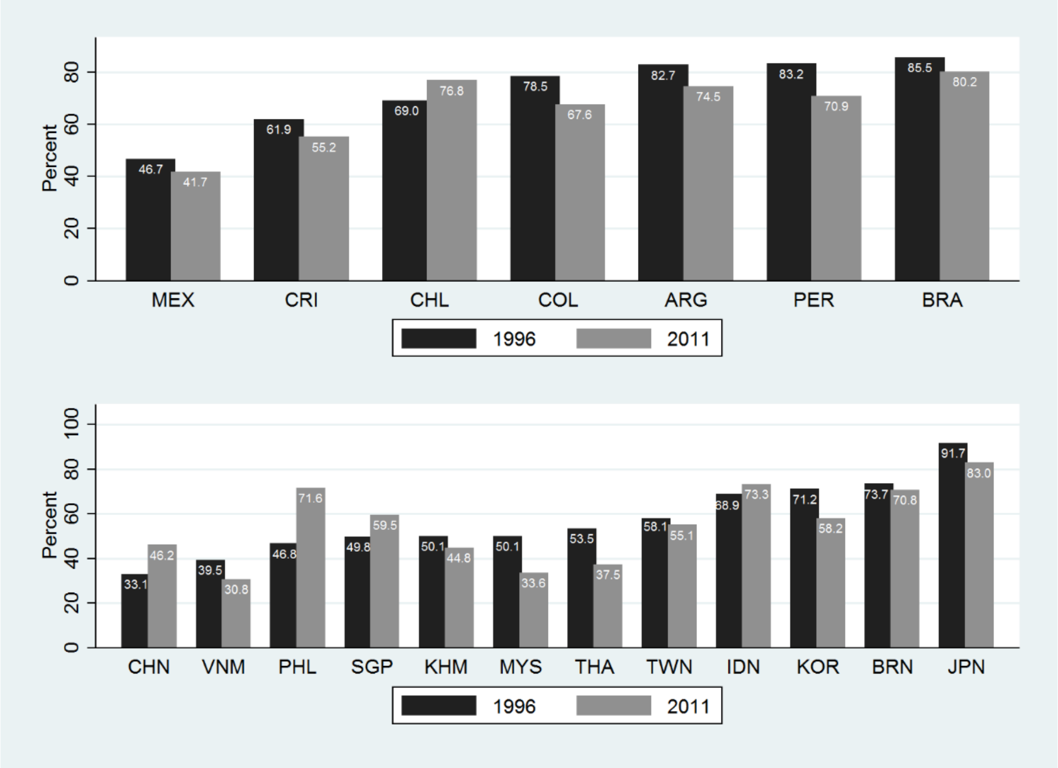
Asian countries. Data on the upper part of figure confirm a strong heterogeneity between the countries that compose LA region, with Mexico presenting the lowest VAX ratios, while Brazil presents the highest ones. The amplitude between the shares are around 40 percentage points. Mexico and Costa Rica are example of countries on the left side of the figure, having the lowest VAX ratios. As observed in the previous chapters, Mexico participates in a back-and-forth production network with United States, consequently a low VAX ratio was already expected, given that a big chunky of the value added in Mexican exports are accounted by intermediates imported from United States. A similar situation applies to Costa Rica, a small economy that depends on the products manufactured by plants installed by Intel. On the opposite extreme, we identify countries that are part of the Mercosur, like Brazil and Argentina, or the Andean Community, like Colombia and Peru. These countries reveal very high levels of VAX ratio. These high levels can be attributed to three main reasons: first, these countries are part of economic blocs that were less integrated to the rest of the world; second, as observed in the previous chapter, some countries like Brazil maintain a protectionist policy that stipulate, among other things, levels of national contents for the installation and production of multinationals enterprises; and a third important reason is the fact that these countries are rich in natural resources, supplying the raw materials that will be used in the production of electric machineries. Despite of the initial levels of VAX ratios, the figure shows that there was a decrease in these shares along the period, Chile is an exception, corroborating the idea that Latin American countries are slowly engaging in electric machinery production networks.

The lower part of Figure 3.3 also reveals a strong heterogeneity in the EA countries' VAX ratios. Countries like Japan and South Korea have very high ratios, while

China and Vietnam shares represent less than half of the Japanese and Korean ones. The high levels of value added in the Japanese and Korean exports can be attributed to the fact that these countries maintain the production of high-skill intensive parts and components. On the opposite side, China and Vietnam are responsible for labor-intensive tasks like the assembling the final products. Consequently, they do not aggregate much value added in their exports. In general, we observe that for the majority of the countries there was a decrease in their VAX ratios, including Japan and South Korea, a fact that can be attributed to the increasing production fragmentation in the region. The most interesting exception case is observed for the Chinese economy. There was an increase in China's VAX ratio and this is attributed to the fact that China moved in the production ladder, from the simple assembly tasks to other production steps that aggregate more value added to the final product. Finally, we observer some relatively high levels of VAX ratio for some countries, like Indonesia and Brunei, that are not known for their high-skilled intensive products. These results should be attributed to the fact that these countries are rich in natural resources.

Next, we present the same indicators for the same groups of countries, but considering the transport equipment industry. We observe that the upper part of Figure 3.4 has a similar configuration to the upper part of Figure 3.3. Once again, Mexico has the lowest VAX ratios, confirming the importance of back-and-forth transactions with the United States also in the transport equipment industry. In the opposite side of the figure, Brazilian and Argentinean data reveal a restricted participation of these countries in transport equipment GVCs. Another interesting feature is the fact that Costa Rican VAX ratios increased more than 10 percentage points when compared to electric machinery values. This is attributed to the fact that transport equipment industry in Costa Rica is not as strong as the electric machinery one. Once again, we observe a trend of decrease in the VAX ratios for the majority of the countries, emphasizing the idea that production fragmentation advanced during the studied period.

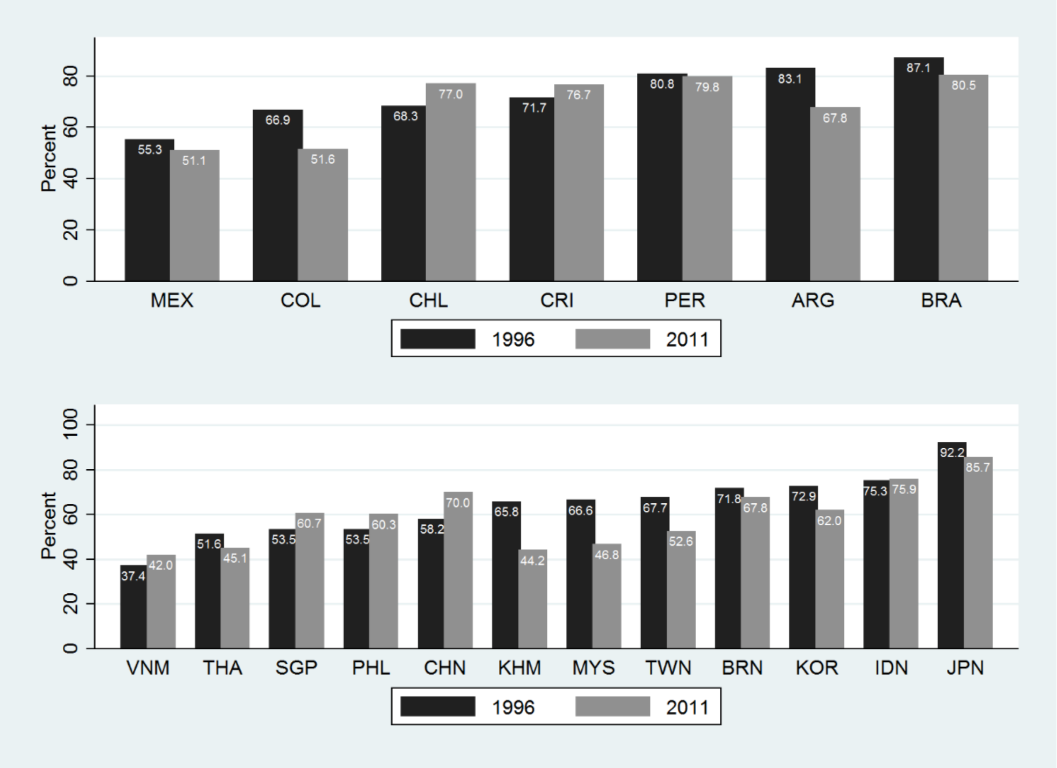
Figure 3.3 – VAX ratio of East Asian and Latin American countries: electrical and optical equipment



Source: Author's calculation using data from the OECD-TiVA Database.

The lower part of the Figure 3.4 is also similar to Figure 3.3, but the VAX ratios are higher, confirming that transport equipment are less prone to production fragmentation than electric machinery. This time, countries like Vietnam and Thailand have lower VAX ratios, while Chinese exported products have higher domestic value added. Once again, we can observe a decrease in VAX ratio for some economies, while for others there was an increase. These movements result from the increasing engagement of some countries in fragmented productions, while others that were already engaged moved from pure assemble tasks to other tasks where they can aggregate more value added. The latter applies for the Chinese case.

Figure 3.4 – VAX ratio of East Asian and Latin American countries: transport equipment

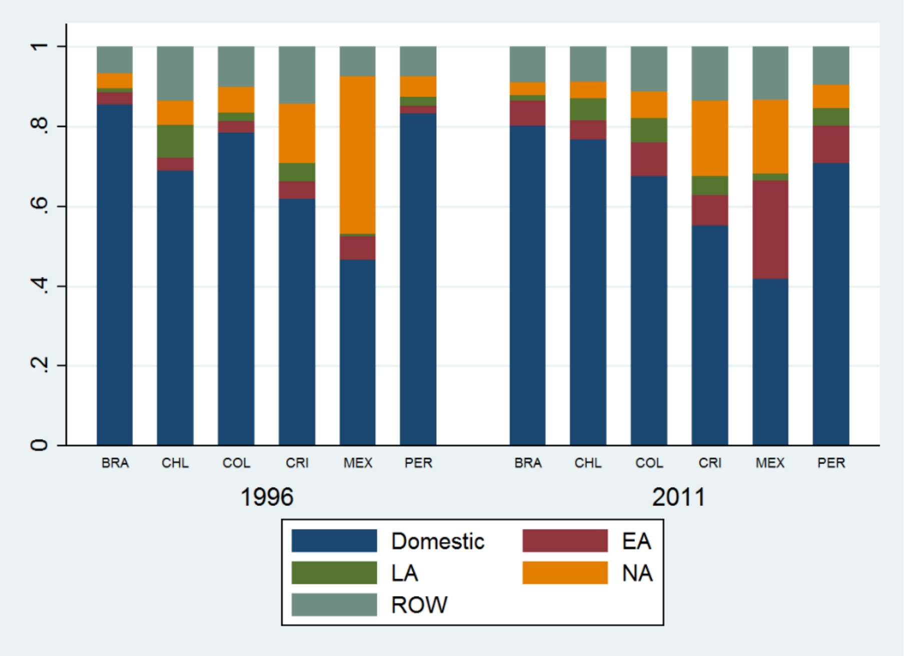


Source: Author's calculation using data from the OECD-TiVA Database.

The calculations using the ICIO tables allow for one more exercise considering the VAX ratio indicator. Given that the origin of the value added in a given country exports can be traced, Figures 3.5 and 3.6 display this information for LA and EA countries' exports of electrical and optical equipment.

From Figure 3.5 we verify that in 1996 the origin of foreign value added in Mexican exports was mainly Canada and United States (NA). However, in 2011 there was a tiny increase in value added from LA, while NA lost almost half of its share to EA. In other words, there was an increase in Mexican use of intermediate products with highly value added produced by East Asian countries to manufacture electrical and optical equipment for exports. We observe a similar pattern in all other Latin American countries. This information indicates that Latin American countries are using more intermediates with East Asian value added to produce electric machineries.

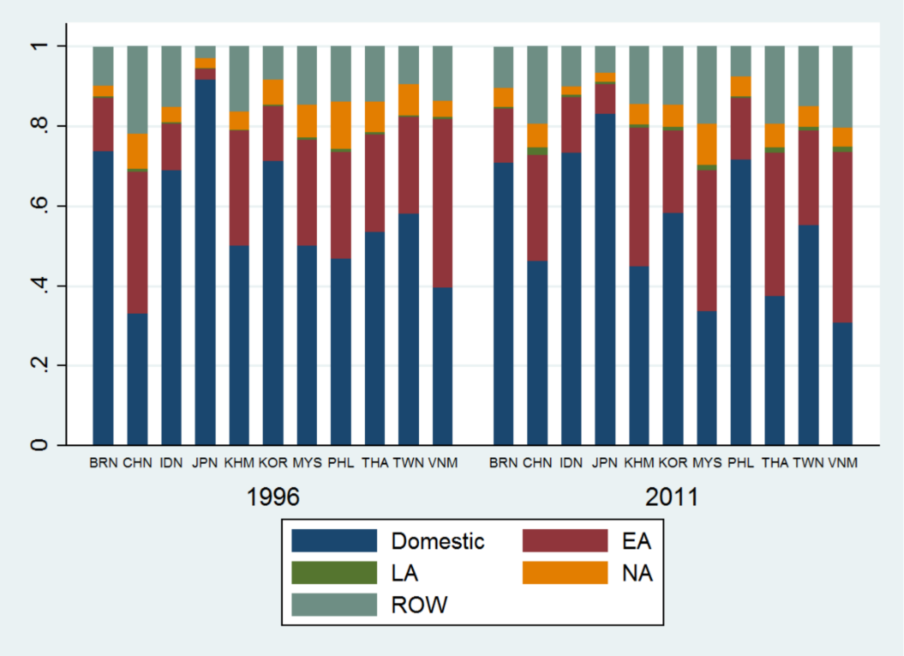
Figure 3.5 – Latin American countries composition of value added in exports: electrical and optical equipment



Source: Author's calculation using data from the OECD-TiVA Database.

Figure 3.6 also reveals an increase in the value added share attributed to intermediate products produced in third East Asian countries on East Asian countries exports. This change can be attributed to the increase in production fragmentation of electrical and optical equipment in the region. The only exception is China that presented a decrease in the share of valued added attributed to intermediate inputs imported from other East Asian countries. This decrease is explained by the fact that China absorbed more steps of the production process, increasing the domestic value added in the products it exports.

Figure 3.6 – East Asian countries composition of value added in exports: electrical and optical equipment

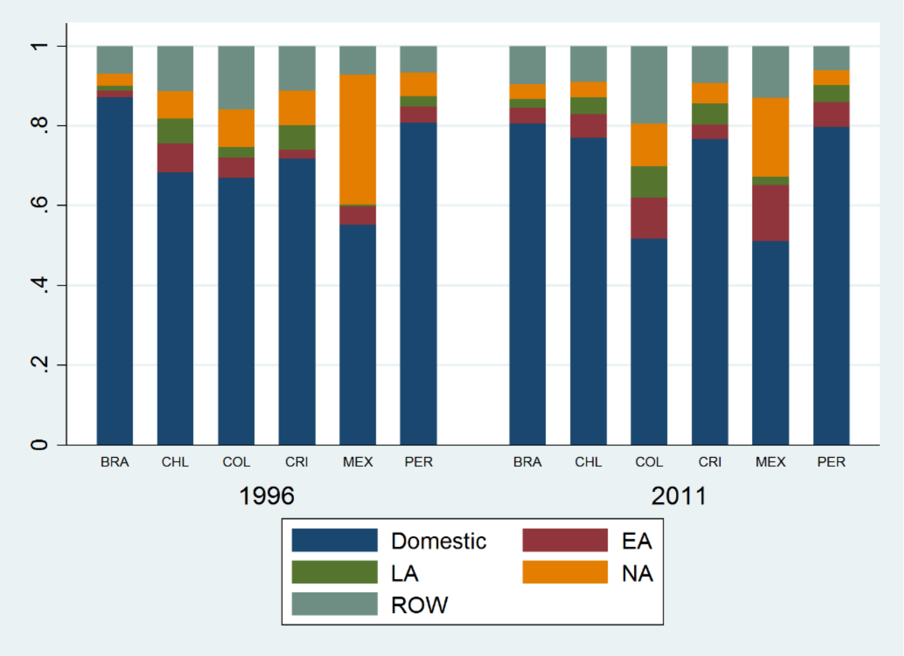


Source: Author's calculation using data from the OECD-TiVA Database.

Figures 3.7 and 3.8 provide data for the same exercise considering the transport equipment. Figure 3.7 demonstrates that the change in the pattern of transport equipment industry for Latin American countries is similar to the one observed in the electric machinery case, with an increase in the share of value added attributed to EA countries. However, these changes occurred in a slower pace. We also observe a small increase in Latin American shares.

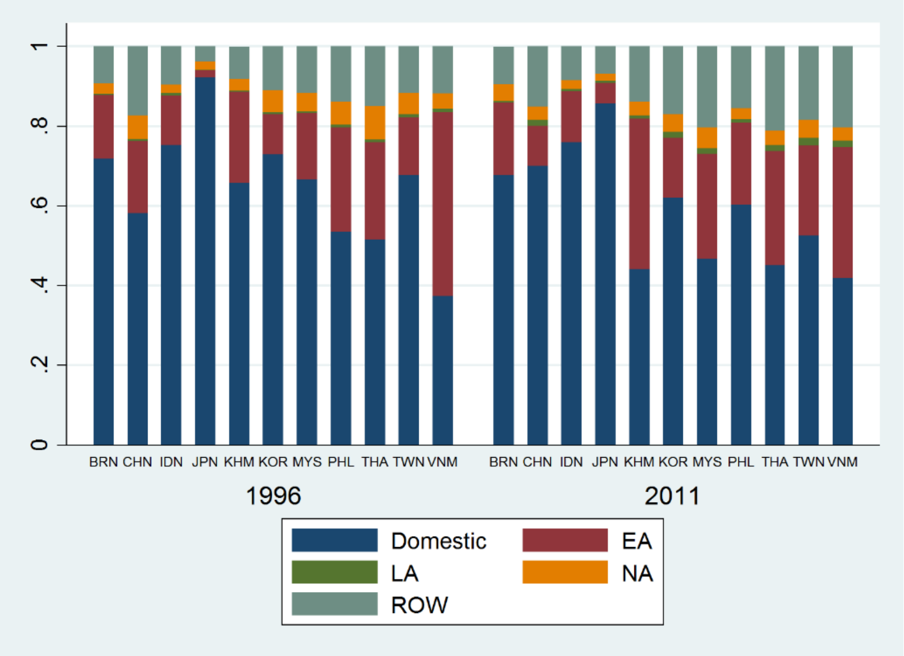
Figure 3.8 represents the situation for East Asian countries. Once again, the changes indicate an increase of EA shares. However, this change happened in a slower pace than the one observed for electric machinery. For the cases of China, Thailand, and Vietnam, we verify a clear decrease in EA shares in detriment of the domestic ones. The reason behind this happening is the same as already mentioned above: the transport equipment industry in these countries are moving from simple assembly tasks to others where they can aggregate more value added in the final product.

Figure 3.7 – Latin American countries composition of value added in exports: transport equipment



Source: Author’s calculation using data from the OECD-TiVA Database.

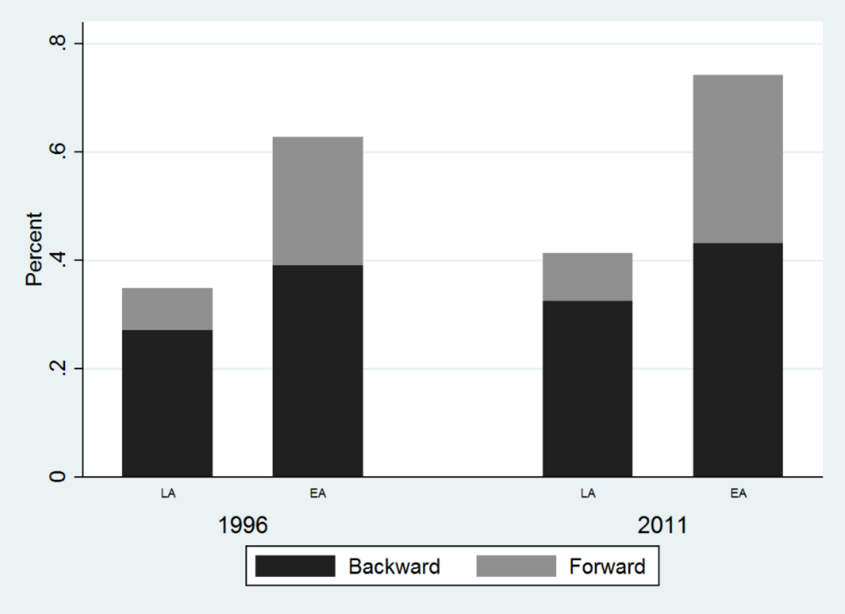
Figure 3.8 – East Asian countries composition of value added in exports: transport equipment



Source: Author’s calculation using data from the OECD-TiVA Database.

In order to capture other features from the ICIO tables, next we calculate the vertical specialization indexes with the intention of identifying the share of exports involved in a vertically fragmented production process. Figure 3.9 illustrates the participation index of EA and LA region, identifying the percentage of gross exports that is attributed to foreign inputs (backward participation) and domestically produced inputs that are used in third countries' exports (forward participation). First, the participation index is higher for EA than LA, reflecting the higher integration of this region in vertically fragmented production processes. Second, the shares increased from 1996 to 2011, especially for East Asian region. Lastly, one important difference between LA and EA is the fact that, in comparison with EA, backward participation in the Latin American region is proportionately bigger than forward participation. This can be explained by the fact that production in LA does not generate intermediate inputs to be used in other countries' production.

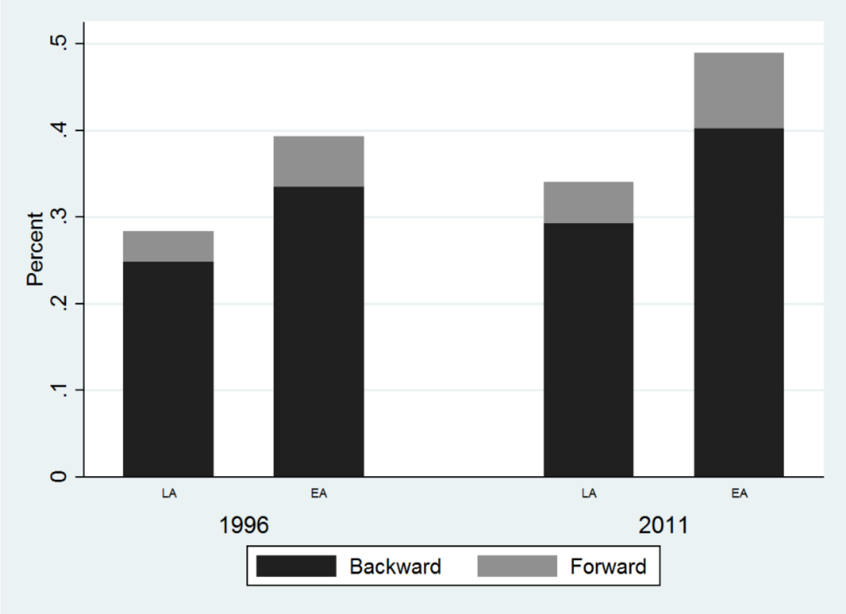
Figure 3.9 – GVC participation index of East Asia and Latin America: electrical and optical equipment



Source: Author's calculation using data from the OECD-TiVA Database.

Figure 3.10 reveals that for the transport equipment industry the participation in GVCs is smaller than in electric machinery industries for both regions. Once again, LA participation shares are smaller than EA ones, reflecting a smaller engagement in GVCs. Another interesting feature is the fact that compared to the electrical and optical equipment industry, in the transport equipment case the backward participation is relatively higher than the forward participation.

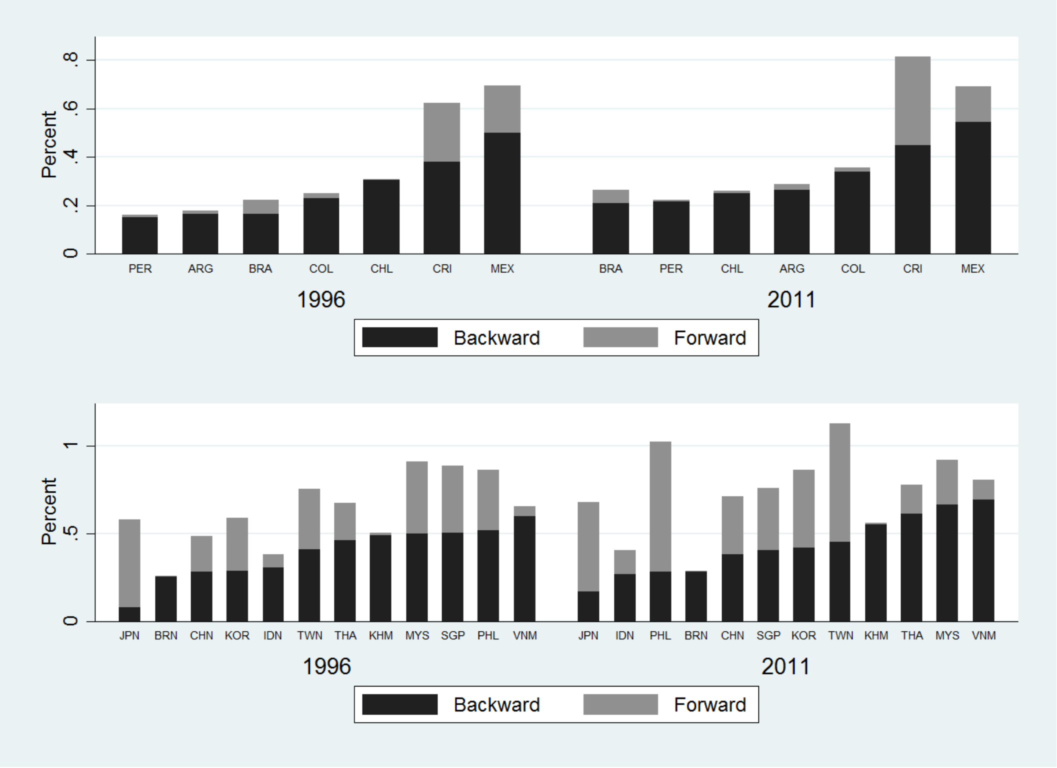
Figure 3.10 – GVC participation index of East Asia and Latin America: transport equipment



Source: Author's calculation using data from the OECD-TiVA Database.

Figures 3.11 illustrate the participation index for the Latin American and East Asian countries considering the electrical and optical equipment industry. In accordance with the findings from Figure 3.3, we observe that for the case of electric machinery, Mexico and Costa Rica participation indexes are higher than the indexes of the rest of the countries, endorsing the deeper participation of these countries in GVCs. We also observe that along the period Costa Rica increased considerably its participation in GVCs, especially the forward participation share. Another important feature is the fact that the forward participation share of Argentina, Chile, Colombia, and Peru is close to zero, revealing that these countries do not produce electric machinery intermediate inputs that can be used to produce goods that will be exported by third countries. These countries basically acquire foreign inputs that will be used in their exports of electrical and optical equipment. This fact is in accordance with the information revealed in the previous chapter that Latin American countries basically import final electric machinery products for domestic consumption. In the lower part of the figure, we observe the data for East Asian countries. The participation indices are in general higher than the Latin American ones. For the majority of the countries the backward participation is bigger than the forward participation. Two countries deserve special attention: Japan and Brunei. The first country has very high shares of forward participation that can be attributed to the fact that Japan provides intermediate inputs with high value added that are used in third countries to produce electrical and optical equipment that are exported. On the opposite side, Brunei share of forward participation is almost zero, indicating that this country does not generate intermediate inputs that are used in the production of electrical and optical equipment in third countries.

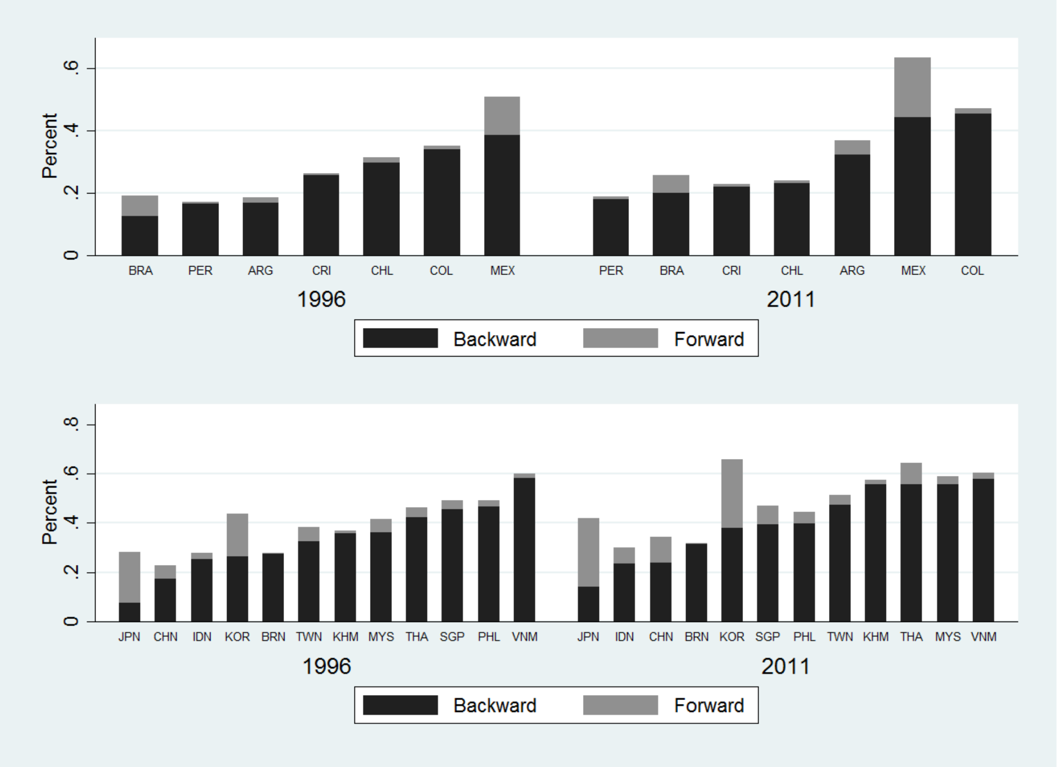
Figure 3.11 – Countries GVC participation index: electrical and optical equipment



Source: Author’s calculation using data from the OECD-TiVA Database.

Figure 3.12 presents the same kind of indicator for transport equipment. LA data reveal similar patterns to the ones observed in Figure 3.11, however the participation indices are lower. This is expected, given that this industry is less prone to production fragmentation than the electric machineries industry. Also, as expected, Costa Rican forward participation in this industry is almost null, confirming that this country participation in GVCs is mainly attributed to the electric machinery industry.

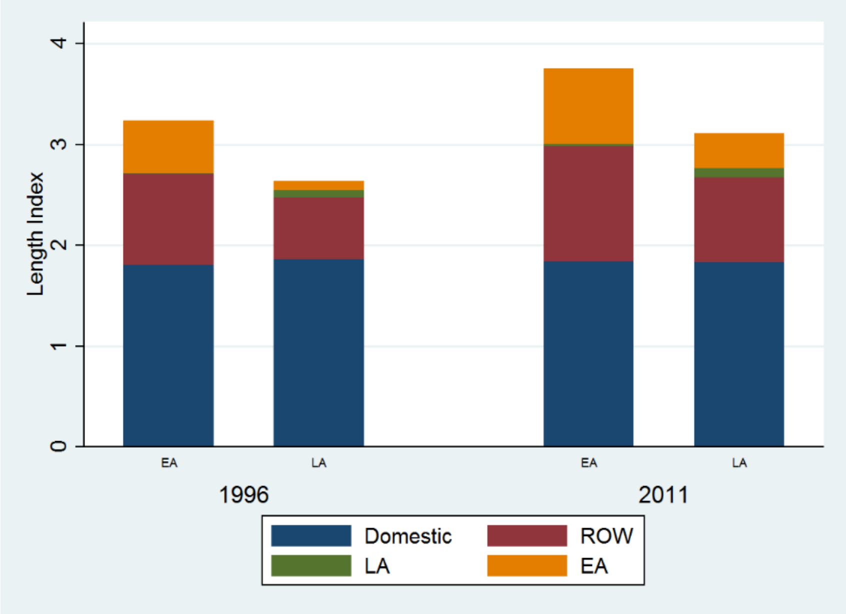
Figure 3.12 – Countries GVC participation index: transport equipment



Source: Author's calculation using data from the OECD-TiVA Database.

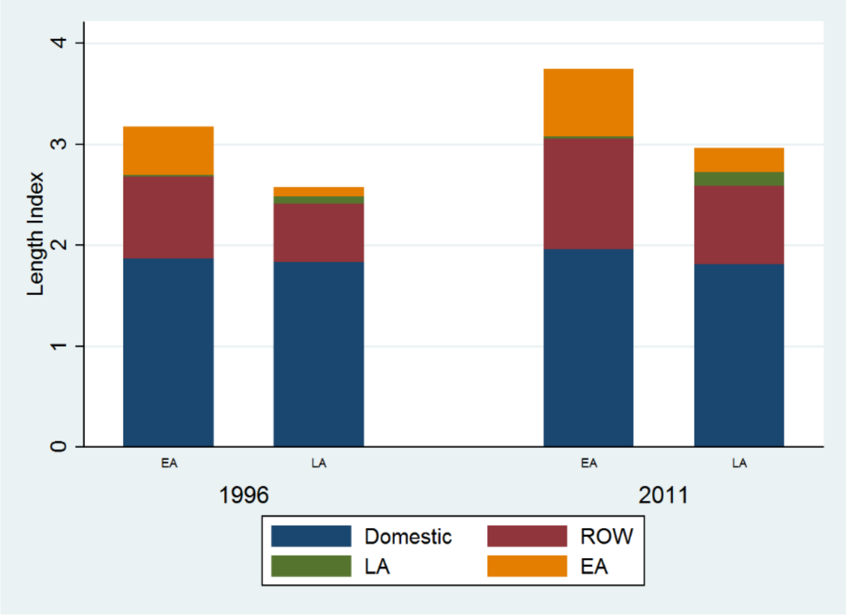
The vertical specialization indices provide information about the participation of a country on vertical specialization, but they do not offer a measure of the size of these production networks. In other words, the previous data do not provide an insight about the number of production stages, consequently, a high backward participation, for example, can be attributed to the use of just one intermediate input that has a high value added or to the use of many intermediate inputs with low value added. The ICIO tables permit the calculation of another indicator called production length that estimates the average number of stages involved in the production chain. The data also allows the discrimination of the production steps according to the country it takes place. Figure 3.13 reveals the size of electrical and optical equipment production networks. The first feature we observe is that GVCs' size increased during the studied period and this change was manly attributed to an increase in the stages of foreign produced inputs. Indeed, the change is mainly attributed to increases in the production steps performed by the East Asian countries. A second attribute is that East Asian GVCs are longer than Latin American ones. Figure 3.14 reveals that the length index of transport equipment industry is very similar to the electrical and optimal equipment ones.

Figure 3.13 – Average length of GVCs by region: electrical and optical equipment



Source: Author's calculation using data from the OECD-TiVA Database.

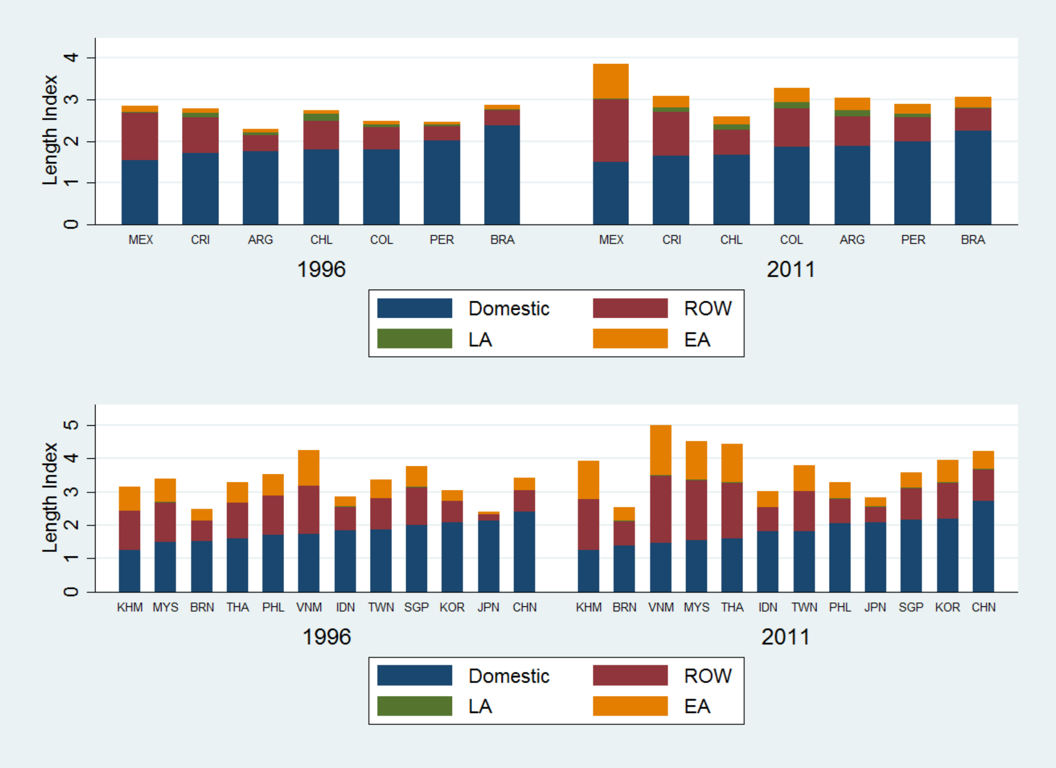
Figure 3.14 – Average length of GVCs by region: transport equipment



Source: Author's calculation using data from the OECD-TiVA Database.

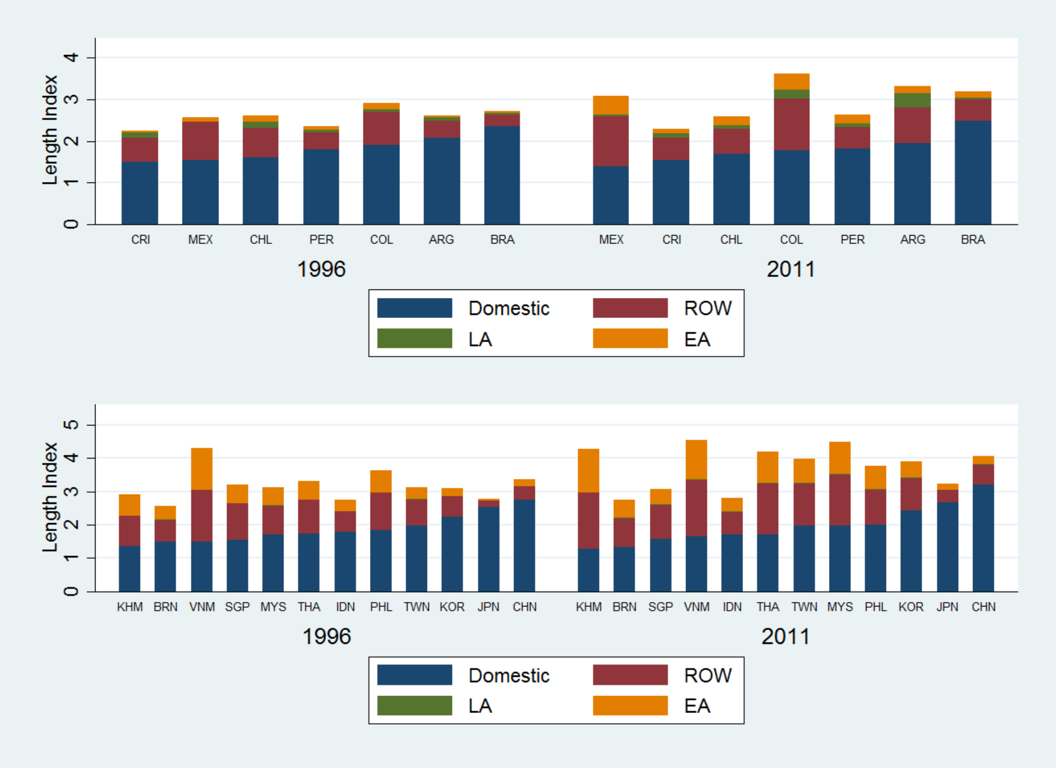
Figures 3.15 and 3.16 represent the estimation of the length index for each country. The upper part of Figure 3.15 reveals two important information: first, there was an increase in the production length from 1996 to 2011, reflecting an increase in Latin American countries engagement in production networks; and second, this change can be mainly attributed to increases in use of inputs from East Asian countries. The lower part of Figure 3.15 reveals a similar pattern, with an increase in the size of production length promoted by the increase in production fragmentation of East Asian countries. Another relevant information can be obtained from the comparison between Japan and China. We observe that the foreign size of the GVCs that Japan was engaged in increased, while the domestic size decreased. On the opposite size, China presented an increase in the East Asian countries length, as well as, an increase in the domestic length, indicating that China is indeed absorbing more production tasks.

Figure 3.15 – Average length of GVCs by country: electrical and optical equipment



Source: Author's calculation using data from the OECD-TiVA Database.

Figure 3.16 – Average length of GVCs by country: transport equipment



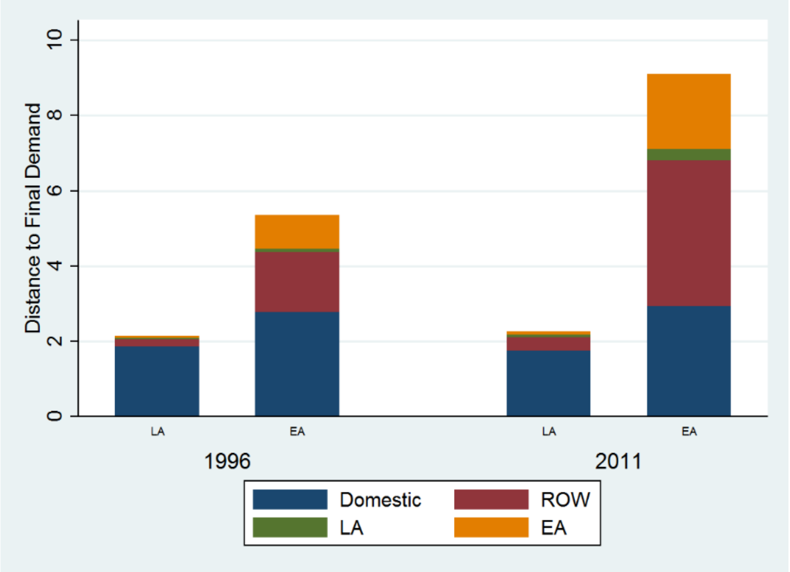
Source: Author's calculation using data from the OECD-TiVA Database.

The data in Figure 3.16 also reveals an increase in the length of transport equipment GVCs. This change can be attributed to an increase in the use of inputs produced in East Asian countries, as well as, an increase in the fragmentation of the production process inside this region.

Finally, the ICIO tables permit a calculation of one last index that indicates the position of a countries' industry in a GVC. In other words, the distance to the final demand indicator reveals if an industry in a country is localized more upstream or downstream in the production network. According to Figure 3.17, the Latin American region is localized more downstream in production networks and we observe a very small change in the period analyzed. This result is in accordance with the findings of the previous two chapters that indicate a very low participation of LA in production networks. On the opposite side, the index indicate that East Asia is localized in a more upstream position, revealing that EA exports more intermediate inputs that are used in many stages until the production of the final product. From 1996 to 2011, there was an increase in the distance. This increase can be mainly attributed to countries outside EA. This finding is in accordance with the idea that EA is fomenting production networks in third regions.

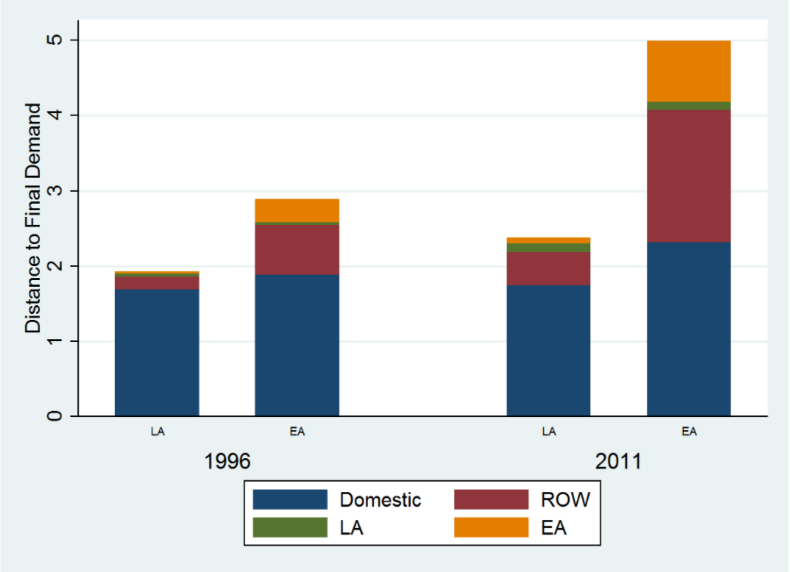
Figure 3.18 exposes similar patterns in terms of increase in upstreamness along the period. However, we observe that the distance to the final demand is smaller in the transport equipment industry, corroborating the idea presented in the previous chapters that this sector is less prone to production fragmentation.

Figure 3.17 – Distance to final demand by region: electrical and optical equipment



Source: Author’s calculation using data from the OECD-TiVA Database.

Figure 3.18 – Distance to final demand by region: transport equipment

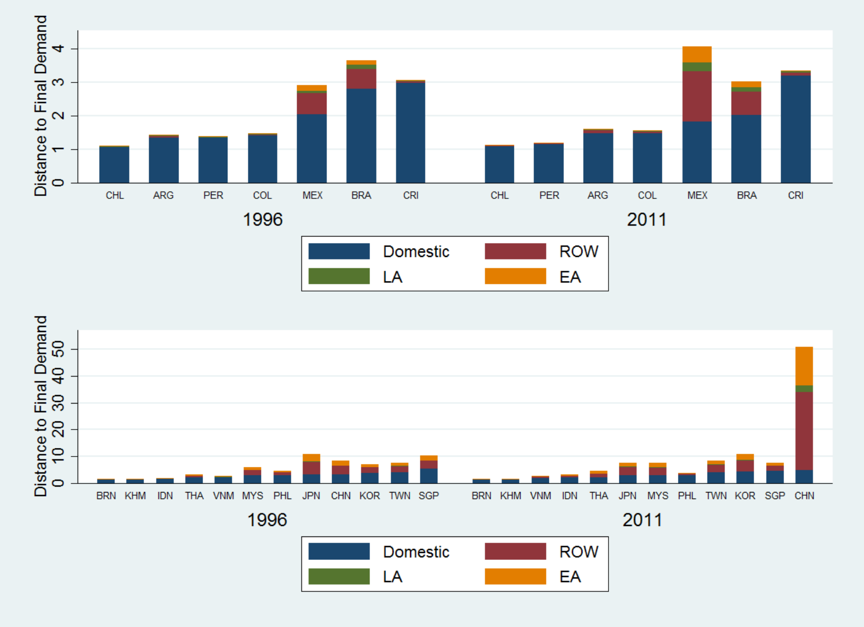


Source: Author’s calculation using data from the OECD-TiVA Database.

Figure 3.19 reveals that only Brazil, Mexico, and Costa Rica have a higher level of upstreamness in the electrical and optical equipment industry. For the other countries, the index is close to 1, indicating that their products are confined to the domestic market. The lower part of the table discloses that East Asian countries are localized in a more upstream position than LA countries. Besides this, we verify a big increase in the distance of Chinese products from the final demand, corroborating the idea that along the period

China moved up in the production ladder, shifting away from pure assembly tasks. Indeed, the increase attributed to the rest of the world (ROW) share corroborates with the idea that China is fomenting production networks in third regions of the globe.

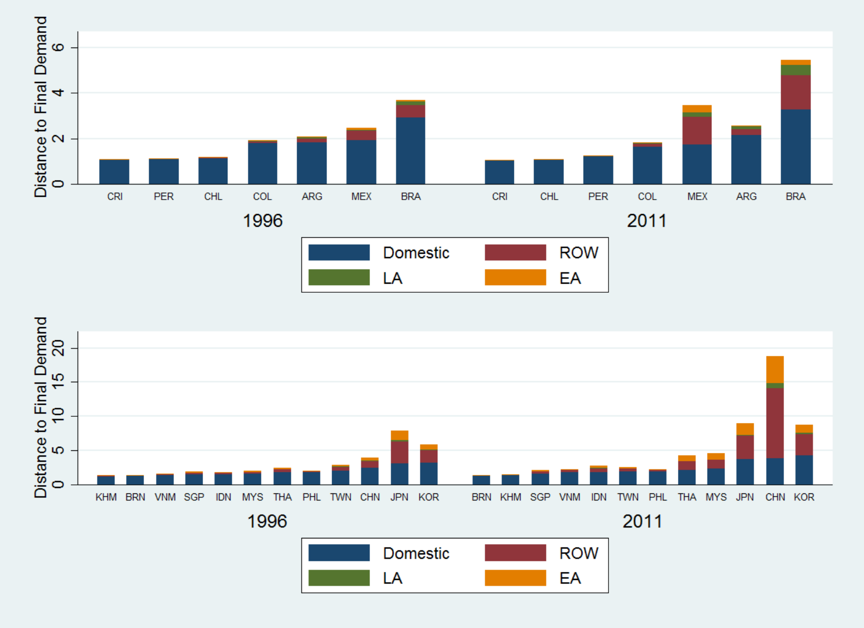
Figure 3.19 – Distance to final demand by country: electrical and optical equipment



Source: Author's calculation using data from the OECD-TiVA Database.

Figure 3.20 reveals a similar pattern. In the upper part of the figure, we observe that comparing with the electric machinery index, Costa Rica position moved from the extreme right side to the extreme left side, confirming that the production in the transport equipment industry is smaller. At the same time, Argentina made the opposite movement, revealing the importance of this sector to the Argentinean economy. However, just Mexican and Brazilian intermediate inputs are used in third countries' production of transport equipment. The lower part of the figure reveals a similar pattern with just a few countries fomenting third countries' with intermediate inputs. These countries localized in more upstream positions in 2011 were Thailand, Malaysia, Japan, China, and Korea. Finally, we observe that the changes from 1996 to 2011 were smaller than the ones observed for the electric machineries, but once again, China moved from a position localized more downstream to a position more upstream.

Figure 3.20 – Distance to final demand by country: transport equipment



Source: Author's calculation using data from the OECD-TiVA Database.

3.5 Final considerations

The indicators presented in this chapter provided evidences of the East Asian and Latin American production fragmentation structure that could not be captured using trade data. The use of international IO tables permitted the estimation of indicators that revealed features like the level of integration in vertically fragmented production networks, the length of this production networks and the distance to the final demand, allowing a tractable comparison between East Asian and Latin American countries.

The results supported what was observed in the previous chapters, confirming the dissimilarities in both regions production fragmentation patterns. It was also possible to observe the heterogeneity of the countries that compose each region, through the characterization of their engagement in machinery production networks. In general, the indicators demonstrated that East Asian countries were more engaged in production fragmentation than Latin American ones. It was also possible to observe that East Asian countries exported products that contained less domestic value added than Latin American ones. Furthermore, we observed that East Asian countries participated more in fragmented productions, presenting higher shares in the indices of vertical specialization. Finally, these countries also engaged in production networks with a higher number of stages. All these characteristics indicate that East Asian countries have a higher level of engagement in production networks than Latin American countries.

CHAPTER 4 – Machinery Production Networks in Latin America: a quantity and quality analysis[22]

In this chapter we investigate the effects that the increase in the importation of machinery parts and components and the changes in the supplier composition had in the trade of final products and parts and components inside Latin America. In our analysis, we consider these effects according to two dimensions: a quantity one that captures whether there was an intensification of trade and a quality one that captures changes in the sophistication of the traded goods. The research employs disaggregated trade data obtained from UN Comtrade for 17 Latin American countries between 1996 and 2011. We find evidence that an increase in the importation of parts and components from Latin America had positive impacts on both the quantity and quality dimensions. Subregional heterogeneities revealed that, in general, imports from East Asia had positive effects on the quantity dimension, nurturing the expansion of machinery production networks inside Latin America, and on the quality dimension, increasing the sophistication of the products traded inside Latin America, especially for Mercosur member exports. Imports from North America had positive quantity effects, especially for exports of countries from the Andean Community, Central America, Chile, and Mexico.

4.1 Introduction

In the past decades, international trade has increased exponentially and production fragmentation was one of the main causes. The fragmentation process, referred as "trade in tasks" by Grossman and Rossi-Hansberg (2008), has led to an increase in global integration, generating a web of economic interactions commonly denoted as

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[22] The revised version of this chapter is in Latin American Economic Review, vol. 26(9).

international production networks. In the beginning, this change involved mostly trade among rich nations, but the real "revolution started when supply chain trade gained importance among high-tech and low-wage nations between 1985 and 1995" (Baldwin & Lopez-Gonzalez, 2015). Production fragmentation opened new possibilities of economic growth to developing countries, allowing their engagement in the production process of manufactured goods that they were not able to produce.

The expansion of production networks changed the rules of the economic development game, facilitating developing countries' access to networks, global markets, capital, knowledge, and technology (OECD, 2013). Previously, a country had to climb every single step in the industrial development ladder, mastering all production processes, to manufacture a given good. However, the advent of production networks offered the possibility of skipping steps in the catch-up procedure through the acquisition of knowledge and technology from third countries and the specialization in one or few steps of the production process. Understanding these changes and their consequent implications is crucial to draw policies that integrate a country in this new production structure and allow it to explore the best possibilities for guaranteeing sustainable economic growth and development.

The empirical literature about production fragmentation is very rich, with many studies focusing on the regions where production fragmentation is more developed: East Asia, the European Union, and North America[23]. Although the demand is growing for the analysis of the current situation and the effects that this new trend can have on Latin America, the literature is still incipient.

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[23] For papers on production networks in the mentioned regions please refer to Ng and Yeats (2003), Ando and Kimura (2005), Athukorala and Yamashita (2006), Kimura, Takahashi, & Hayakawa (2007), Yokota (2008), Kohpaiboon and Yamashita (2011), Ando and Kimura (2013a), Ando and Kimura (2013b).

A few papers provide some information about the status of production fragmentation in Latin America based on descriptive analysis. Aminian, Fung, and Ng (2009) compared the economic integration process in East Asia and Latin America, analyzing the characteristics and intensity of intra-bloc and inter-bloc trade. They used a revealed comparative advantage (RCA) index to identify the share of traded manufacture parts and components with comparative advantage in the intra-bloc trade. Curran and Zignago (2013) studied the regionalization of trade in South America from 1994 to 2007, differentiating the trade flows by the end use of the products and the level of embodied technology. They concluded that the trade agreements have not extensively affected the regional trade level and that trade of intermediate products was still very low, indicating that regional production networks were still under-developed. Calfat, Cassimon, Flôres Jr., and Rivas (2011) investigated the participation of Argentina, Brazil, Guatemala, and Nicaragua in fragmented world production. They concluded that Brazil was the only country with a consolidated participation in fragmented production. Fung, Garcia-Herrero, and Siu (2015) used manufacturing trade data, classified according to the Standard International Trade Classification (SITC), to compare production sharing in Latin America, North America, and East Asia from 1985–2006. They identified the existence of a relatively thick production network involving the trade of parts of motor vehicles, telecommunication equipment, and electronic components. However, it was concentrated on Mexico's trade with US and Canada, while Brazil also played a smaller role. Fung, Hwang, Ng, and Seade (2015) used the same data and methodology to compare Brazil, China, and Mexico's participation in production networks. They analyzed the international trade patterns for the period 1990–2010, identifying that China's global presence in the trade of parts and components increased. Although Mexico concentrated its trade of parts and components with the US, the data showed that China has become a major source of parts and components to Mexico and Brazil. The authors highlight the increasing importance of a Pan-Pacific link and a possible creation of a China-Brazil-Mexico production network.

Florensa, Márquez-Ramos, Martínez-Zarzoso, and Recalde (2015) produced the first paper that used a quantitative framework to analyze economic integration and production fragmentation in Latin America. Using trade data classified according to the Broad Economic Categories (BEC), the authors analyzed the impact that changes in import of intermediate goods from different world regions had in the development of Latin America's regional trade. They found evidence of increasing regional production networks and the importance of other regions as suppliers of intermediate products, with special attention on China.

Given the importance of this topic to the development literature and that production networks in Latin America are still understudied, this work contributes to the literature shedding light on the evolution of Latin American machinery industry. The first reason to focus on this industry is that machinery final products have a high level of complexity and use of a large number of parts and components, being the most developed manufacturing industry in terms of production fragmentation. Consequently, when the industry is more fragmented, a country will have more opportunities to engage in the production network. The second reason is that the high level of fragmentation and the availability of disaggregated trade data allow us to classify this industry into four different sectors. This division permits the development of a finer correspondence between parts and components and final products for a specific sector, reducing the bias that more aggregated data can generate. Finally, the share of machinery in Latin American exports and imports of manufactured products in 1996 was approximately 49.5% and 55.8%, respectively, while in 2011, the shares increased to 55.5% and 56.7%, respectively. Therefore, machinery is the most important industry in the region's manufacturing trade.[24]

The contribution of this article is threefold. First, to the best of our knowledge, this is the first article to analyze the quality effects that the changes in the structural composition of suppliers of parts and components have had in the development of regional machinery production networks in Latin America. Second, different from the previous papers on Latin American production networks that use aggregated intermediate manufacture data, we focus our analysis on a specific industry and use disaggregated data. Third, in this study we adopt a model similar to Florensa et al. (2015) but estimate it using the Poisson pseudo-maximum-likelihood (PPML) method instead of the ordinary least squares (OLS) to control the zero trade values and the data heteroscedasticity.

The chapter is organized as follows. Section 2 includes a descriptive analysis of Latin America's participation in the machinery trade. In section 3, we present the data and in section 4 we describe the empirical methodology employed. Section 5 shows the results of the quantity analysis, while section 6 contains the results for the quality analysis. The final considerations of the chapter are available in section 7.

4.2 Machinery international trade and Latin America

In this section, we used trade data—classified according to the Harmonized System disaggregated to the six-digit level—to analyze the machinery international market and Latin America's participation in it in 1996 and 2011. We also considered the

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[24] The shares were calculated based on the HS classification. The manufactured goods range from HS 28 to HS 92, while machinery products range from HS 84 to HS 92.

changes in trade patterns from a trade margin and product sophistication perspective to identify modifications in Latin American countries' trade basket composition.

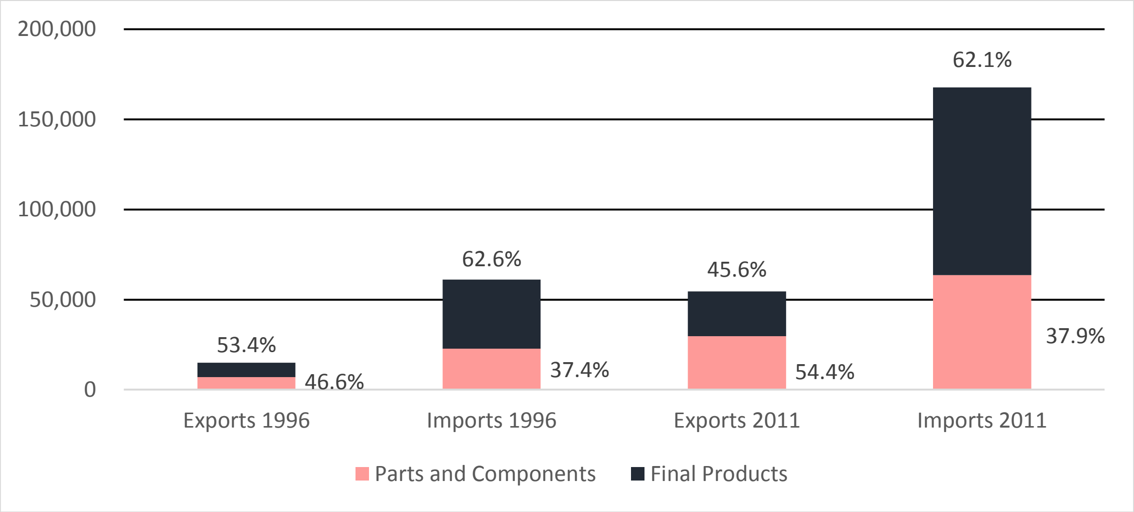
4.2.1 Descriptive analysis: traded values

Production networks, in particular the machinery ones, are constituted mainly of geographical agglomerations that form regional blocs of production. As already observed in the previous chapters, three main regional blocs are recognized for machinery production networks: the East Asian region, the European Union, and NAFTA. In general, machinery trade studies focus on these main areas, ignoring the situation in Latin America and the rest of the world.

The idiosyncrasies of Latin America, a heterogeneous region composed of countries of different sizes and governments with different political and economic orientation, localized in a vast territory full of geographical barriers, such as the Andes Mountains and the Amazon Forest, are possible reasons for its low level of engagement in production networks. Another reason, identified by Moreira, Blyde, Martincus, and Molina (2013), is the quality of the local infrastructure that penalizes the trade, increasing the freight costs or simply making it impracticable at competitive prices.

Nevertheless, Figure 4.1 reveals that for the period 1996–2011 parts and components traded value increased relative to final products. Latin American export data show an increase in traded parts and components from 46.6 percentage points to 54.4 percentage points. Although import data reveal an increase in traded parts and components share of just 0.5 percentage points, in terms of values this change represents a substantial increase, given that imported machinery parts and components value is higher than the exported machinery total value. Even though traded values are still smaller than the three main blocs, the increase in import of parts and components indicate that Latin America is slowly adhering to production networks in the machinery industry.

Figure 4.1 – Latin America's machinery products total trade values (in million US$)



Source: Author's calculation using data from the UN Comtrade.

Table 4.1 displays the compound annual growth rate of the machinery trade, revealing that Latin America had the highest growth rate for total machinery export and the second highest for machinery import. In fact, considering just the trade of parts and components, the region had the highest growth rates, corroborating the idea that participation in machinery production networks is growing in this region.

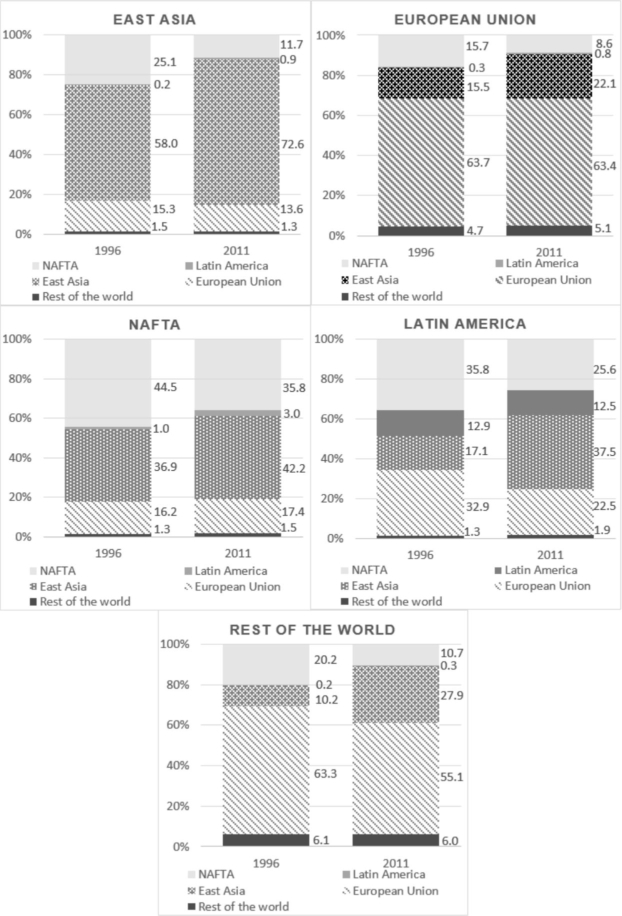
Table 4.1 – Compound annual growth rate of machinery trade from 1996 to 2011

		Parts and Components	Final Products	Total
East Asia	Exports	7.1%	6.4%	6.7%
	Imports	6.6%	4.6%	5.7%
EU	Exports	4.5%	3.7%	4.1%
	Imports	4.2%	3.6%	3.9%
NAFTA	Exports	1.2%	2.3%	1.8%
	Imports	2.6%	4.0%	3.4%
LA	Exports	**10.1%**	**7.9%**	**9.0%**
	Imports	**7.1%**	6.9%	7.0%
ROW	Exports	5.1%	5.7%	5.4%
	Imports	6.9%	**7.9%**	7.6%

Note: The higher compound annual growth rates are highlighted using bold text.
Source: Author's calculation using data from the UN Comtrade

According to fragmentation theory, the core of a production network is concentrated in regional agglomerations, given the reduced costs incurred in shorter distance transport freights, reduced lead time, and the possibility of faster coordination for the whole network (Harrigan & Venables, 2004; Kimura, Takahashi, & Hayakawa, 2007). Nonetheless, the development of the internet and other communication and coordination technologies, as well as the decrease in freight cost, has led to a decrease in the service link costs (Jones & Kierzkowski, 2005), allowing for a growth in interactions between regional blocs. As a result, the East Asian region increased its role as a supplier of machinery parts and components to other region's production networks. Bearing this fact in mind, in Figure 4.2 we observe the composition of parts and components suppliers for all five regions to verify changes and patterns. As expected, except for NAFTA in 2011, the intra-bloc import of machinery parts and components is dominant in the three main regions. We also verify an increase of the East Asian share in all regions. Data for Latin America reveal a few things: first, the Latin American share as a supplier is irrelevant in all regions except Latin America; second, its intra-bloc share is smaller than the shares of the three main regions; and third, NAFTA and European Union shares decreased considerably, substituted mainly by imports from East Asia. In fact, Latin America was the region where the share of East Asian parts and components increased the most, a growth of more than 20 percentage points.

Figure 4.2 – Composition of machinery parts and components suppliers in 1996 and 2011



Source: Author's calculation using data from the UN Comtrade.

From the perspective of production fragmentation logic, a country purchases more parts and components from a given region if these products have some comparative advantage. The existing literature highlights two channels through which access to inputs can benefit a country: an efficiency gain in the production process by the acquisition of cheaper and/or higher quality inputs (Amiti & Konings, 2007; Goldberg, Khandelwal, Pavcnik & Topalova, 2010) and the possibility of having access to inputs that previously could not be produced domestically or obtained from a third country (Goldberg, Khandelwal, Pavcnik & Topalova, 2009). In both cases, a gain in productivity and changes in production pattern are expected. Based on this fact, we consider the hypothesis that the increase in import of parts and components, especially from East Asia, should be beneficial to Latin American machinery production networks.

In the next subsection, we analyze the trade margins to identify possible trade pattern modifications.

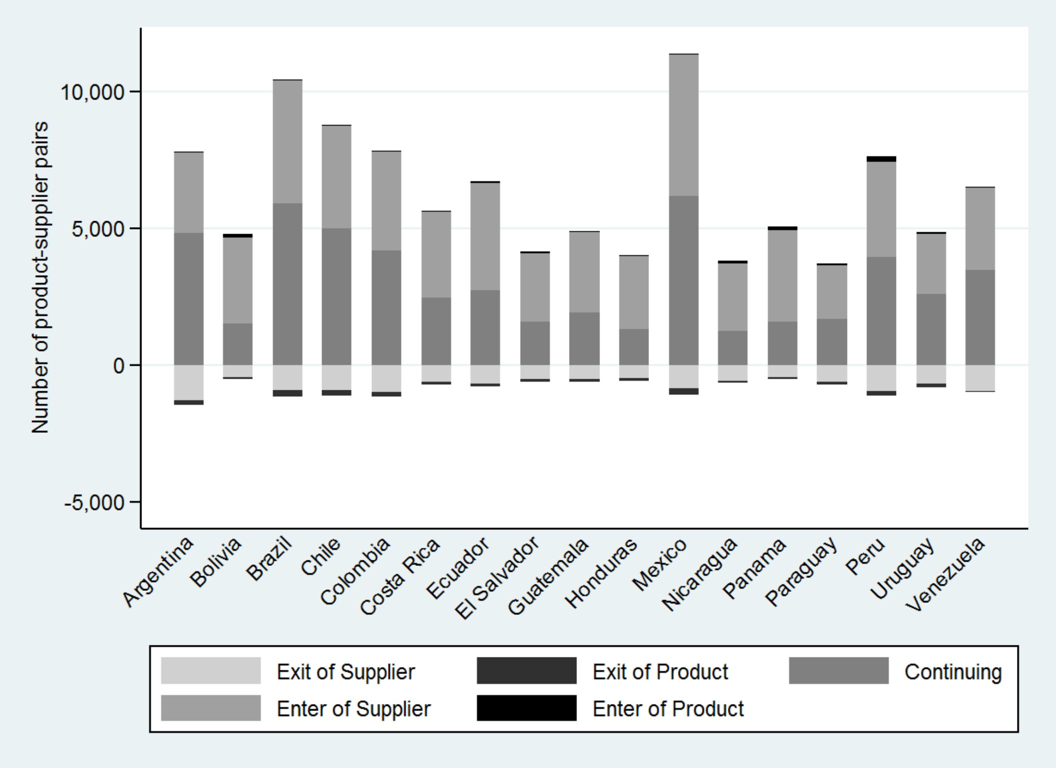
4.2.2 Descriptive analysis: the trade margins approach

The trade flow can be decomposed in extensive and intensive margins, revealing how the intensification of trade in existing relations and the beginning or ending of trade relations contribute to change this flow. Although the intensive margin is expected to be the main factor responsible for the changes, authors such as Hummels and Klenow (2005) and Kehoe and Ruhl (2013) identified that in situations of considerable trade growth the extensive margin contribution is also relevant. Our main interest in observing the extensive margins is to identify evidence of changes in Latin American countries' import and export baskets.

A country's trade relation is understood as a product-destination pair in the case of exports and a product-supplier pair in the case of imports. Given an initial and a final period, if a pair is active in both periods it is classified as a continuing pair. If country *A* imported (exported) a given product from (to) country *B* in the first period and then does not in the second period, but it still imports (exports) the product in question from (to) a third country, we have an exit of supplier (destination). If a similar situation occurs, but in the second period the product in question is not imported (exported) from (to) any other country, then it is classified as an exit of product. If in the second period, country *A* imports (exports) a product that was not imported (exported) from (to) any other country in the first period, then this new relation is classified as an enter of product. If in the second period, country *A* starts to import (export) from (to) country *B* a product that was already imported (exported) in the first period from (to) a third country, then this new relation is classified as an enter of supplier (destination).

Considering only the number of relations, Figure 4.3 illustrates the margins of each Latin American country import of machinery parts and components. Mexico and Brazil had the highest number of product-supplier active pairs in 2011, while El Salvador, Honduras, Nicaragua and Paraguay had the lowest number of active pairs. The data reflect the diversification of the industrial park in each country. The entry of supplier margin had a very important contribution in all cases, signaling an increasing integration of Latin America in the international economy.

Figure 4.3 – Number of product-supplier pairs in machinery parts and components imports according to the trade margins from 1996 to 2011



Source: Author's calculation using data from the UN Comtrade.

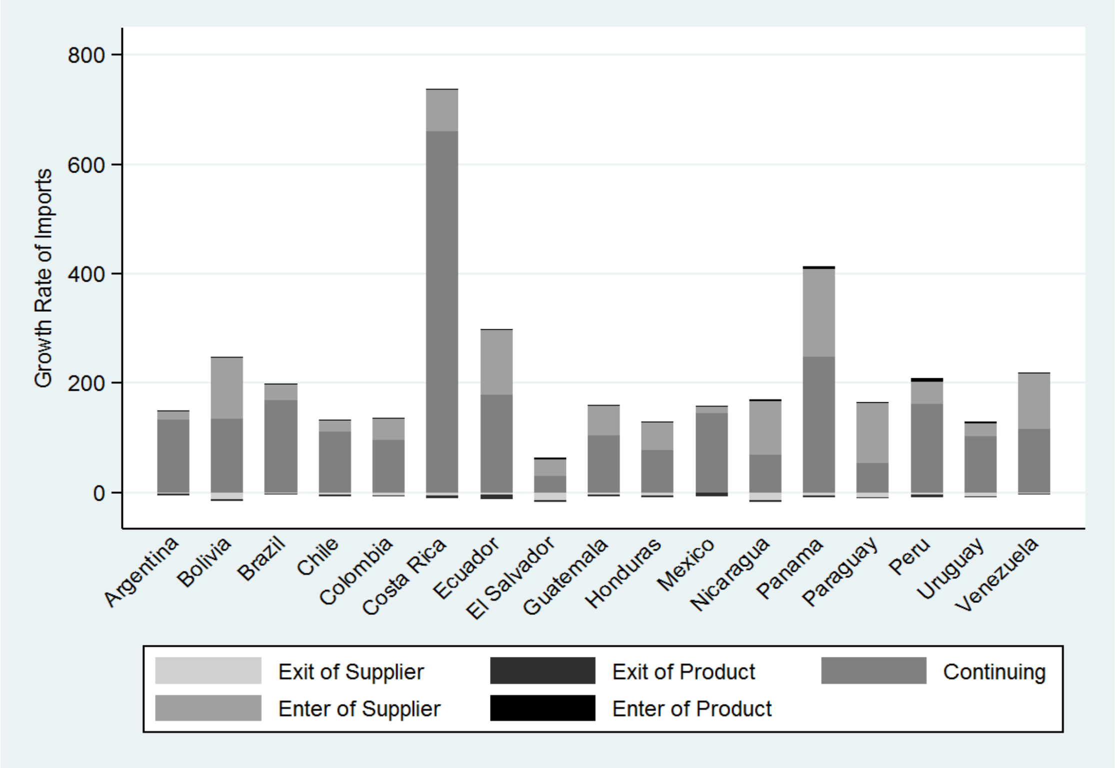
Following Obashi and Kimura (2016), we identify the contribution that each margin had in the trade growth. To calculate these contributions, we use the following methodology:

$$\frac{\sum_i x^c_{i,t_1} - \sum_i x^c_{i,t_0}}{\sum_i x^c_{i,t_0}} = \frac{\sum_{i\in I^c}(x^c_{i,t_1} - x^c_{i,t_0})}{\sum_i x^c_{i,t_0}} + \frac{\sum_{i\in ENP^c} x^c_{i,t_1}}{\sum_i x^c_{i,t_0}} + \frac{\sum_{i\in ENC^c} x^c_{i,t_1}}{\sum_i x^c_{i,t_0}} - \frac{\sum_{i\in EXP^c} x^c_{i,t_0}}{\sum_i x^c_{i,t_0}} - \frac{\sum_{i\in EXC^c} x^c_{i,t_0}}{\sum_i x^c_{i,t_0}} \quad (1)$$

where the value of a country c's trade flow x for product-country pair i in period t is denoted as $x^c_{i,t}$, I^c are the continuing pairs, ENP^c are the entering products, ENC^c are the entering countries, EXP^c are the exiting products, and EXC^c are the exiting countries.

Figure 4.4 confirms that the most important contribution is the intensive margin. Even though the supplier entry contribution is not as big as in the previous figure, it still accounted for an important portion of the parts and components import growth, indicating that the Latin American countries increased their diversity of parts and components suppliers.

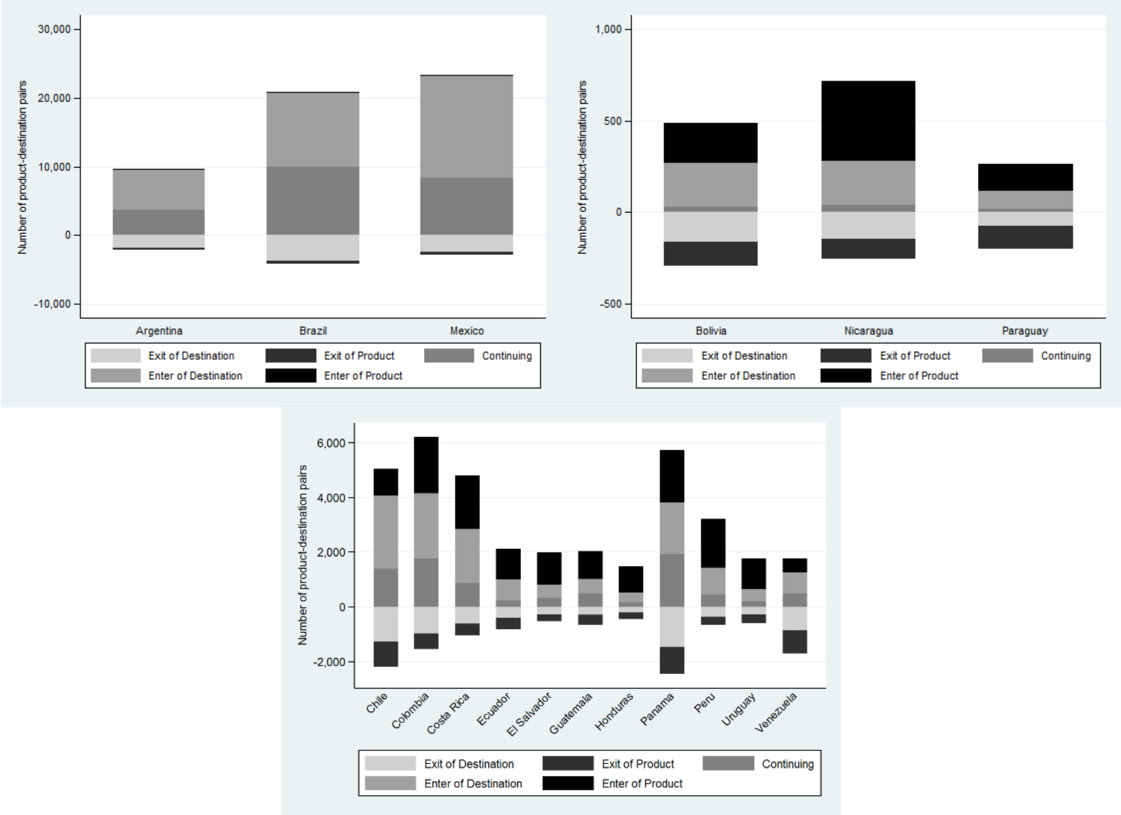
Figure 4.4 – Decomposition of growth in machinery parts and components imports according to the trade margins from 1996 to 2011 (%)



Source: Author's calculation, using data available from the UN Comtrade.

We also observe the contribution of the extensive and intensive margins in Latin American countries exports to verify if there were changes in the variety of exported products and destinations. Figure 4.5 shows the export margins considering only the numbers of product-destination pairs. Once again, the entry of new destinations and the continuation of existing pairs are important margins. However, this time the entry of new products is also important, indicating a change in the exported goods variety. Argentina, Brazil, and Mexico already had a more developed industrial park in 1996; consequently, their entry of products is very small. Another interesting feature is that in some cases the exit of products and destinations is large, also indicating a change in the export basket composition.

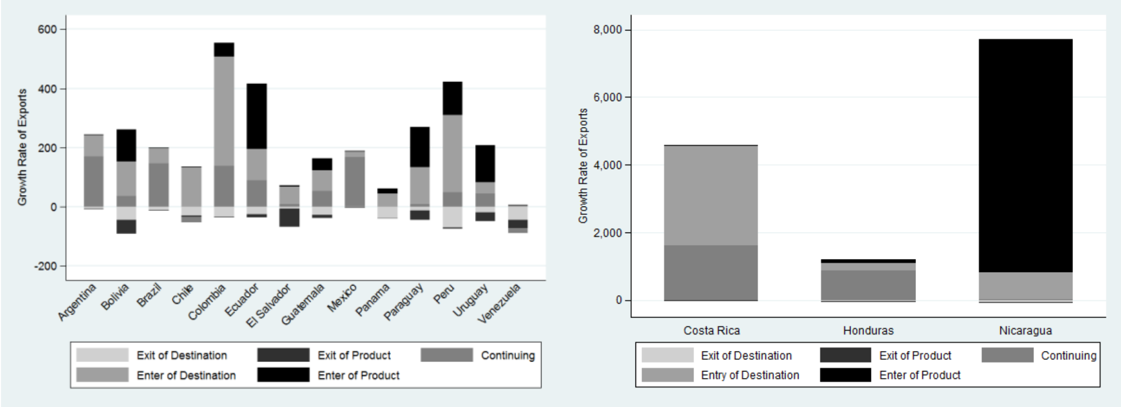
Figure 4.5 – Number of product-destination pairs in machinery exports according to the trade margins from 1996 to 2011



Source: Author's calculation using data from the UN Comtrade.

Next, we decompose the export growth according to its respective margins. Figure 4.6 reveals different patterns. The growth in countries with more developed industrial parks such as Argentina, Brazil, and Mexico focused on the intensive margin (Honduras is an exception, having a similar pattern to these countries). The entry of new products was an important margin in countries such as Ecuador, Nicaragua, Paraguay, and Uruguay, while in other cases, the entry of new product-destination pairs was more important. In countries such as Bolivia, El Salvador, Peru, and Venezuela, the exit of products and destinations had an important role, showing an export basket specialization tendency.

Figure 4.6 – Decomposition of growth in machinery parts and components exports according to the trade margins from 1996 to 2011 (%)



Source: Author's calculation using data from the UN Comtrade.

The previous figures offer evidence that the pattern of Latin American countries' imports and exports changed during the studied period. We performed one additional exercise to identify changes in the number of machinery products traded by country pair.[25] The upper part of Figure 4.7 shows an increase in the variety of parts and components and final products imported. The main changes are attributed to an increase in products traded with China. The lower part of Figure 4.7 reveals a predominant increase in the variety of exports to Latin American countries, followed by an increase in the variety of parts and components exported to other regions.

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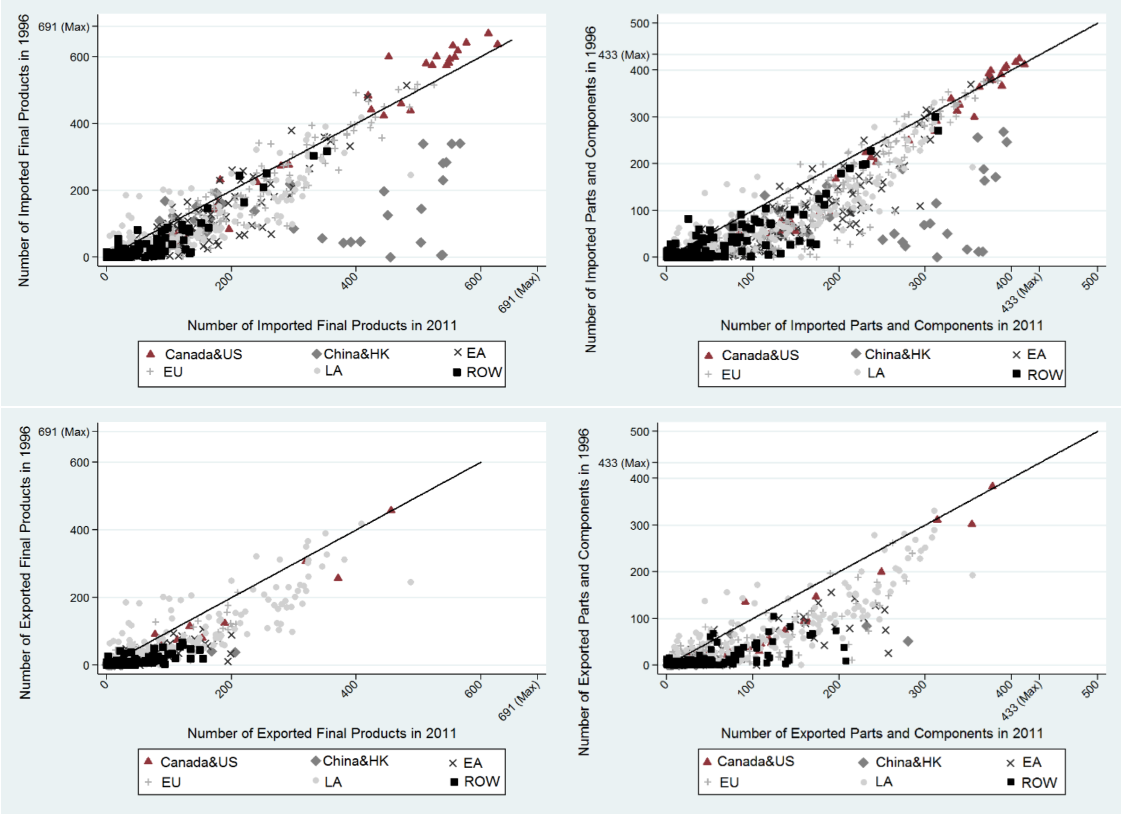
[25] Given the economic growth of China after the WTO accession in 2001, we consider the importance of disentangling the impacts of this country from the rest of the East Asian region. We separate the East Asian region into two groups: a first group composed only of China and Hong Kong (hereafter referred to as China), and a second group composed of the other countries in the region that we address as East Asia (EA). As mentioned before, after this subsection we consider Mexico as a member of Latin America.

Figure 4.7 – Number of machinery products traded by country according to their region



Note: There are a total of 433 machinery parts and components and 691 machinery final products.
Source: Author's calculation using data from the UN Comtrade.

Given the evidence of change in the import and export pattern of Latin American countries, in the next subsection we analyze the changes on traded products quality.

4.2.3 Descriptive analysis: sophistication level

Concomitant to the increase in Latin America's machinery trade flow and changes in the structural composition of machinery parts and components suppliers a modification in the trade basket composition is expected. To evaluate this change, we used the PRODY index[26] developed in Hausmann, Hwang, and Rodrik (2007). According to the authors, the PRODY "index is a weighted average of the per capita GDP of countries exporting a

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[26] More specifically, the PRODY index of a product k is defined as $PRODY_k = \sum_j \frac{(x_{jk}/X_j)}{\sum_j (x_{jk}/X_j)} Y_j$., where x_{jk}/X_j is the value-share of the commodity k in the country j's overall export basket; $\sum_j (x_{jk}/X_j)$ is the aggregated value-shares across all countries exporting good k.

given product, and thus represents the income level associated with that product". In other words, this index attributes to each one of the products a value that varies according to the share and per capita GDP of the countries that export it. This result means that products with higher PRODY values were exported more by developed countries, while products with lower PRODY values were exported more by developing countries. The PRODY index can be used as a proxy for the sophistication of the product.

Table 4.2 contains the PRODY index summary statistics for all products according to the HS classification disaggregated to the six-digit level. The index varies from 747.7 to 46,860.5, and the mean is 14,171.7. Although the index represents the income level associated with a given product, it is hard to attribute a sense of cardinality, making it easier to interpret as an ordinal index. In the lower part of the table, the products were classified into three different categories.[27] We observe that non-manufactured products have the lowest PRODY index mean, while machinery products have the highest. Additionally, the standard deviation of the machinery goods PRODY index is the lowest, indicating that, in general, the products of this category are more sophisticated than the others.

Table 4.2 – Summary statistics of the PRODY index by products aggregation

Products Aggregation	Mean	Median	SD	Min	Max	Observations
All Goods	14,171.7	14,076.5	6,110.3	747.7	46,860.5	5023
Non-Manufactured Goods	11,670.5	10,999.9	6,191.0	747.7	32,835.9	1022
Manufactured Goods	13,896.5	13,446.5	6,097.1	809.5	46,860.5	2877
Machinery Goods	17,150.3	17,289.3	4,705.8	3,730.2	35,433.8	1124

Source: Author's calculation using data from Hausmann et al. (2007).

Next, we use the PRODY index to calculate the sophistication of the parts and components import basket and the intra-bloc export basket. The objective is to verify if

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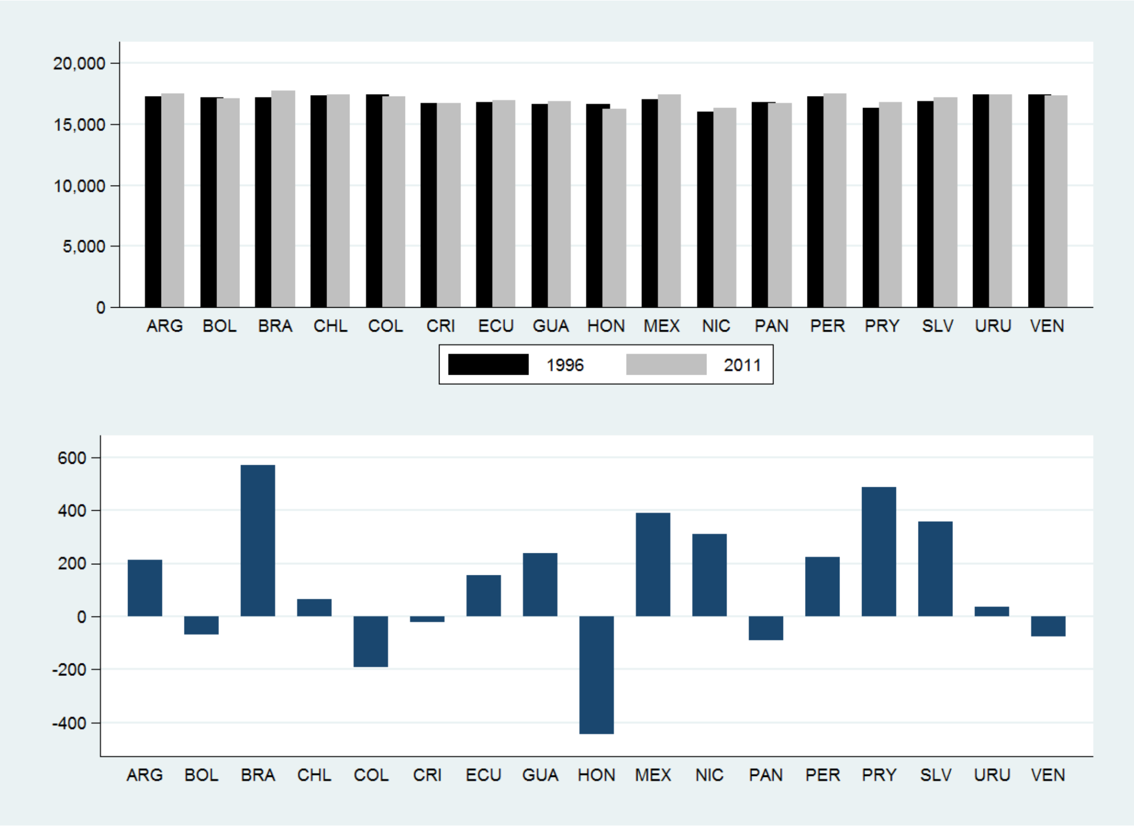
[27] Non-manufactured goods are the products classified from HS 1 to HS 27 and HS 93 to HS 99; manufactured goods are the products from HS 28 to HS 83, and machinery includes the products from HS 84 to HS 92.

changes in the parts and components import pattern led to changes in the pattern of the Latin American intra-bloc trade. Figure 4.8 reveals that for six countries the average sophistication degree of their machinery parts and components imports decreased, while the rest experienced an increase in the sophistication level. Figure 4.9 illustrates the changes in the sophistication of the intra-regional export basket. We observed a decrease in the sophistication level of the final products export basket for seven countries, while the same occurs for just five countries in the parts and components export basket case. Although the results are not homogeneous, we verify gains in the export basket sophistication for the majority of the countries.

Figure 4.8 – Average sophistication level of the machinery parts and components import basket



Source: Author's calculation using data from the UN Comtrade.

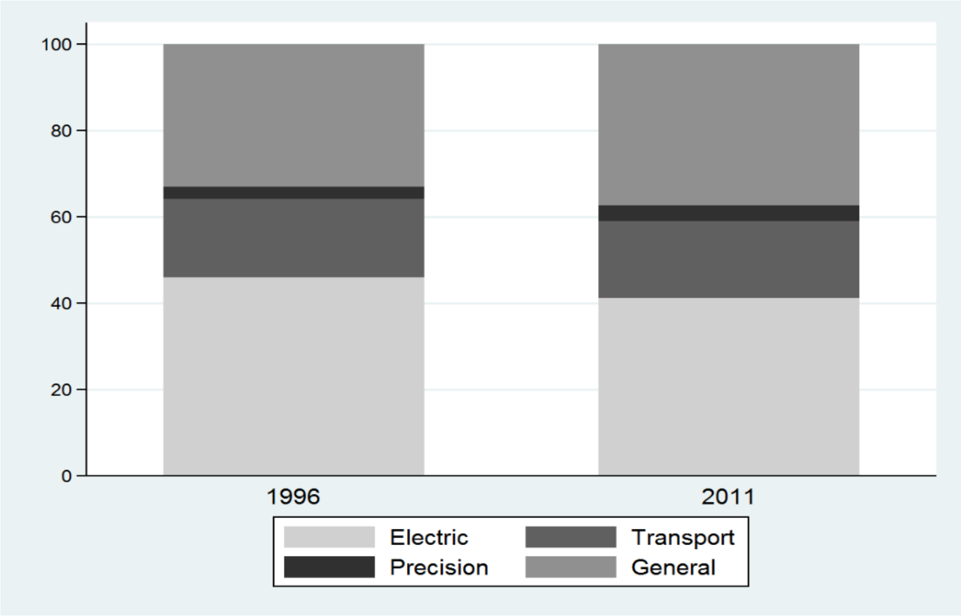
Figure 4.9 – Average sophistication level of the machinery parts and components and final products export basket

Source: Author's calculation using data from the UN Comtrade.

4.2.4 Descriptive analysis: machinery sector data

According to previous studies on machinery production networks, the machinery industry can be classified into four different sectors: general machinery, electric machinery, transport equipment, and precision machinery. Based on this classification, Figure 4.10 reveals Latin America's machinery parts and components imports by sector. We observe that electric parts and components had the biggest share in both years, although it declines in 2011. General machinery had the second biggest share, followed by transport equipment. Figure 4.11 plots the share of each sector in regional exports of final products and parts and components. Despite the observed increase in the share of general machinery imports, regional exports were focused mainly in transport equipment. From 1996 to 2011, we identify a change in the final products export pattern with electric machinery achieving the second biggest share. A similar movement occurred for the case of parts and components exports. Observing the total exports share, we identify that transport equipment products were the most exported ones inside Latin America, while electric machinery became the second most traded in 2011. Based on the importance of these two sectors and the fact that the study of their heterogeneity is a common practice in the literature, we also investigate them independently.

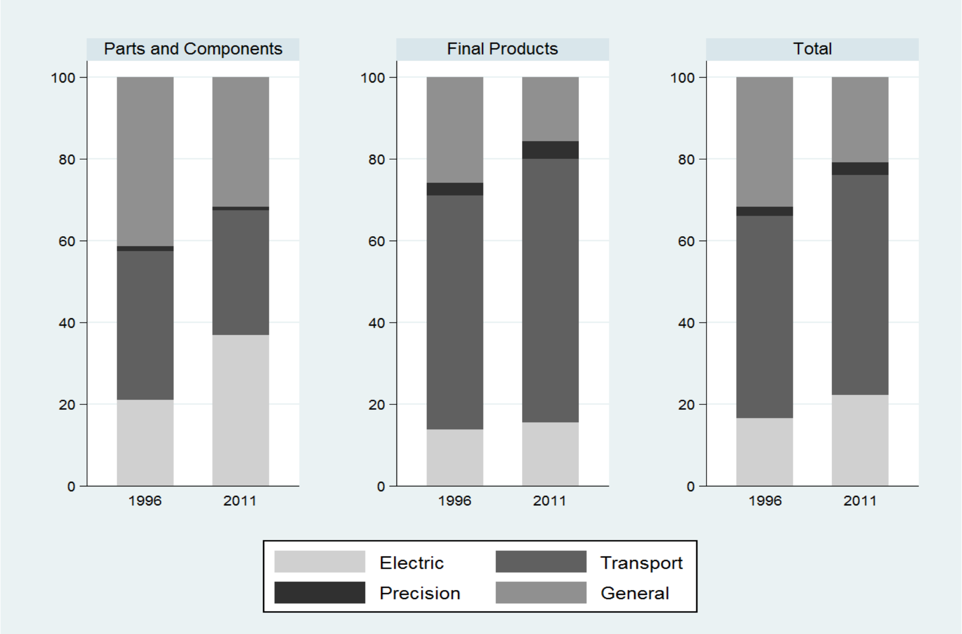
Figure 4.10 – Latin America's machinery parts and components import composition by sector



Source: Author's calculation using data from the UN Comtrade.

In view of the facts presented in this section, the change in Latin America's machinery trade pattern, the increase in trade flows and the modification in the average sophistication level of the traded products, in the next sections, we present the data and methodology employed to study the effects that changes in the structural composition of machinery parts and components suppliers had in the expansion of Latin American production networks and in the sophistication of the intra-bloc export basket.

Figure 4.11 – Latin America's machinery export composition by sector



Source: Author's calculation using data from the UN Comtrade.

4.3 Data

In the economics literature, many studies have been conducted on the fragmentation of production with different ways of defining the object of study. Some scholars employ a more comprehensive definition of production networks, including in their analysis all inputs used, from the raw materials to the final product. To capture all production steps they use international input-output tables.[28] On the other hand, some scholars do not consider the raw materials in their analysis, understanding that just the trade of parts and components used in a given industry should be analyzed. This second group of researchers adopt a more refined classification to isolate parts and components from final products.[29]

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[28] For example, Timmer, Dietzenbacher, Los, Stehrer, and de Vries (2015) used the World Input-Output Database (WIOD), while Baldwin and Lopez-Gonzalez (2015) employed WIOD and OECD-WTO TiVA data to analyze production networks.

[29] For example, Athukorala (2005) separates manufacturing parts and components from final products using the SITC data, while Ando and Kimura (2005) do the same for the machinery industry using HS data.

We embrace the second view for two reasons: no international input-output data are available for the majority of the Latin American countries, and the second definition permits the use of more disaggregated and specific data. Considering that the machinery industry presents a high level of complexity and uses a large number of parts and components, we adopted this industry as our object of study.

The analysis of machinery production networks was based on the classification of the machinery trade in parts and components and final products.[30] The data used was collected from the UN Comtrade, classified according to the HS disaggregated to the six-digit level. The machinery industry is comprised of all the goods categorized as general machinery sector (HS84), electric machinery sector (HS85), transport equipment sector (HS86–89), and precision machinery sector (HS90–92).

We consider the import of parts and components from countries that were responsible for at least 0.01% of the international machinery trade in 2011. The selected 89 countries are grouped in six regions.[31] We define Latin America as the group of 17 countries consisting of Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay, and Venezuela.

The PRODY measure was employed as the qualitative measure for the export and import basket of Latin American countries.[32] We also used tariff data and the depth of the

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[30] This process was performed in accordance with the classification presented in Ando and Kimura (2005).

[31] The list containing the 89 countries divided by regions is available in the Appendix.

[32] We use the PRODY measures calculated by Hausmann et al. (2007). According to the authors they "constructed the PRODY measure for a consistent sample of countries that reported trade data in each of the years 1999–2001.These indexes are the result of an average of three years" (Hausmann et al., 2007). Because the chosen years are previous to the Chinese accession to the World Trade Organization, the possibility of a downward bias in the ranking of the machinery goods (in particular, final goods, given the increase in multinationals assembling their final products China) is minimized.

Preferential Trade Agreements (PTA) to account for the level of integration of the Latin American economies. The tariff data was collected from the World Integrated Trade Solution (WITS)[33] and the PTAs depth measures were calculated based on Mulabdic, Osnago, and Ruta (2017) using the contents of trade agreements from the World Bank database (Hofmann, Osnago, & Ruta, 2017). Given the availability of tariff and trade data, this study is restricted to the period from 1996 to 2011.

4.4 Methodology

Because the core of production networks is regionally concentrated, in this work, we focus on the impacts that changes in the structural composition of parts and components suppliers have on Latin America's intra-bloc exports. For this empirical exercise, we use a model known as the workhorse of empirical international trade analysis: the gravity model (Baier & Bergstrand, 2007). The gravity model is distinguished by its good fit and its parsimonious and tractable representation of economic interactions among many countries, also allowing for disaggregation of the trade in different levels of geographical organization and product classification (Anderson, 2011).

To quantify the impact that changes in the structural composition of parts and components suppliers had on the development of the intra-bloc machinery trade we follow the methodology proposed by Florensa et al. (2015), an augmented gravity model that accounts for the effect of the import of intermediate products. The adoption of such a framework is justified by the fact that, different from the standard gravity framework, this version accounts for the effect that the import of parts and components of a given sector from a given supplier have on the Latin American intra-bloc exports. The proposed

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[33] Tariff data was classified to HS six-digit level and when necessary was converted to the HS1992 version following the classification in Kimura and Obashi (2010).

model assumes that in the first period, Latin American countries can import parts and components from any region of the world. These parts and components are employed to produce other parts and components that in a second period will be used domestically or traded with another country. Alternatively, they can be used to manufacture a final product that will be consumed domestically or traded with a third country. We assume that Latin American production networks are created when Latin American countries use parts and components imported from any region of the world to produce a final product or other parts and components that are exported to another Latin American country.

The Latin American intra-bloc trade of final products and parts and components in a given year is explained by the tariffs imposed by the importer country in the same year and the exporter country imports of parts and components in the previous year. We augment the Florensa et al. (2015) model to capture the possible effects of the non-tariff barriers by adding a PTA depth measure. The PTA depth index calculation follows Mulabdic et al. (2017): based on the content of the trade agreements database, we count the number of legally enforceable provisions covered by each agreement and normalize it between 0 and 1.

Fixed-effect dummies are used to capture all sources of unobserved heterogeneity that are constant for each period of time, individual, and sector. Following Anderson and van Wincoop (2003; 2004), exporter-time and importer-time dummies are employed to control for the multilateral resistance, sector dummies control for unobserved heterogeneities of each machinery sector, while exporter-importer dummies are added to guard against unobserved heterogeneities on the relation of each country-pair (Baier and Bergstrand, 2007). The proposed models were defined as follows:

$$ln(XF_{ijkt}) = \alpha_0 + \sum_{r=1}^{7} \alpha_r lnM\_pc_{rikt-1} + \alpha_8 ln(1 + tariff_{jikt}) + \alpha_9 ln(1 + depth_{ijt}) + \gamma_{it} + \varphi_{jt} + s_{ij} + \omega_k + \varepsilon_{ijkt} \quad (2)$$

$$ln(XPC_{ijkt}) = \beta_0 + \sum_{r=1}^{7} \beta_r lnM\_pc_{rikt-1} + \beta_8 ln(1 + tariff_{jikt}) + \beta_9 ln(1 + depth_{ijt}) + n_{it} + \tau_{jt} + z_{ij} + \mu_k + \delta_{ijkt} \quad (3)$$

where the XF_{ijkt} and XPC_{ijkt} denote the traded value of final products and parts and components from country i to country j (these countries are limited to Latin American countries only) of sector *k* in year *t*. The traded values are explained by country *i*'s imports of parts and components of sector *k* from a given region *r* in year *t-1* ($\mathrm{M\_pc_{rikt-1}}$), the tariff imposed by the importing country *j* over the product of sector *k* provided by country *i* in time *t* $tariff_{jikt}$, the depth measure of the PTA between country i and j in year *t* $depth_{ijt}$, exporter-time and importer-time dummies (time is defined as a 5-year period), the sector and the importer-exporter dummies.

One difference between this work and that of Florensa et al. (2015) is the definition of the object of study. As already mentioned, we selected a more specific object of study, focusing on the machinery industry alone. This allows us to use more disaggregated and detailed data, increasing the refinement of the parts and components and final products correspondence. Additionally, we can classify machinery industry products into four different sectors, decreasing the bias that can result from the use of aggregated data.

Based on previous works about production fragmentation and use of imported inputs, it is expected that the purchase of parts and components from another country should provide some efficiency gain or advantage to Latin American countries. Based on this fact, we expect that the increase in imports of parts and components from the East

Asian region should guarantee a production gain for Latin American countries, increasing the intra-bloc machinery trade.

An important contribution of this work is that the analysis is not limited to the quantity impact of the import of parts and components on the intra-bloc trade; we also propose a way of verifying quality changes. Since we know that there was a change in the shares of machinery parts and components providers, we attempt to evaluate if this variation also produced a modification in the Latin American intra-bloc trade pattern. Once again, it is expected that if the East Asian region is more efficient in the production of machinery parts and components, providing inputs with higher quality and/or cheaper prices, Latin American countries should be able to diversify and improve the quality of their intra-bloc trade basket.

To check this hypothesis, we propose a substitution of the traded values by a trade basket sophistication index that is calculated based on the PRODY index developed in Hausmann et al. (2007). The PRODY index can be used as a proxy for the sophistication of the product, and according to Hausmann et al. (2007), countries that have an export basket more similar to the developed countries tend to register economic growth in the subsequent periods. Based on this concept and the importance of economic growth for the development of Latin American countries, we use the PRODY index to calculate the composition of the import basket of parts and components (IMPY index) and the intra-bloc export basket (EXPY index). The objective is to estimate if the imports of parts and components from specific regions contributed or not to bring the Latin American intra-bloc export basket closer to the developed countries. The proposed models are defined as follows:

$$ln\left(EXPYF_{ijkt}\right) = \alpha_0 + \sum_{r=1}^{7} \alpha_r lnIMPY\_pc_{rikt-1} + \alpha_8 ln\left(1 + tariff_{jikt}\right) +$$
$$\alpha_9 ln\left(1 + depth_{ijt}\right) + \gamma_{it} + \varphi_{jt} + s_{ij} + \omega_k + \varepsilon_{ijkt} \tag{4}$$

$$ln\left(EXPYPC_{ijkt}\right) = \beta_0 + \sum_{r=1}^{7} \beta_r lnIMPY\_pc_{rikt-1} + \beta_8 ln\left(1 + tariff_{jikt}\right) +$$
$$\beta_9 ln\left(1 + depth_{ijt}\right) + n_{it} + \tau_{jt} + z_{ij} + \mu_k + \delta_{ijkt} \tag{5}$$

where $EXPYF_{ijkt}$ and $EXPYPC_{ijkt}$ denote the EXPY index attributed to the basket of the final products and parts and components exported from country *i* to country *j* (these countries are limited to Latin American countries only) of sector *k* in year *t*. The EXPY index is calculated as the weighted average of the PRODY index of each component of the basket of a given sector. The EXPY index attributed to the baskets of final products and parts and components traded inside Latin America is explained by the IMPY index attributed to the basket of parts and components of sector *k* that country *i* imported from a given region *r* in year *t-1* ($\mathrm{IMPY\_pc_{rikt-1}}$), the depth measure of the PTA between country *i* and *j* in year *t* $depth_{ijt}$, the tariff imposed by the importing country *j* over the product of sector *k* provided by country *i* in time *t* $tariff_{jikt}$, the exporter-time and importer-time dummies (time is defined as a 5-year period), and the sector and the importer-exporter dummies.

4.5 Results: quantity analysis

A common characteristic of trade data is the existence of missing and zero trade values. As the natural logarithm of zero does not exist, the estimated regressions do not consider the zero trade values that are important information about the trade pattern. The dropped data are information not used in the estimation, possibly leading to a bias in the regression results.[34] To avoid this problem, we estimate the regressions using the PPML method (Santos Silva & Tenreyro, 2006). The PPML is the most accepted technique in the gravity model literature, allowing us to account for the observations with zero trade values.[35] In addition, trade data are plagued by heteroscedasticity, consequently the use of OLS can lead to the estimation of biased elasticities (Santos Silva & Tenreyro, 2006).

We first estimate equations (2) and (3) for the values of the pooled machinery intra-bloc exports. We also consider separate estimations for the main machinery sectors: electric machinery and transport equipment.

The first half of Table 4.3 contains the results for the intra-bloc exports of machinery final products. The tariff coefficient for the pooled data regression is negative and statistically significant, indicating that reductions in import tariffs of machinery final products are associated with increases in their intra-bloc exports. Consequently, the advance of the regional integration in Latin America through the decrease in the import tariffs imposed over the intra-bloc machinery trade have a positive impact on the development of Latin American machinery production networks. On the opposite side, the coefficient for PTA depth is statistically insignificant, showing that changes in non-tariff barriers do not affect production networks. The variables related to the origin of the imported parts and components reveal that an intensification of imports from the rest of the World (ROW), East Asia (EA), and Latin American (LA) countries, increase the intra-bloc trade of final products in the subsequent period. The results reveal that a 1% increase in imports of parts and components from LA leads to an increase of 0.53% in the intra-

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[34] The share of dropped values when the OLS method is employed ranges from around 17% to 29% of the total values estimated with the PPML technique.

[35] In our database, we also have missing tariff and trade data for a given group of countries and products that affect the independent variables. Unfortunately, the PPML model cannot address this problem.

bloc exports of final products. The coefficient for imports from EA is also high, approximately 0.45%, while imports from the ROW have a smaller effect, approximately 0.15%. On the other hand, the coefficient of imports from the North America[36] and China are negative, indicating a decrease on the intra-bloc trade of final machinery products of 0.32% and 0.27%, respectively. Although it is not possible to identify the exact reasons why imports from these suppliers do not stimulate intra-bloc trade, we consider a few hypotheses. The first is that an important share of imported parts and components are used in domestic production networks being consumed in the domestic market. Given the lack of data we cannot verify this hypothesis. A second possibility is that a share of these parts and components are used to produce goods exported to countries outside Latin America. This case is beyond the scope of this research. It could also be the case that imports from these regions are used to produce parts and components that are exported to other Latin American countries. If that is the case, coefficients will be positive in the second half of the table, when dependent variables are parts and components exports.

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[36] The term North America refers to US and Canada.

Table 4.3 – Machinery parts and components import composition effect on Latin American intra-bloc machinery exports

	Final Products			Parts and Components		
	Pooled Machinery	Electric Machinery	Transport Equipment	Pooled Machinery	Electric Machinery	Transport Equipment
Tariff	**-0.17*****	**-0.12****	-0.05	-0.03	-0.03	-0.05
	(0.05)	(0.06)	(0.08)	(0.04)	(0.04)	(0.04)
Lagged imports of parts and components from ROW	**0.15*****	**-0.24****	**0.18****	**0.19*****	0.08	0.04
	(0.05)	(0.09)	(0.07)	(0.05)	(0.07)	(0.06)
Lagged imports of parts and components from EU	-0.03	0.18	-0.03	-0.20	**-0.42*****	-0.08
	(0.08)	(0.23)	(0.21)	(0.13)	(0.12)	(0.12)
Lagged imports of parts and components from EA	**0.45*****	0.00	0.15	0.05	**0.38*****	0.31
	(0.06)	(0.15)	(0.19)	(0.07)	(0.10)	(0.20)
Lagged imports of parts and components from LA	**0.53*****	0.07	-0.12	**0.64*****	0.16	**0.39*****
	(0.08)	(0.09)	(0.18)	(0.08)	(0.11)	(0.14)
Lagged imports of parts and components from US & Canada	**-0.32*****	**-0.52*****	-0.32	**0.31*****	**-0.17***	**-0.49*****
	(0.08)	(0.15)	(0.23)	(0.08)	(0.09)	(0.18)
Lagged imports of parts and components from China & HK	**-0.27*****	**0.22****	0.06	-0.02	0.02	0.02
	(0.05)	(0.09)	(0.10)	(0.06)	(0.10)	(0.07)
PTA Depth	-0.24	**-0.66*****	-0.20	-0.33	-0.09	0.03
	(0.26)	(0.22)	(0.65)	(0.29)	(0.20)	(0.49)
Observations	16943	4320	4032	16667	4256	3794
R^2	0.87	0.90	0.94	0.87	0.94	0.97

Note: Results that are statistically significant are highlighted using bold text.

Given a restriction of space, the coefficients of secondary variables are omitted. Robust standard errors in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Results in the second column refer to the electric machinery trade. The import tariff coefficient is negative, indicating that a decrease of 1% in the tariffs imposed on electric machinery parts and components imports, all *ceteris paribus*, stimulates an increase of 0.12% in intra-bloc exports of electric machinery final products. Once again, the coefficient for imports from North America is negative, indicating that a 1% increase in imports from this region causes a decrease in the intra-bloc exports of final electric machinery of 0.52%. Imports from the ROW also have a negative impact of 0.24%. On the opposite side, a 1% increase in imports of electric machinery parts and components from China promotes an intensification of 0.22% in the intra-bloc trade of final products. The PTA depth coefficient is statistically significant and indicates that deeper agreements lead to a decrease in the intra-regional trade of electric machinery final products. According to Hofmann et al. (2017), agreements between developing countries are in general less deep and focus more on the decrease of import tariffs, since they are still high.[37] This is in accordance with our findings that show that decreases in import tariffs are more efficient than deeper agreements in the promotion of intra-bloc electric machinery final products exports. Additionally, in Latin America shallow agreements embrace more members, while deeper ones are in general bilateral agreements involving Mexico and Central American countries. Consequently, members of shallower agreements, such as the Mercosur, promote higher trade flows among themselves than members of deeper agreements. Lastly, according to Baier and Bergstrand (2007), all PTAs are "phased-in" over time, approximately 5 to 10 years. Therefore, older and shallower agreements, implemented in the 1990s, should have bigger impacts than the deeper ones, the majority of which were implemented in 2009, only two years before the end of the period studied.[38]

With regards to transport equipment, the results are almost all statistically insignificant. The exception is the coefficient for imports from the ROW, indicating that a 1% increase in imports of transport equipment parts and components from this region leads to an increase of 0.18% in intra-bloc exports of final transport equipment.

The second half of Table 4.3 displays the intra-bloc parts and components export coefficients. In this case, import tariff and PTA depth coefficients are statistically insignificant, signaling an increase in regional integration through the decrease of the import tariffs or non-tariff barriers would not affect the production fragmentation and relocation inside Latin America. Imports of parts and components from LA, North America, and the ROW have positive and statistically significant coefficients. As

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[37] The mean of the import tariff between Latin American countries in the studied period was 6.89% for machinery final products and 5.64% for machinery parts and components. For the case of electric machinery, the average import tariffs are 9.92% for final products and 6.62% for parts and components.

[38] Table A.4.2 in the Appendix contains the list of PTAs in force during the studied period.

observed in Florensa et al. (2015), imports of parts and components from these regions generate what they called a “complementary effect”. In other words, they stimulate production fragmentation and its relocation inside Latin America, since parts and components imported by a Latin American country in the first period produce other parts and components that will be used in a third Latin American country, promoting these countries engagement in machinery productions networks. A 1% increase in parts and components imports from LA results in an increase of 0.64% of the intra-bloc export of parts and components. Imports from North America promote an increase of 0.31%, while imports from the ROW have a smaller effect of 0.19%.

In the specific case of electric machinery, imports from EA stimulate the intra-bloc trade of parts and components with a coefficient of 0.39%, while imports from European Union (EU) and North America have a negative effect. In the case of transport equipment, the LA coefficient is positive, while the North American one is negative. Florensa et al. (2015) refer to the situation when coefficients are negative as the “substitution effect”, because instead of enhancing the development of production networks among Latin American countries, it promotes trade inside domestic markets or with countries in third regions.

Evidence indicates that increases in the import of parts and components from LA have the biggest positive impact in the creation of a Latin American machinery production network. This result aligns with Florensa et al. (2015) and the production fragmentation theory that states that the core of production networks is regionally organized. Imports from North America, a region that is geographically close to Latin America and known for engaging in back-and-forth intra-firm production network transactions with Mexico and Central American countries, presented mixed results. It stimulates the intra-bloc trade of machinery parts and components in general, but decreases the trade of final products. Conversely, the results indicate that in the specific case of electric machineries, imports from EA and China foment production fragmentation. This result also aligns with Florensa et al. (2015) and Fung, Hwang, Ng, and Seade (2015) who verified an increase of parts and components supplies from Asian countries supporting Latin America's engagement in production networks.

As mentioned in section 2, Latin America is an area where economic integration still lags behind other regions of the globe. Although there are 21 different PTAs signed by LA countries, none of them integrates the whole region. Given this fact, we perform one extra exercise to explore the heterogeneity inside the region. Based on economic proximity and negotiated PTAs, we classified Latin America into three subregions: one composed of Argentina, Brazil, Paraguay, and Uruguay, who are members of Mercosur; a second composed of Bolivia, Colombia, Ecuador, Peru, and Venezuela who are members of the Andean Community (CAN); and a third with the members of Central America (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama), Mexico and Chile.[39]

Table 4.4 contains the results of machinery exports from each subregion.[40] Given the reduction in the number of observations, we consider only the pooled machinery data results. The majority of the coefficients are statistically insignificant for the case of CAN exports. Indeed, among the three subregions, CAN is the one with the smallest machinery trade. The results reveal that imports from LA and EA countries enhance the intra-regional trade of final machinery by 0.5% and 0.36%, while imports from North America

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[39] Venezuela was classified as part of CAN, because during the majority of the studied period it was a member of it. Chile and Mexico were aggregated with Central American economies given the existence of many PTAs among them and because both countries are not members of either Mercosur or CAN.

[40] Once the regions were selected based on PTAs, the PTA depth was dropped from the regressions.

enhance the intra-regional trade of machineries parts and components by 0.4%. In the cases of Central America, Mexico and Chile, we observe that imports from EA, LA and North America enhance the intra-regional trade of machinery final products by 0.15%, 0.32%, and 0.42%, respectively. Imports from these three regions and the ROW enhance the regional trade of parts and components by 0.25%, 0.45%, 0.58%, and 0.23% respectively. On the opposite side, imports from China and EU have negative effects. The results indicate that production fragmentation in Central America, Mexico and Chile is stronger than in CAN, with EA, LA and North America, who, in ascending order, have been important suppliers for the regional production networks. Though composed of only four economies, Mercosur is responsible for the biggest intra-bloc machinery trade. The results also indicate that imports from the ROW and EA stimulate the exports of final products, while imports from the ROW and China enhance the exports of parts and components inside Latin America. Coefficients for EA and China are higher than the ROW: a 1% increase in import of parts and components from EA induced an increase of 0.66% in the intra-bloc trade of final products compared with 0.15% for imports from the ROW, while imports from China promoted a 0.26% increase in the intra-bloc trade of parts and components compared with 0.10% for imports from the ROW. On the opposite side, imports from North America do not stimulate the intra-bloc export of machinery.

We conclude that, different from Central American, Mexico and Chile, production networks promoted by Mercosur countries depend more on imports from China and EA, while imports from North America have a negative impact. In this case, it seems that geographical and economic proximity still play an important role, with North American imports fomenting the first regions' engagement in production fragmentation, while in

Mercosur's case, a region more distant from North America, the imports from EA and China are more important.

Table 4.4 – Machinery parts and components import composition effect on Latin American intra-bloc machinery exports by subregion

	Final Products			Parts and Components		
	CE, Mexico & Chile	Andean Community	Mercosur	CE, Mexico & Chile	Andean Community	Mercosur
Tariff	**-0.28*****	0.06	**-0.23*****	0.05	-0.05	**-0.10*****
	(0.07)	(0.09)	(0.07)	(0.08)	(0.10)	(0.03)
Lagged imports of parts and components from ROW	0.04	-0.13	**0.15****	**0.23*****	-0.14	**0.10****
	(0.06)	(0.09)	(0.07)	(0.06)	(0.12)	(0.05)
Lagged imports of parts and components from EU	-0.18	-0.18	0.12	**-0.45*****	-0.17	-0.17
	(0.13)	(0.25)	(0.19)	(0.12)	(0.20)	(0.13)
Lagged imports of parts and components from EA	**0.15*****	**0.36****	**0.66*****	**0.25*****	-0.04	0.03
	(0.06)	(0.17)	(0.13)	(0.08)	(0.19)	(0.09)
Lagged imports of parts and components from LA	**0.32*****	**0.49*****	0.10	**0.45*****	0.16	0.05
	(0.09)	(0.13)	(0.11)	(0.07)	(0.12)	(0.09)
Lagged imports of parts and components from US & Canada	**0.42*****	-0.02	**-0.92*****	**0.58*****	**0.40***	**-0.25*****
	(0.10)	(0.25)	(0.15)	(0.10)	(0.21)	(0.09)
Lagged imports of parts and components from China & HK	**-0.22*****	**-0.38*****	-0.12	0.06	0.13	**0.26*****
	(0.05)	(0.13)	(0.09)	(0.07)	(0.11)	(0.05)
PTA depth	**-0.60*****	0.48	0.66	**-1.29*****	-0.06	1.03
	(0.22)	(0.56)	(1.02)	(0.35)	(0.31)	(0.85)
Observations	0.71	0.69	0.91	0.90	0.73	0.92
R^2	7807	5104	4032	7635	5104	3928

Note: Results that are statistically significant are highlighted using bold text.

Given a restriction of space, the coefficients of secondary variables are omitted. Robust standard errors in parentheses: $^{*} p < 0.10$, $^{**} p < 0.05$, $^{***} p < 0.01$.

4.6 Results: quality analysis

Considering the wide range of machinery products and that some are more sophisticated than the others, our next step is to examine which regions provide parts and components that promote Latin American production networks of products more similar to the ones produced by developed countries. Being involved in the manufacturing process of products with higher sophistication level instead of just buying the final product from other regions, Latin American countries gain access to technology, benefit from positive spillover effects, and increase the possibilities of enjoying economic growth.

The first half of Table 4.5 presents the results for the intra-bloc trade of final products, while results for the intra-bloc trade of machinery parts and components are in the second half. The first notable feature is that the tariff coefficient is positive in all columns, indicating that a decrease in the import tariff leads to a decrease in the sophistication of the machinery export basket. In other words, the export basket becomes more similar to the developing countries. One possible interpretation for this fact is that with higher tariffs, products with lower sophistication and lower values that are comparatively easier to be produced by developing countries were manufactured in most of the countries and were consumed in the domestic market, while machinery products with a higher level of sophistication were produced by just a few countries in the region and traded inside the bloc. The import tariff reduction allowed for an increase in the intra-bloc trade and specialization. This phenomenon promoted a faster growth in the trade of less sophisticated products than the sophisticated ones.

Considering parts and components suppliers, we verify that imports from the ROW, EU, EA, LA, and North America promoted an increase in the sophistication of the final products traded inside Latin America. A 1% increase in North American participation in the import basket composition, all *ceteris paribus,* promotes an increase of 0.06% in the quality of the intra-bloc export basket, while imports from EU promoted an increase of 0.04%, followed by increases of 0.02% in the case of imports from LA or EA, and 0.01% for the ROW. The second column reveals that imports just from LA and North America had a positive effect in the electric machinery sector, while the coefficients for imports from other regions are statistically insignificant. Increases of 1% in imports from North America promote an increase of 0.07% in the quality of final electric machinery intra-bloc export basket, while imports from LA promote an increase of 0.06%. Transport equipment coefficients were all statistically insignificant. In the second half of Table 4.5, we verify similar results for the case of pooled machinery data. North American imports promote an increase of 0.1% in the quality of the parts and components export basket, while imports from the EU and EA promote an increase of 0.04% each. In column 5, the coefficients are slightly different, revealing that imports only from China promote a 0.04% increase in the intra-bloc export basket of electric machinery parts and components, while imports from EA have a negative effect. Once again, transport equipment coefficients are statistically insignificant.

Table 4.5 – Machinery parts and components import composition effect on Latin American intra-bloc machinery exports sophistication

	Final Products			Parts and Components		
	Pooled Machinery	Electric Machinery	Transport Equipment	Pooled Machinery	Electric Machinery	Transport Equipment
Tariff	**0.05*****	**0.07*****	**0.05*****	**0.08*****	**0.08*****	**0.06*****
	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)
Lagged imports of parts and components from ROW	**0.01****	0.02	0.00	**0.04*****	0.01	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Lagged imports of parts and components from EU	**0.04*****	**0.04***	0.03	**0.04*****	-0.03	-0.01
	(0.01)	(0.02)	(0.05)	(0.01)	(0.02)	(0.05)
Lagged imports of parts and components from EA	**0.02*****	0.03	0.01	**0.04*****	**-0.04***	-0.03
	(0.01)	(0.03)	(0.04)	(0.01)	(0.02)	(0.03)
Lagged imports of parts and components from LA	**0.02*****	**0.06****	-0.03	**0.02****	0.03	0.00
	(0.01)	(0.03)	(0.06)	(0.01)	(0.03)	(0.05)
Lagged imports of parts and components from US & Canada	**0.06*****	**0.07*****	-0.02	**0.10*****	-0.01	0.01
	(0.01)	(0.03)	(0.04)	(0.01)	(0.03)	(0.04)
Lagged imports of parts and components from China & HK	0.00	0.03	0.02	0.01	**0.04*****	0.00
	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)
PTA depth	0.01	0.03	0.04	0.01	-0.08*	0.07
	(0.03)	(0.05)	(0.07)	(0.04)	(0.05)	(0.06)
Observations	16943	4320	4032	16667	4256	3794
R^2	0.42	0.46	0.49	0.44	0.51	0.55

Note: Results that are statistically significant are highlighted using bold text.

Given a restriction of space, the coefficients of secondary variables are omitted. Robust standard errors in parentheses: $^{*} p < 0.10$, $^{**} p < 0.05$, $^{***} p < 0.01$.

Results in this section partially support the hypothesis that an increase in imports of parts and components from Asian countries promotes an increase in the quality of the intra-bloc export basket. Nevertheless, imports from EU and North America had a bigger positive effect. Table 4.6 presents the PRODY mean of the import basket from each region in 1996 and 2011, revealing that import baskets from EU and North America were still composed of products with a high sophistication level. Given the increase in Asian product imports share in the detriment of imports from both regions, we can conclude that imports from EU and North America concentrated in higher sophistication products, while Asia supplied products with a slightly lower level of sophistication at very competitive prices. Another interesting feature is that, although the share of imports from the ROW is the smallest one, imports from this region are concentrated in products with a very high level of sophistication.

Table 4.6 – Imported machinery parts and components PRODY index mean

	Latin America		CE, Mexico & Chile		Andean Community		Mercosur	
	1996	2011	1996	2011	1996	2011	1996	2011
ROW	18,273.1	18,358.7	17,997.5	18,005.2	18,569.9	18,808.3	18,453.3	18,503.4
EU	17,492.8	17,652.7	17,418.5	17,327.4	17,581.6	18,067.0	17,530.3	17,785.3
North America	16,870.1	17,576.7	16,735.8	17,245.1	17,032.2	17,577.7	16,935.9	18,238.5
EA	16,629.9	17,106.3	16,535.6	16,930.5	16,742.7	17,258.1	16,677.4	17,268.1
LA	16,389.4	16,313.9	16,256.1	15,845.9	16,188.2	16,486.5	16,907.2	17,034.1
China	15,109.2	16,445.3	15,589.5	16,272.3	15,006.5	16,549.7	14,276.8	16,660.5

Source: Author’s calculation using data from Hausmann et al. (2007).

As in the previous section, we perform a similar exercise considering the exports of countries classified in three different subregions to explore their differences. Table 4.7 reveals that for Mexico, Chile, and Central American countries the imports from the ROW, EU, and EA promote an increase in the sophistication of the final products this region produced and exported inside LA. Conversely, imports from North America and China have a surprisingly negative effect. The pattern does not change even when intra-bloc exports of parts and components are considered. The only difference is that LA imports have a negative impact. Table 4.6 reveals that from 1996 to 2011 the PRODY mean of this subregion import basket decreased, justifying the negative coefficient. Finally, the depth index indicates an increase in the sophistication of the intra-bloc exports of parts and components. The PTA depth coefficient is positive and statistically significant only in this case comprising the Central American countries Chile and Mexico, a subregion with the deepest PTAs.

Table 4.7 – Machinery parts and components import composition effect on Latin American intra-bloc machinery exports sophistication by subregion

	Final Products			Parts and Components		
	CE, Mexico & Chile	Andean Community	Mercosur	CE, Mexico & Chile	Andean Community	Mercosur
Tariff	**0.04*****	0.01	**-0.24*****	**0.11*****	**0.04****	0.02
	(0.01)	(0.02)	(0.07)	(0.01)	(0.02)	(0.01)
Lagged imports of parts and components from ROW	**0.02*****	-0.01	**0.14****	**0.04*****	**0.03*****	**0.07*****
	(0.01)	(0.01)	(0.06)	(0.01)	(0.01)	(0.01)
Lagged imports of parts and components from EU	**0.04*****	**-0.08****	-0.25	**0.05*****	**-0.10*****	-0.01
	(0.02)	(0.04)	(0.19)	(0.02)	(0.04)	(0.04)
Lagged imports of parts and components from EA	**0.02***	**0.04***	**0.39*****	**0.04*****	**-0.07*****	**0.06*****
	(0.01)	(0.02)	(0.14)	(0.01)	(0.03)	(0.02)
Lagged imports of parts and components from LA	0.01	-0.02	-0.13	**-0.02****	-0.02	0.01
	(0.01)	(0.03)	(0.12)	(0.01)	(0.03)	(0.02)
Lagged imports of parts and components from US & Canada	**-0.04***	**0.13****	**-0.77*****	**-0.05***	-0.09	**-0.08*****
	(0.02)	(0.06)	(0.14)	(0.03)	(0.05)	(0.03)
Lagged imports of parts and components from China & HK	**-0.04*****	-0.02	-0.12	**-0.04*****	**-0.08*****	**-0.03***
	(0.01)	(0.02)	(0.08)	(0.01)	(0.02)	(0.02)
PTA depth	0.06	**-0.14****	0.56	**0.15*****	-0.06	**-0.24***
	(0.04)	(0.06)	(1.01)	(0.05)	(0.08)	(0.14)
Observations	0.46	0.34	0.91	0.47	0.37	0.51
R^2	7807	5104	4032	7635	5104	3928

Note: Results that are statistically significant are highlighted using bold text.

Given a restriction of space, the coefficients of secondary variables are omitted. Robust standard errors in parentheses: $^{*}\ p < 0.10$, $^{**}\ p < 0.05$, $^{***}\ p < 0.01$.

For the Andean Community members, imports of parts and components from EU have a negative impact, while imports from EA and North America increase the sophistication of the machinery final products they export inside Latin America. When intra-bloc exports of parts and components are considered, imports from the ROW assume a positive coefficient. Although Table 4.6 revealed no decrease in the PRODY mean from 1996 to 2011, after econometrically controlling all variables, the model reveals a negative effect on intra-bloc exports of parts and components in the cases of imports from China, EA and EU.

Increases in EA and the ROW participation in Mercosur's import basket composition have a positive impact on Mercosur members' exports of machinery final products and parts and components, while North American participation in the import basket have a negative impact.

These results indicated that depending on the subregion, the origin of the imports can have a positive or negative effect on the sophistication level of the machinery exports inside Latin America. In general, imports from EA and the ROW had positive effects, while imports from North America and China had negative impacts. However, when we consider all Latin American countries, we verify positive contributions from North American imports. The results indicate that in the case of imports from China, the effect on the intra-bloc exports sophistication level were not positive as expected, revealing that its exports to Latin America were still composed of cheaper and less sophisticated parts and components. The exception is in the specific case of electric machinery, where imports from China increased the sophistication of the intra-bloc exports of parts and components.

4.7 Final considerations

In this chapter, we investigated how the changes in the structural composition of Latin America’s suppliers of machinery parts and components affected the development of Latin American regional production networks. In our analysis, we considered a quantity and a quality dimension of the impact of these imports.

In the first part of the chapter, the descriptive analysis indicated a growth in the import of parts and components from all regions of the world. However, we observed that the growth in imports from the East Asian region was higher, resulting in a change in the structural composition of the suppliers. Concomitant with this composition change we also verified a modification in the sophistication level on the intra-bloc exports. In the second part of the chapter, we proceeded with an econometric analysis to identify from which regions the import of parts and components contributed more to develop production networks inside Latin America and increase the sophistication level of the traded products. The quantity analysis provided evidence that Latin American production networks increased during the studied period, and they were fomented by import of machinery parts and components from the ROW, LA, EA, and North America. Imports of parts and components from LA had the biggest positive impact in the creation of a Latin American machinery production network, while imports from North America stimulated the intra-bloc trade of machinery parts and components in general, decreasing the trade in specific machinery sectors. The expected result that the increase in imports from EA and China fomented production networks inside Latin America was confirmed for the specific case of electric machineries. Conversely, imports of parts and components from North America did not stimulate the intra-bloc trade of machineries final products and parts and components for the two specific sectors analyzed.

Exploring subregional heterogeneities, we identified that imports from North America had the highest positive impact in intra-bloc exports in the cases of the exports from Central America, Chile and Mexico subregions, as well as the Andean Community. Imports from EA and China had the highest positive effects in the case of exports from Mercosur countries. It is possible that geographical and economic proximity played an important role in this result, with North American imports fomenting the first two regions' engagement in production fragmentation, while imports from EA and China were more important for Mercosur members.

Considering the second dimension studied, the sophistication of the products traded in Latin America's regional production networks, the results provided evidence that partially supported the hypothesis that increases in imports of parts and components from Asian countries promote an increase in the quality of the intra-bloc export basket. The EA coefficient was positive for the pooled machinery data in Latin America and almost all subregions, while imports from China increased the sophistication of intra-bloc exports of electric machinery parts and components. The coefficients for subregional pooled machinery data imports from China were negative, revealing that its exports to Latin America were still composed of cheaper and less sophisticated parts and components. The results from imports from North America were mixed, with negative coefficients in the subregional cases and positive coefficients when all Latin American countries were analyzed.

The findings of this chapter indicate that Latin American governments should consider the possibility of being more proactive in the development of regional policies to facilitate the import and use of machinery parts and components. The heterogeneity between subregions indicates that countries from Mercosur could benefit more from imports from the EA and China to foment the expansion of regional production networks and the increase in the sophistication level of the machinery products traded inside Latin America, while North America appears as a natural and better option for the other countries. Moreover, Latin American countries could take advantage of the internalization of some machinery production steps to engage in machinery production networks and decrease the imports of machinery final products from third regions. These initial policies can proportionate economic growth and other positive spillover effects. In the medium and long term, these strategies could help Latin American countries overcome the lack of competitiveness in given machinery products and enhance the region’s participation in the international machinery trade.

CHAPTER 5 – Machinery Production Networks and Import Tariff Evasion[41]

In this chapter we followed Fisman and Wei's (2004) approach to estimate the effects of import tariff rates on import tariff evasion. We focus on East Asian countries import of machinery products and our main objective is to test if the trade realized inside production networks (intra-regional) is less prone to import tariff evasion than imports from countries outside it (inter-regional). In this study we considered the differences in tariff evasion between intra and inter-regional imports; parts and components and final products; and the heterogeneity between electric machinery and transport equipment. The data provide evidences that intra-regional imports are less prone to tariff evasion than inter-regional imports. Besides this, we identify differences in the channels employed to evade tariff. The results suggest that underreport of quantities was the main channel employed in intra-regional imports tariff evasion, while inter-regional import tariffs were evaded through unit price misreport.

5.1 Introduction

Import tariff evasion is an important issue, but the difficulty in directly observing it contributes to make this an understudied matter. According to Jean and Mitaritonna (2010), there are many ways to evade customs duties, including the smuggling, bribery, and fallacious declarations. Independent of the chosen method the result is a decrease in the collected tariffs. The lack of transparency and law enforcement impose difficulties for the international trade and affect countries that depend heavily on such tariffs.[42]

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[41] The revised version of this chapter is in The International Economy, vol. 20.

[42] According to Bausgaard and Keen's data (2009) the share of trade tax revenue in total tax receipts in 2001-2006 amounted to an average of 2.5% in high-income countries, 18.1% in middle-income countries and 22% in low-income countries.

Bhagwati (1964, 1967) produced the first studies that proposed a way to overcome the lack of available data, using the discrepancies between matched import and export declarations at product level to reveal customs duty evasion. He studied the Turkish case, identifying the existence of under-invoicing of imports, in special for manufactured products. Pritchett and Sethi (1994) analyzed customs data from three developing countries (Jamaica, Kenya, and Pakistan) and found that collected and official tariff rates were only weakly related, with variance of collected rate increasing strongly with the level of the official rate. More recently, Fisman and Wei (2004) interpreted the existence of econometrical relations between import tariff rate level and the existence of gaps between reported import and export values, what they referred to as missing imports or evasion gap, as an evidence of tax evasion. Using public available data of Hong Kong reported exports to China and Chinese reported imports from Hong Kong to quantify the effects of tax rate on tax evasion, they discovered that a one percentage point increase in the tax was associated with a 3% increase in tax evasion.

Mishra, Subramanian, and Topalova (2008) analyzed the case of Indian imports and Javorcik and Narciso (2008) analyzed the imports of ten Eastern European countries from Germany, employing the same methodology as Fisman and Wei (2004). Both works contributed to the tariff evasion literature confirming the existence of a positive relation between import tariff rates and tariff evasion, and discovering that products classified as homogeneous goods, according to the classification of Rauch (1999), are less vulnerable to tariff evasion than differentiated goods. According to the authors, homogeneous goods have prices that are widely known, while differentiated goods have prices that are less known and usually determined in specific transactions, creating opportunities for unnoticed misreports. Other studies performed similar exercises for different countries and periods of time.[43]

In a recent research Javorcik and Narciso (2017) analyzed the unintended impact that accession to the World Trade Organization (WTO) have on tariff evasion. According to their study, countries accessing the WTO have to comply with the Customs Valuation Agreement (CVA) that stipulates that customs officers cannot exercise discretion with respect to assessing values of imported goods, having to accept invoice prices. Using data for 15 countries that joined the WTO between 1996 and 2008 the authors verify that this rule effectively closed down one import tariff evasion channel (misreport of the unit value), increasing evasion through undercounting of quantities and misclassification.

The second unbundling (Baldwin, 2011) and the development of production networks, resultant from the outsourcing and offshoring processes, lead to an increase in trade of parts and components, especially in the machinery industry that is known for the use of many parts and components to assemble a final product. Given that the majority of machinery parts and components and final products are classified as differentiated goods, being more exposed to tariff evasion, and that production fragmentation increases the number of times parts and components cross borders until the final good is assemble, this work investigates the import tariff evasion of machinery products.

Engagement on production networks presuppose production efficiency, fine harmonization between all production steps, and competitive costs. Consequently, tariff evasion is a very sensitive topic for this type of production organization. In other words, troubles in the customs can undermine the efficiency of production networks, given the

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[43] For other studies on import tariff evasion verify: Levin and Widell (2014) that analyze the tariff evasion in Kenya and Tanzania; Bouët and Roy (2012) that study the case of Kenya, Mauritius and Nigeria; Epaphra (2015) that researches the case of Tanzania; and Kume, Piani, and Miranda (2011) that study the case of Brazil.

producers exposition to unexpected extra time and monetary costs in the clearance process, attributed to bribe negotiations, plus the creation of future uncertainties.

To the best of our knowledge, the only study to approach this topic is Lin (2017) that investigated the trade of machinery final products and parts and components inside the "Factory Asia".[44] The author analyzed the import tariff impact on tariff evasion in the intra-regional trade, concluding that an increase in one percentage point of import tariff lead to an increase in tariff evasion that varies from 0.78% to 1.2%. It was also verified that parts and components are more prone to suffer from tariff evasion than final products.

In this study we complement the existing literature investigating East Asian machinery imports from countries inside and outside the "Factory Asia" in order to attest if there are differences in tariff evasion patterns. The main objective is to verify if production networks trade is less vulnerable to tariff evasion than trade with countries outside production networks. A secondary contribution is the study of import tariff evasion heterogeneity for different machinery sectors. We decompose the machinery trade focusing on the main machinery sectors: electric machinery and transport equipment.

The rest of this chapter is organized as follows: section 2 reports the database construction. Section 3 briefly exposes some summary statistics and trends of tariff rates and tariff evasion gap. Section 4 explains how we set the model, while section 5 presents the results, section 6 robustness check exercises, and section 7 the concluding remarks.

5.2 Data

In this study we use data collected from two main sources. The first one is the World Integrated Trade Solution (WITS) that provides different schemes of import tariffs

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[44] According to Athukorala (2011) the East Asian region is the most outstanding example of machinery production networks due to deeper and wider intra-regional trade of machinery parts and components.

based on UNCTAD's Trade Analysis and Information System (TRAINS) database. This source provides detailed tariff information, such as importer, exporter, year of trade, product imported and tariff rate at the Harmonized System six-digit level. We use the available applied tariffs data and complement our database with the value of the nearest year (preference is given to previous year data) to replace missing tariffs. The analyzed period covers different versions of HS classification. The products code might slightly change depending on the specific HS version. To address this problem, we use a conversion table to convert all variations to the HS1992 classification.

The second source is the UN Comtrade that provides HS 6-digit level trade data. Following Lin (2017), we use the recorded imports of eleven East Asian countries[45]. Exporters are limited to 93 countries[46] that comprise around 99.5% of East Asian countries import value in 2011. Import values recorded by East Asian countries and export values recorded by exporter countries are all classified according to HS1992 classification. Following the literature, we match these data and drop products that have missing values on one of the sides.

Given data availability, the analysis covers the period from 1996 to 2011. Machinery industry is comprised by all the goods categorized as general machinery sector (HS84), electric machinery sector (HS85), transport equipment sector (HS86-89), and precision machinery sector (HS90-92). These products are classified as parts and components and final products according to Kimura and Obashi (2010) classification.

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[45] East Asia in this paper is composed of the countries from ASEAN+3 (Brunei, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Singapore, the Philippines, Thailand and Vietnam plus China, Japan and South Korea), excluding Lao PDR from the sample due to data limitation. Although Hong Kong is also part of East Asia, its data is used only when it appears as an exporter to other East Asian countries. The same applies to Singapore, given that the import tariff of these two countries are zero for all machinery products.

[46] The list containing the 93 countries divided by regions is available in the Appendix.

5.3 Import tariff rates, trade gap, and machinery sector: a descriptive analysis

In this chapter we focus on the relationship between import tariff rate and tariff evasion for the East Asian countries intra and inter-regional import of machinery products. Our objective is to examine whether the business environment created by the development of machinery production networks inside East Asia leads to lesser import tariff evasion than in imports from countries outside these production networks. In this exercise we consider the differences in tariff evasion between parts and components and final products. We also analyze the differences in tariff evasion between the two main machinery sectors: electric machinery and transport equipment.

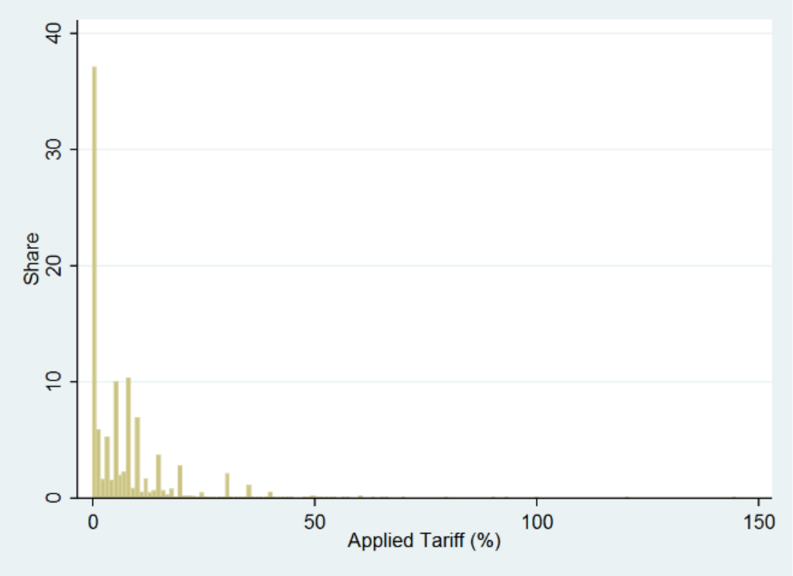
To perform the mentioned exercises we define trade gap following Fisman and Wei (2004). Trade gap is defined as the log difference between the value of exports recorded by the exporting country and the value of imports recorded by the importing country. The gap is calculated at the 6-digit level HS product for each exporter-importer pair and year. According to Epaphra (2015) a discrepancy between the recorded values is to be expected, because the export values are expressed in FOB (free on board) terms, while imports are recorded in CIF (including the cost, insurance and freight). Intuitively, values in CIF should be higher than values in FOB. Besides this, countries tend to monitor imports more carefully than exports, consequently, in the absence of tariff evasion one would expect the difference to be negative. If the gap is positive, that suggests a possible presence of tariff evasion. The trade gap is defined as follows:

$$gap\_value_{ijkt} = \ln(Export_{value})_{ijkt}^{i,record} - \ln(Import_{value})_{ijkt}^{j,record} \qquad (1)$$

where country *i* exports to country *j* the product *k* in year *t*. The notations *i,record* and *j,record* represent exports recorded by an exporting country and imports recorded by an importing country, respectively.

The distribution of East Asian countries imported machinery products import tariff rates are shown in Figure 5.1. The variation in the import tariff rates is low, with a concentration of products around zero tariff rate achieving almost 40%. Since zero tariff products account for more than one-third of all machinery products (approximately 34.7%), we examine if there is a significant difference on trade gap between zero import tariff and non-zero import tariff products. It is expected that the lower the tariff rate the smaller would be the incentive for importers and corrupt customs officers to evade import tariff, while for zero tariff products this incentive should be almost null.[47]

Figure 5.1 – Distribution of East Asian countries HS 6-digit level machinery products import tariff rates



Source: Author's calculation using data from WITS.

Table 5.1 shows the summary statistics for the evasion gap[48] of products with zero

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[47] The existence of other types of tax, like the VAT, and non-tariff barriers can also be interpreted as minor incentives to customs evasion and positive trade gaps.

[48] We refer to evasion gap and trade gap as synonyms.

and non-zero import tariff levels. As expected, products whose tariff rates are zero have lower evasion gap than products whose tariff rates are larger than zero. In fact, the products with zero tariff have a negative mean, indicating none or very small levels of tariff evasion. Decomposing the machinery imports in final products and parts and components we identify a similar pattern: zero tariff products have a negative mean, while non-zero tariff products have a positive mean. In particular, parts and components evasion gap mean is smaller than final products one for zero and non-zero tariff products, indicating a smaller probability of tariff evasion. The results suggest that the evasion gap magnitude can have some relation with the type of products and the level of tariff rates.

Table 5.1 – Trade gap summary statistics of zero and non-zero import tariff products

Zero tariff products	Mean	Median	SD	Min	Max	Observations
All	-0.071	-0.033	2.221	-16.758	15.375	750379
P&C	-0.130	-0.055	2.307	-16.758	15.335	371434
Final	-0.012	-0.016	2.131	-16.238	15.375	378945
Non-Zero tariff products	Mean	Median	SD	Min	Max	Observations
All	0.095	0.017	2.248	-15.323	15.583	570087
P&C	0.075	0.022	2.292	-15.323	15.583	343492
Final	0.126	0.013	2.179	-14.583	13.054	226595

Source: Author's calculation using data from WITS and the UN Comtrade.

Next, we disaggregate the data and perform the same exercise for the main machinery sectors: electric machinery and transport equipment. Since zero tariff products are less prone to tariff evasion, we focus on non-zero tariff products. Table 5.2 contains both machinery sectors summary statistics. The first thing we observe is that electric machinery products seem to be less prone to tariff evasion than transport equipment, since the mean of the latter is higher than the former. Besides this, final electric products seem to be more exposed to tariff evasion. On the other hand, transport equipment descriptive analysis indicates the opposite: parts and components are more prone to tariff evasion.

Table 5.2 – Trade gap summary statistics of non-zero import tariff products according to machinery sector

Electric Machinery	Mean	Median	SD	Min	Max	Observations
All	0.038	-0.014	2.366	-14.583	14.875	193378
P&C	-0.038	-0.051	2.377	-14.193	14.875	130771
Final	0.196	0.063	2.335	-14.583	12.897	62607
Transport Equipment	**Mean**	**Median**	**SD**	**Min**	**Max**	**Observations**
All	0.247	0.076	2.394	-12.849	12.661	15122
P&C	0.262	0.109	2.512	-12.849	12.661	9560
Final	0.222	0.035	2.177	-11.282	10.444	5562

Source: Author's calculation using data from WITS and the UN Comtrade.

As our main objective is to verify the differences in trade inside and outside the "Factory Asia", we disaggregate the data in intra and inter-regional imports. Our hypothesis is that intra-regional mean evasion gap would be smaller than the inter-regional one, however the summary statistics in Table 5.3 reveals the opposite pattern with inter-regional evasion gap mean being smaller. Although the descriptive analysis result do not corroborate with the hypothesis that intra-regional trade is less prone to tariff evasion, one needs to analyze carefully this result. As already mentioned, our main interest is not identifying the trade gap per se, since these results also involve possible measurement errors, misclassification involving re-exports, and other discrepancies that are not necessarily related to tariff evasion. Consequently, we still need to perform some econometrical exercises to verify the existence or not of a statistical relation between import tariff rate and trade gap for different groups sorted according to the above mentioned characteristics.

Table 5.3 – Trade gap summary statistics of non-zero import tariff products according to exporter region

Intra-regional	Mean	Median	SD	Min	Max	Observations
All	0.250	0.103	2.282	-15.323	15.583	186737
P&C	0.245	0.115	2.345	-15.323	15.583	106489
Final	0.258	0.091	2.196	-14.583	12.897	80248
Inter-regional	**Mean**	**Median**	**SD**	**Min**	**Max**	**Observations**
All	0.020	-0.019	2.228	-13.620	13.838	383350
P&C	-0.001	-0.018	2.264	-13.620	13.838	237003
Final	0.054	-0.020	2.167	-12.654	13.054	146347

Source: Author's calculation using data from WITS and the UN Comtrade.

In the next section we present the methodology and model employed to perform econometrical exercises that test if the summary statistics results hold.

5.4 Empirical strategy

As highlighted in the previous section, just the analysis of the trade gap per se does not constitute a conclusive evidence, given the existence of measurement errors and other factors mentioned before. A stronger evidence of corruption would be the existence of a systematic relationship between import tariff level and tariff evasion, reflecting not random, but intentional misreports. In accordance with the previous literature, we model this relationship and use fixed effects to control for importer-year, exporter-year and product specific characteristics.[49] Intra-regional dummy and an interaction term of this dummy and tariff level was added to capture possible differences between tariff evasion inside and outside production networks. For the most detailed specification we also control for differences between parts and components and final products adding a parts and components dummy, an interaction between this dummy and the tariff level, and an interaction between tariff level, intraregional and parts and components dummy:

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[49] Following the literature we also cluster the standard errors at the 6-digit product level to account for potential serial correlation of evasion for a particular product.

$$gap\_value_{ijkt} = \ln(Export_{value})_{ijkt}^{i,record} - \ln(Import_{value})_{ijkt}^{j,record} = \beta_0 + \beta_1 Tariff_{jikt} + \beta_2 Tariff_{jikt} * intraregional_i + \beta_3 intraregional_i + \beta_4 Tariff_{jikt} * PC_k + \beta_5 PC_k + \beta_6 Tariff_{jikt} * intraregional_i * PC_k + \theta_{it} + \pi_{jt} + \mu_k + \varepsilon_{ijtk} \quad (2)$$

where *tariff*$_{jikt}$ refers to the tariff rate imposed by country *j* on imports of product *k* from country *i* at year *t*; *intra-regional*$_i$ is a dummy that has the value of one if the exporter *i* is an East Asian country; *PC*$_k$ is a dummy that has the value of one if the traded product *k* is a part or component ; θ_{it} is a vector of fixed effects for exporter-year that controls for changes in exporter policies; π_{jt} is a vector of fixed effects for importer-year countries that controls for changes in importer policies; and μ_k is a vector of HS 6-digit product fixed effects that controls for time-invariant factors on particular products.

If evasion induced by tariff rate is prevalent, we expect $\beta_1>0$, like in the previous literature. Our main interest is in β_2 that explains the evasion with respect to the tariff rates in the case of imports inside the East Asian production network. It is expected that $\beta_2<0$, indicating that production network imports are less prone to tariff evasion.

According to the literature, there are three different forms of evading import tariffs. The first way is undercounting the physical quantities of imported products, while the second channel is through the misreport of the imported products unit value. These two forms of evading tariffs are accounted in the following specifications:

$$gap\_quantity_{ijkt} = \ln(Export_{quantity})_{ijkt}^{i,record} - \ln(Import_{quantity})_{ijkt}^{j,record} = \beta_0 + \beta_1 Tariff_{jikt} + \beta_2 Tariff_{jikt} * intraregional_i + \beta_3 intraregional_i + \beta_4 Tariff_{jikt} * PC_k + \beta_5 PC_k + \beta_6 Tariff_{jikt} * intraregional_i * PC_k + \theta_{it} + \pi_{jt} + \mu_k + \varepsilon_{ijtk} \quad (3)$$

$$gap\_unitprice_{ijkt} = \ln\left(\frac{Export_{value}}{Export_{quantity}}\right)_{ijkt}^{i,record} - \ln\left(\frac{Import_{value}}{Import_{quantity}}\right)_{ijkt}^{j,record} = \beta_0 + \beta_1 Tariff_{jikt} + \beta_2 Tariff_{jikt} * intraregional_i + \beta_3 intraregional_i + \beta_4 Tariff_{jikt} * PC_k + \beta_5 PC_k + \beta_6 Tariff_{jikt} * intraregional_i * PC_k + \theta_{it} + \pi_{jt} + \mu_k + \varepsilon_{ijtk} \quad (4)$$

The third channel is through mislabeling or misclassification of similar products. According to Fisman and Wei (2004), a misclassification between similar products happens when a higher-taxed product is reported as a lower-taxed variety. The authors proposed that products can be consider similar if they are classified under the same 4-digit HS code. They control for tariffs on similar products by including in the model the weighted average tariff of the products similar to k (w_avg($Tariff_{jikt}$)):

$$gap\_value_{ijkt} = \beta_0 + \beta_1 Tariff_{jikt} + \beta_2 w\_avg(Tariff_{jikt}) + \theta_{it} + \pi_{jt} + \mu_k + \varepsilon_{ijtk} \quad (5)$$

In the presence of goods misclassification it is expected that $\beta_2<0$, meaning that when the own product tariff rate is held constant, the lower the weighted average tariff rate of the similar products the higher will be the incentive to misclassify product *k* as one of its similar.

5.5 Estimation results

5.5.1 Trade gap, quantity gap, unit price gap, and mislabeling

Our first exercise is to estimate the models presented in the previous section. As highlighted in section 3, almost 35% of the variety of imported machinery products have a zero import tariff. Provided that products with zero import tariff are less prone to trade evasion, based on the lack of incentives to incur in illegal actions, just non-zero tariff products will be considered in this investigation. The outcome for the estimations of trade value gap are reported in columns 1-4 in Table 5.4. The first thing we observe is if the estimated β_1 is positive and statistically significant for machinery products, what would be an evidence of tariff evasion. Column 1 reveals that a one percentage point increase in the tariff rate is associated with an increase in the trade gap of 0.6%. In the next column we test if mislabeling is one of the channels used to evade tariffs by adding the weighted average tariff on similar products.[50] Once again the tariff coefficient is positive and statistically significant, while the weighted average tariff on similar products coefficient is negative and statistically significant at the 10% level, providing a weak evidence that mislabeling could be a secondary channel used to evade tariffs. In the next column we test for the difference in intra and inter-regional trade by adding a dummy variable that assumes the value of one when imports are from East Asian countries and an interaction of this dummy with the tariff variable. The interaction term reveals how the marginal effects of intra-regional imports differ from the marginal effects of inter-regional imports. To facilitate the analysis of the results in the lower part of the table we report the combined marginal effects. The tariff coefficient is still statistically significant and positive, indicating the presence of intentional tariff evasion in inter-regional imports. On the opposite side, the result from the sum of the tariff coefficient and the interaction of tariff and intra-regional trade coefficient is positive and smaller, indicating that machinery intra-regional imports are less prone to tariff evasion than inter-regional ones. According to the results in column 3 a one percentage point increase in the tariff rate is associated with an increase in the trade gap of 0.8% for inter-regional imports and 0.2% for intra-regional imports. However, the F statistic is not statistically different from zero in the intra-regional imports case, indicating the inexistence of intentional tariff evasion in intra-

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[50] To calculate the weighted average tariff of similar products it is necessary data of at least one similar product. Consequently, products without a similar product are dropped from the estimation, slightly decreasing the number of observations.

regional imports. Finally, in the fourth column a dummy for parts and components as well as the necessary interactions were added in order to identify the differences between parts and components and final products tariff evasion. Results reveal that a one percentage point increase in the tariff rate is associated with an increase in the trade gap of 1.0% in inter-regional imports of final products, 0.7% in inter-regional imports of parts and components, and 0.4% in intra-regional imports of parts and components. Again the F statistic is not statistically different from zero in intra-regional imports of final products and parts and components. These initial results indicate that machinery inter-regional trade suffers with tariff evasion, while the same does not apply to intra-regional trade.

In order to identify each channel contribution to tariff evasion, columns 5-10 present the results for quantity gap and unit price gap. The majority of the tariff coefficients in columns 5-7 are statistically insignificant, indicating that quantity underreport is not the main channel used to evade tariffs. In column 6 we find evidences that underreport of quantities was employed to evade tariffs in intra-regional imports. In the next column the intra-regional imports are separated in parts and components and final products, with parts and components coefficient being positive and statistically significant at the 5% level, while final products one is positive, but smaller and statistically significant at 10% level. Evidences were found that a one percentage point increase in parts and components import tariff leads to an increase of 0.8% in the quantity gap, while weak evidences indicate that a one percentage point increase in final products import tariff leads to an increase of 0.5% in the quantity gap. This result indicates that trade evasion through the misreport of traded quantities is constrained to the intra-regional trade of machinery and more specifically to parts and components.

Table 5.4 – Effect of tariff rate, regional trade, and product type on import tariff evasion

		Trade Gap				Quantity Gap			Unit Price Gap		
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Tariff		0.006***	0.008***	0.008***	0.010***	0.003	0.001	0.004	0.003***	0.007***	0.006***
		(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.001)	(0.001)	(0.001)
Tariff*PC					-0.003			-0.005			0.002
					(0.003)			(0.003)			(0.002)
Tariff*Intra-regional				-0.006***	-0.010***		0.005*	0.001		-0.011***	-0.011***
				(0.002)	(0.002)		(0.002)	(0.003)		(0.001)	(0.001)
Tariff*Intra-regional*PC					0.007**			0.008**			0.000
					(0.003)			(0.003)			(0.002)
Tariff on Similar Products			-0.004*								
			(0.002)								
Tariff+Tariff*Intra=0 F stat				1.04	0.01		7.12	3.03		18.18	16.32
p-value				0.307	0.916		0.008	0.082		0.000	0.000
Tariff+Tariff*PC=0 F stat					7.15			0.25			48.99
p-value					0.007			0.620			0.000
Tariff+Tariff*Intra+Tariff*PC +Tariff*Intra*PC=0 F stat					2.48			6.05			5.73
p-value					0.115			0.014			0.017
Combined Effects											
Inter-regional	Final	0.006***	0.008***	0.008***	0.010***	0.003	0.001	0.004	0.003***	0.007***	0.006***
	P&C				0.007***			-0.001			0.008***
Intra-regional	Final			0.002	0.000		0.006***	0.005*		-0.004***	-0.005***
	P&C				0.004			0.008**			-0.003**
Tariff on Similar Products			-0.004*								
R^2		0.064	0.066	0.064	0.064	0.066	0.066	0.066	0.114	0.115	0.115
Observations		570087	520069	570087	570087	570087	570087	570087	570087	570087	570087

Given a restriction of space, the coefficients of secondary variables are omitted. Robust standard errors in parentheses: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Columns 8-10 report the coefficients considering the unit price gap. Tariff coefficients are all statistically significant and positive. The coefficient in column 8 indicates that a one percentage point increase in the tariff leads to an increase in the unit price gap of 0.3%. The interaction between intra-regional dummy and tariff in column 9 has a negative coefficient, indicating that intra-regional trade is less prone to tariff evasion than inter-regional trade. Coefficients in column 10 indicate that a one percentage point increase in the tariff leads to an increase in the unit price gap of 0.6% in inter-regional trade of final products, 0.8% in inter-regional trade of parts and components, and declines in intra-regional unit price gap of 0.5% for final products and 0.3% for parts and components. In fact, the negative coefficients in columns 9 and 10 provide an unexpected and counter-intuitive result. There are two possible explanations for these results. Kellenberg and Levinson (2016) pointed out that tariff evasion is a product of the interaction of two offsetting forces: the higher the tariffs the more incentive will exist for the importer to evade the tariff and for the government to accurate report the imports and collect the tariffs. Consequently, it is possible that increases in tariff rate generate decreases in tariff evasion. Another cause is related to the fact that country-product level tariff data cannot account for the existence and use of export processing zone schemes. These schemes allow for the exemption of import tariffs in cases when machineries and parts and components are imported and used, inside specific geographical zones, in the production of goods that will supply the external market. Consequently, for these cases the nominal tariff is positive, but in reality the importer pays no import tariff, having no incentive to evade tariffs. This bias decreases the values of the coefficients. Therefore, instead of focusing on the absolute values of the coefficients we are more interested in the existence of statistically significant relationship between import tariff rate and evasion gap, an evidence of tariff evasion, and the relative values of these coefficients.

Results in this subsection revealed that, in general, intra-regional imports are less prone to tariff evasion than inter-regional imports. The engagement in production networks presuppose efficiency and low cost of production. Thus, the existence of bureaucracy and corruption in the customs can be a hindrance to the engagement on it. Consequently, the creation of the business environment necessary to participate in production networks, resultant from agreements and other tacit measures that complement the decrease in import tariffs, should favor tariff evasion reduction in intra-regional trade. Another interesting feature is related to the difference in channels used to evade tariff in the intra and inter-regional cases. In the former case, underreport of quantities was the main channel employed, while in the later the underreport of unit price was the adopted channel. Given that customs are the same for both types of imports, the results reflect the existence of differences between imports inside and outside the production networks. Provided that production network members promote large volumes and high frequency trade, it is expected that customs officers are more used to the correct unit price of these imported products. However, opening the containers, inspecting how many items were imported and the weight of each imported variety, especially in the case of tiny parts and components, is a more complicated task to perform. These facts could explain the difference in channels adopted to evade tariffs in intra and inter-regional trade.

5.5.2 Trade gap, quantity gap, unit price gap, and mislabeling by machinery sector

In this subsection our interest is to use the heterogeneity between machinery sectors to analyze if the previous results depend or not on the machinery characteristics. We restrict our study to the two most important sectors of machinery: electric machinery and transport equipment. Based on the physical characteristic of each sector's parts and components (electric machinery ones tend to be tinier than the transport equipment ones) we can test if the practice of underreporting imported quantities is more common for one type of machinery than the other.

Following the same pattern of the previous subsection, Tables 5.5 and 5.6 present electric machinery and transport equipment results. Columns 1-2 in Table 5.5 reveal a weak relationship between tariff and trade evasion for electric machinery, while mislabeling coefficient is statistically insignificant. In column 3 the tariff coefficient is positive and statistically significant in the inter-regional imports, while the F statistic reveals no statistically significant relation in the intra-regional imports. Results in column 4 indicate the existence of a statistically significant relation between tariff and trade evasion just in inter-regional imports of electric machinery final products. A one percentage point increase in the tariff leads to an increase in the trade gap of 0.9% in inter-regional trade of final products. The F statistic reveals that there is no statistically significant relation between tariff and trade gap for intra and inter-regional imports of parts and components.

Columns 5-7 focus on the quantity gap. In column 5 the tariff coefficient is positive and statistically significant at the 10% level, indicating the existence of a weak relation between tariff level and tariff evasion. In the next column the inter-regional tariff coefficient is statistically insignificant, while the intra-regional one is statistically significant at the 1% level. In column 7 we identify that a one percentage point increase in the tariff of electric machinery leads to an increase in the quantity gap of 1.4% for intra-regional trade of parts and components. The coefficient for the inter-regional trade of final products is statistically significant, but at the 10% level, indicating a remote possibility of tariff evasion through quantity underreport, while no statistical relation is found for inter-regional trade of parts and components and intra-regional trade of final products.

Next, in columns 8-10 we focus on the unit price gap. In column 9 we observe that the coefficient for the tariff is positive and statistically significant, while the combined marginal effect for intra-regional imports is negative and statistically significant, indicating that inter-regional trade of electric machinery is more prone to tariff evasion through misreport of unit price. In column 10 the results indicate that evasion through misreport of unit price is a practice more common in inter-regional trade of parts and components, followed by inter-regional import of final products and intra-regional import of parts and components.

From the electric machinery results we can conclude that intra-regional trade of electric machinery is less prone to tariff evasion. We also observe that unit price misreport is the main channel used to evade import tariffs in the inter-regional trade, while the electric machinery parts and components intra-regional trade evasion occurs mainly through the misreport of traded quantities.

Table 5.5 – Effect of tariff rate, regional trade, and product type on electric machinery import tariff evasion

		Trade Gap				Quantity Gap			Unit Price Gap		
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Tariff		0.006*	0.007*	0.008**	0.009**	0.006*	0.004	0.007*	-0.001	0.004**	0.002
		(0.003)	(0.004)	(0.004)	(0.004)	(0.003)	(0.004)	(0.004)	(0.001)	(0.002)	(0.002)
PC					-0.188***			0.396***			-0.585***
					(0.039)			(0.043)			(0.019)
Tariff*PC					-0.003			-0.007			0.004*
					(0.005)			(0.006)			(0.002)
Intra-regional				-0.224	-0.215		-0.411*	-0.411*		0.187*	0.196*
				(0.211)	(0.213)		(0.217)	(0.219)		(0.109)	(0.110)
Tariff*Intra-regional				-0.005*	-0.011***		0.007**	-0.002		-0.012***	-0.009***
				(0.003)	(0.004)		(0.003)	(0.005)		(0.002)	(0.002)
Tariff*Intra-regional*PC					0.011**			0.016***			-0.005*
					(0.004)			(0.005)			(0.003)
Tariff on Similar Products			-0.002								
			(0.004)								
Tariff+Tariff*Intra=0 F stat				0.53	0.22		7.98	2.00		30.63	15.02
p-value				0.467	0.637		0.005	0.159		0.000	0.000
Tariff+Tariff*PC=0 F stat					1.66			0.01			8.12
p-value					0.198			0.905			0.005
Tariff+Tariff*Intra+Tariff*PC +Tariff*Intra*PC=0 F stat					1.66			8.26			19.67
p-value					0.199			0.004			0.000
Combined Effects											
Inter-regional	Final	0.006*	0.007*	0.008**	0.009**	0.006*	0.004	0.007*	-0.001	0.004**	0.002***
	P&C				0.006			0.000			0.006***
Intra-regional	Final			0.003	-0.002		0.011***	0.005		-0.008***	-0.007
	P&C				0.006			0.014***			-0.008***
Tariff on Similar Products			-0.002								
R^2		0.069	0.072	0.069	0.069	0.067	0.067	0.067	0.137	0.137	0.138
Observations		193378	175805	193378	193378	193378	193378	193378	193378	193378	193378

Given a restriction of space, the coefficients of secondary variables are omitted. Robust standard errors in parentheses: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

According to our hypothesis the intra-regional tariff evasion through quantity underreport was possible for electric machinery parts and components, because they are small and numerous, being harder of keeping track of the correct imported quantities. Nevertheless, if this fact is correct we expect that intra-regional imports of transport equipment should be less exposed to tariff evasion through quantity underreport, given that parts and components in this sector are in general big and consequently easier to be tracked. Table 5.6 exposes the results for transport equipment. The first four columns reveal that no statistically significant relation was found for the tariff coefficient. In column 2 the coefficient for tariff on similar products is statistically significant at the 5% level, revealing that mislabeling could be a channel used to evade tariffs. In the columns referent to quantity gap all coefficients of interest are statistically insignificant or the F statistic reveals that the relations are not statistically different from zero. The exception is the coefficient for the inter-regional import of final products that is weakly statistically significant and negative. From these columns we can conclude that misreport of quantity is hardly a channel used to evade transport equipment import tariff. In the last two columns of the table we identify evidences of tariff evasion in transport equipment. In column 9 the tariff coefficient is statistically significant and positive at the 5% level for the inter-regional import of final products, while the coefficient for the interaction of tariff and intra-regional trade dummy is negative and statistically significant at the 1% level. In the next column the coefficients reveal that inter-regional imports of final products are exposed to tariff evasion, being positive and statistically significant at the 1% level. On the opposite side, the coefficient for intra-regional import of final products is negative, but statistically significant at the 5% level. The coefficients for inter and intra-regional import of parts and components are statistically insignificant.

The results for transport equipment reveal that, compared to electric equipment, this sector hardly suffers with tariff evasion. Evidences were found of imports of final products being exposed to tariff evasion through unit price misreport. No evidences were found that intra-regional imports, in special the parts and components one, suffer with tariff evasion through the quantity misreport channel.

This subsection confirms that intra-regional trade is less prone to tariff evasion than inter-regional trade. The disaggregation of the data in parts and components and final products by machinery sector confirms that misreport of unit price is the main channel used to evade tariffs in inter-regional imports. On the intra-regional imports case we also found some evidences of unit price misreport and strong evidences of quantity misreport for electric machinery parts and components, corroborating the proposed hypothesis.

Table 5.6 – Effect of tariff rate, regional trade, and product type on transport equipment import tariff evasion

		Trade Gap				Quantity Gap			Unit Price Gap		
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Tariff		0.003	0.000	0.004	-0.001	0.000	-0.003	-0.009*	0.004	0.008**	0.008***
		(0.006)	(0.006)	(0.007)	(0.005)	(0.005)	(0.006)	(0.005)	(0.003)	(0.003)	(0.003)
PC					0.182			0.029			0.153
					(0.307)			(0.386)			(0.211)
Tariff*PC					0.016*			0.018*			-0.002
					(0.010)			(0.009)			(0.004)
Intra-regional				-2.477***	-2.493***		-7.730***	-7.739***		5.254***	5.246***
				(0.843)	(0.842)		(0.498)	(0.496)		(0.433)	(0.441)
Tariff*Intra-regional				-0.003	0.001		0.009	0.016**		-0.012***	-0.015***
				(0.007)	(0.006)		(0.007)	(0.006)		(0.003)	(0.003)
Tariff*Intra-regional*PC					-0.019*			-0.029***			0.011***
					(0.010)			(0.010)			(0.004)
Tariff on Similar Products			0.011**								
			(0.005)								
Tariff+Tariff*Intra=0 F stat				0.06	0.00		1.33	1.51		3.07	5.73
p-value				0.805	0.982		0.251	0.221		0.082	0.018
Tariff+Tariff*PC=0 F stat					1.58			0.63			1.77
p-value					0.211			0.429			0.186
Tariff+Tariff*Intra+Tariff*PC +Tariff*Intra*PC=0 F stat					0.05			0.23			0.21
p-value					0.829			0.635			0.651
Combined Effects											
Inter-regional	Final	0.003	0.000	0.004	-0.001	0.000	-0.003	-0.009*	0.004	0.008**	0.008***
	P&C				0.015			0.009			0.006
Intra-regional	Final			0.001	0		0.006	0.007		-0.004*	-0.007**
	P&C				-0.003			-0.004			0.002
Tariff on Similar Products			0.011**								
R^2		0.089	0.097	0.089	0.089	0.099	0.099	0.100	0.124	0.126	0.127
Observations		15122	12390	15122	15122	15122	15122	15122	15122	15122	15122

Given a restriction of space, the coefficients of secondary variables are omitted. Robust standard errors in parentheses: $^{*}\ p < 0.10$, $^{**}\ p < 0.05$, $^{***}\ p < 0.01$.

5.6 Robustness check

5.6.1 Production network products dummy

In the previous section it was analyzed the impact of import tariff rates on import tariff evasion depending on characteristics such as intra or inter-regional trade, the type of product (parts and components or final product), and machinery sector. The main objective of these exercises was to verify if trade related to production networks is less prone to tariff evasion or not. In this subsection we address the same question employing a more refined definition to separate the data in products with higher probability of being part of production networks and a group of non-production network products. Based on the definition of production networks we expect that countries engaged on it maintain stable and intensive trade flows of given products, what allow us to propose two definitions of production network dummies. In the less stringent one a dummy assumes value of one when there is a stable and intensive trade relation involving intra-regional countries. In other words, a given country must import a given product from other East Asian country (intra-regional trade) for at least three consecutive years (a stable trade relation) and the share of import of this product from this given country has to exceed a given threshold (an intensive trade relationship).[51] The second production network dummy has a similar definition, but the products are restricted just to parts and components. This restrictive definition is imposed, because it is not possible to distinguish production network imports from consumption imports. In other words, some countries offshore the assemble process and then import the final product in order to add some final value, through activities like packaging, distribution, and marketing, before exporting it

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[51] We define the import intensity by calculating the share of product k imported by country j from country i in period t over all imports of product k by country j in period t ($share_{ijkt} = (Import_{value})_{ijkt} / (Import_{value})_{jkt}$). We assume different levels of threshold varying from at least 5% to 25%.

to the final consumer. However, we cannot differentiate these cases from cases where the product is imported and consumed in the domestic market.

The first two columns of the top panel of Table 5.7[52] contain the results for trade gap considering products with a threshold of at least 25% share. We observe that a one percentage point increase in the tariff leads to 0.4% increase in the trade gap for production network products and 0.7% for non-production network products. However, the result for production network products is statistically significant just at the 10% level. This result provides a weak evidence that production network products suffer from tariff evasion. Besides this, we observe that production network products are less prone to tariff evasion than non-production network ones. For the more stringent definition a similar tariff increase leads to a growth in the trade gap of 0.6% for non-production and production network products. Nevertheless, the coefficient for production network products is statistically insignificant, indicating the inexistence of tariff evasion. The next two columns report the coefficients for quantity gap. As already verified, this channel was adopted as the main option to promote tariff evasion in East Asian intra-regional trade of parts and components. Observing the coefficients we verify a weak relation between non-production network products and tariff evasion, a coefficient of 0.3% at the 10% level, while for production network products a one percentage point increase in tariff rate leads to a 0.7% increase in quantity gap. When we limit production network products just to parts and components this relation becomes stronger, growing to 1.0%, while the coefficient for non-production network products becomes statistically insignificant. On the opposite side, the coefficients for unit price gap indicate that non-production network products have positive and statistically significant coefficient, while production network

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[52] Given the space constraint, tables 7 to 10 present just the calculated combined effects.

ones are negative. This result suggests that production network products are less prone to tariff evasion through unit price misreport than non-production network products.

Table 5.7 – Effect of tariff rate on production and non-production network products import tariff evasion

25% share threshold						
	Trade Value Gap		Quantity Gap		Unit Price Gap	
	(1)	(2)	(3)	(4)	(5)	(6)
Combined Effects						
Non-Production Network	0.007***	0.006***	0.003*	0.003	0.004***	0.003***
Production Network 1	0.004*		0.007**		-0.002**	
Production Network 2		0.006		0.010**		-0.004***
R^2	0.078	0.072	0.076	0.071	0.114	0.114
Observations	570087	570087	570087	570087	570087	570087

15% share threshold						
	Trade Value Gap		Quantity Gap		Unit Price Gap	
	(1)	(2)	(3)	(4)	(5)	(6)
Combined Effects						
Non-Production Network	0.007***	0.006***	0.004*	0.002	0.004***	0.003***
Production Network 1	0.004*		0.007***		-0.002**	
Production Network 2		0.005*		0.009***		-0.005***
R^2	0.083	0.074	0.080	0.073	0.114	0.114
Observations	570087	570087	570087	570087	570087	570087

5% share threshold						
	Trade Value Gap		Quantity Gap		Unit Price Gap	
	(1)	(2)	(3)	(4)	(5)	(6)
Combined Effects						
Non-Production Network	0.008***	0.006***	0.004*	0.002	0.004***	0.004***
Production Network 1	0.004**		0.008***		-0.003***	
Production Network 2		0.007**		0.01***		-0.003***
R^2	0.093	0.077	0.088	0.076	0.114	0.114
Observations	570087	570087	570087	570087	570087	570087

Given a restriction of space, the coefficients of secondary variables are omitted and just the combined effects are presented. Robust standard errors in parentheses: $^{*} p < 0.10$, $^{**} p < 0.05$, $^{***} p < 0.01$.

Relaxing the definition of trade intensity to share thresholds of 15% and 5% does not alter much the results. The results confirm that production network products are less prone to tariff evasion and indicate that production network tariff evasion happens mainly through quantity underreport, while in non-production network trade it concentrates on unit price underreport.

5.6.2 Comparison with Latin America

In this subsection we promote a comparison with the Latin American case to verify the existence or not of similar patterns. The objective of this exercise is to confirm if the results found were typical from production network organization or not. The first reason to choose Latin America is because it is also a region composed of few high-income and many middle-income countries.[53] Another reason is the existence of many studies in the economics field comparing both regions and their development patterns. The third and most important reason is the fact that, although there are machinery industries in both regions, it is known that differently from East Asia, Latin American regional integration and machinery production networks are still underdeveloped. Thus, if the previous results were attributed to production networks, it is expected that comparing both regions we find import tariff evasion patterns that reveal more dissimilitude than similitudes.

The coefficients in Table 5.8 are higher than the ones in Table 5.4. In the first column we verify that a one percentage point increase in the tariff leads to 1.1% increase in the total trade value gap. In the next column we observe a negative and statistically significant coefficient at the 1% level for similar products, indicating that mislabeling the import as a lower-taxed similar product is also a channel used to evade import tariffs in Latin America. Column 3 reveals that a one percentage point increase in the tariff rate leads to an increase of 1.1% in the inter-regional trade gap and 1.3% in intra-regional case. In the fourth column we observe that separating parts and components from final products

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[53] According to the available information from World Bank in 2016, Chile and Uruguay are classified as high-income countries; Argentina, Brazil, Colombia, Costa Rica, Ecuador, Panama, Paraguay, Peru, Venezuela (upper-middle-income countries), Bolivia, El Salvador, Guatemala, Honduras and Nicaragua (lower-middle-income countries) are classified as middle-income countries.

the former has lower coefficients. Differently from the East Asian case, the tariff impact on the trade gap is similar for intra and inter-regional trade, with just inter-regional trade of parts and components suffering slightly less from trade evasion. This indicates that imports origin, if it is inter or intra-regional, does not influence much in the tariff evasion. The next three columns reveal that the majority of the tariff evasion happens through underreport of quantities with intra-regional trade of parts and components being the only exception. Once again the origin of the trade does not affect the final products coefficients that are very similar. Coefficients in column 9 show that just in intra-regional trade there is import tariff evasion. The last column confirms that intra-regional imports suffer more from tariff evasion through misreport of unit prices, with parts and components being the most affected. Inter-regional trade coefficients are statistically significant, but at the 10% level, while both coefficients for final products are negative and close to zero.

A comparison between East Asian and Latin American results disclose the existence of different patterns in tariff evasion. We observe that coefficients for Latin America are higher than the East Asian ones. We also identify differences in the channels employed to evade tariffs. First, strong evidences of tariff evasion through misclassification were found in Latin America, while the same does not apply to the East Asian case. Second, in Latin America the coefficients for misreport of quantities and unit prices are statistically significant for almost all cases, indicating that all channels were employed to evade tariff. Finally, the most interesting result is the fact that, in general, inter and intra-regional import coefficients do not differentiate much, indicating that the origin of the imports does not matter for tariff evasion. The only exception applies to the fact that unit price misreport is more important than quantity misreport for the intra-regional import of parts and components.

Table 5.8 – Effect of tariff rate, regional trade, and product type on import tariff evasion in Latin America

		Trade Gap				Quantity Gap			Unit Price Gap		
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Combined Effects											
Inter-regional	Final	0.011***	0.020***	0.011***	0.013***	0.010***	0.011***	0.015***	0.001	0.000	-0.002*
	P&C				0.008***			0.006**			0.002*
Intra-regional	Final			0.013***	0.013***		0.010***	0.017***		0.002**	-0.003**
	P&C				0.012***			0.002			0.011***
Tariff on Similar Products			-0.019***								
R^2		0.065	0.068	0.065	0.065	0.088	0.088	0.088	0.143	0.143	0.143
Observations		864512	763650	864512	864512	864512	864512	864512	864512	864512	864512

Given a restriction of space, the coefficients of secondary variables are omitted and just the combined effects are presented. Robust standard errors in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Next, we explore the heterogeneity between different machinery sectors. Tables 5.9 and 5.10 contain the results for electric machinery and transport equipment. Once again the coefficients are slightly higher than the East Asian ones. A one percentage point increase in the import tariff leads to 0.9% increase in the trade gap for electric machinery and 0.9% for transport equipment. Mislabeling is also a tariff evasion channel utilized in both sectors. For electric machinery, evasion through quantity underreport occurs for the final products independent of the imports origin, while unit price misreport happens for the intra-regional import of parts and components at the 1% level and inter-regional import of final products at the 10% level. For transport equipment, evasion through unit price underreport is concentrated in parts and components imports, independent of the origin, while quantity underreport is verified just in inter-regional imports of final products.

The results in this subsection reveal the existence of different patterns of tariff evasion between East Asia and Latin America. In addition, we observe no clear pattern of differences in intra and inter-regional import tariff evasion in Latin America, while in the East Asian case the intra-regional imports are less prone to tariff evasion than the inter-regional ones. Furthermore, for the Latin American case all channels were employed to evade the import tariff, while in the East Asian case the channels were chosen according to the exporter region and if final products or parts and components were imported.

Table 5.9 – Effect of tariff rate, regional trade, and product type on Latin American electric machinery import tariff evasion

		Trade Gap				Quantity Gap			Unit Price Gap		
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Combined Effects											
Inter-regional	Final	0.009***	0.016***	0.007**	0.009**	0.008**	0.008*	0.013***	0.001	-0.001	-0.004*
	P&C				0.006			0.005			0.001
Intra-regional	Final			0.012***	0.015***		0.007*	0.017***		0.005***	-0.001
	P&C				0.009**			-0.001			0.011***
Tariff on Similar Products			-0.023***								
R^2		0.078	0.082	0.078	0.078	0.096	0.096	0.096	0.137	0.137	0.137
Observations		270662	236322	270662	270662	270662	270662	270662	270662	270662	270662

Given a restriction of space, the coefficients of secondary variables are omitted and just the combined effects are presented. Robust standard errors in parentheses: $^{*} p < 0.10$, $^{**} p < 0.05$, $^{***} p < 0.01$.

Table 5.10 – Effect of tariff rate, regional trade, and product type on Latin American transport equipment import tariff evasion

		Trade Gap				Quantity Gap			Unit Price Gap		
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Combined Effects											
Inter-regional	Final	0.009***	0.013***	0.011***	0.013***	0.008**	0.010***	0.013***	0.001	0.001	0.000
	P&C				0.002			-0.003			0.006**
Intra-regional	Final			0.001	0.003		0.002	0.006		-0.001	-0.003
	P&C				-0.004			-0.012			0.009***
Tariff on Similar Products			-0.009**								
R^2		0.081	0.086	0.081	0.081	0.094	0.094	0.095	0.177	0.177	0.178
Observations		96073	83122	96073	96073	96073	96073	96073	96073	96073	96073

Note: Given a restriction of space, the coefficients of secondary variables are omitted and just the combined effects are presented. Robust standard errors in parentheses: $^{*} p < 0.10$, $^{**} p < 0.05$, $^{***} p < 0.01$.

5.7 Final considerations

This chapter contributes to the production network and tariff evasion literature by examining if the environment created by the development of machinery production networks affected the levels of import tariff evasion inside and outside this production structure. We followed Fisman and Wei's (2004) approach to estimate the relationship between import tariff rate and import tariff evasion for East Asian countries intra and inter-regional import of machinery products. Differences in tariff evasion between parts and components and final products were considered. We also analyzed the differences in tariff evasion between the main machinery sectors: electric machinery and transport equipment.

The econometric estimations revealed that inter-regional imports are more prone to tariff evasion than intra-regional ones. This evidence is in accordance with the hypothesis that the business environment necessary for the engagement in production networks favor the reduction in tariff evasion. The study of the different channels available to evade tariffs and the heterogeneity between different machinery sectors and product types revealed that quantity underreport is a practice more common in intra-regional imports of electric machinery parts and components. On the opposite side, underreport of unit prices was the main channel employed to evade tariffs in the inter-regional import case.

The employment of dummies with the purpose of improving the data classification in production and non-production network products resulted in very similar outcomes, with production network products been less prone to tariff evasion and having quantity underreport as the main channel employed to evade tariffs. In contrast, the unit price underreport was the main channel employed to evade tariffs in East Asian imports of non-production network products.

Finally, a comparison between the import tariff evasion patterns of East Asia and Latin America revealed that in the latter case, a region where machinery production networks are still underdeveloped, the coefficients are higher than in the former one. Besides this, there were no clear differences between Latin American intra and inter-regional import tariff evasion. Furthermore, for the Latin American case all channels were employed to evade the import tariff. The prevalence of dissimilitude in the tariff evasion patterns between the two regions endorse the hypothesis that the patterns found in the East Asian case are specific of production network.

APPENDIX

Table A.1.1 – List of Machinery Parts and Components

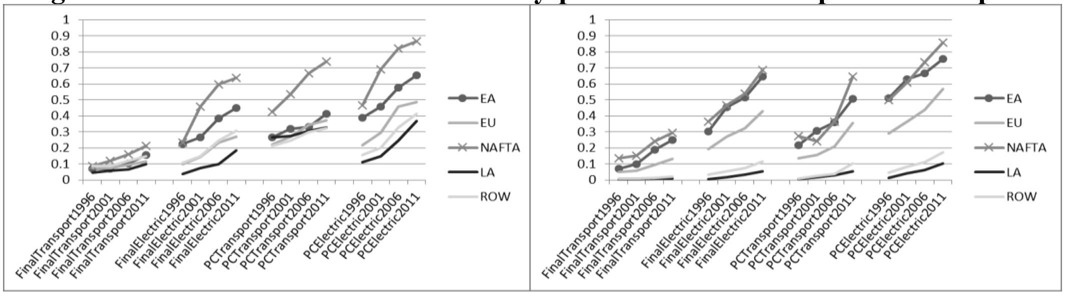
HS 1992 (433 parts & components and 691 finished products; 1,124 product codes in total)
840140, 840290, 840390, 840490, 840590, 8406, 8407, 8408, 8409, 8410, 8411, 8412, 8413, 8414, 841590, 8416, 8417, 841891, 841899, 841990, 842091, 842099, 842123, 842129, 842131, 842191, 8431, 843290, 843390, 843490, 843590, 843691, 843699, 843790, 843890, 843991, 843999, 844090, 844190, 844240, 844250, 844390, 8448, 845090, 845190, 845240, 845290, 845390, 845490, 845590, 8466, 846791, 846792, 846799, 846890, 8473, 847490, 847590, 847690, 847790, 847890, 847990, 8480, 8481, 8482, 8483, 8484, 8485, 8503, 850490, 8505, 850690, 8507, 850890, 850990, 851090, 8511, 8512, 851390, 851490, 851590, 851690, 851790, 851840, 851850, 851890, 8522, 8529, 853090, 8531, 8532, 8533, 8534, 8535, 8536, 8537, 8538, 8539, 8540, 8541, 8542, 854390, 8544, 8545, 8546, 8547, 8548, 8607, 8706, 8707, 8708, 870990, 8714, 871690, 8803, 8805, 9001, 9002, 9003, 900590, 900691, 900699, 900791, 900792, 900890, 900990, 901090, 901190, 901290, 9013, 9014, 901590, 901790, 902490, 902590, 902690, 902790, 902890, 902990, 903090, 903190, 903290, 9033, 9104, 9110, 9111, 9112, 9113, 9114, 9209.

Source: Kimura and Obashi (2010).

Table A.1.2 – Country List

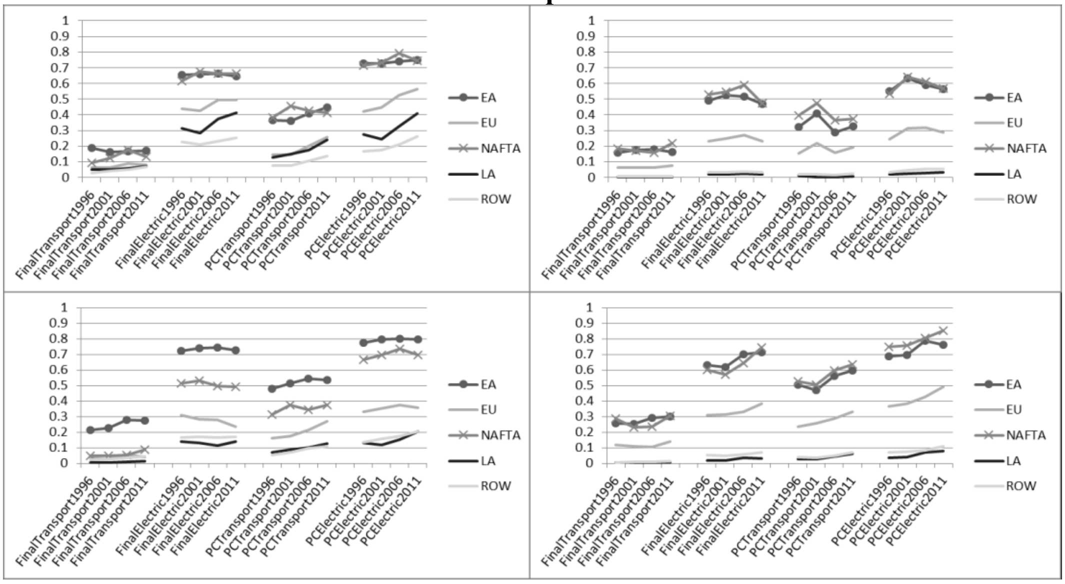
ISO3	Name	ISO3	Name	ISO3	Name
ALB	Albania	GRC	Greece	PER	Peru
DZA	Algeria	GTM	Guatemala	PHL	Philippines
ARG	Argentina	HND	Honduras	POL	Poland
AUS	Australia	HUN	Hungary	PRT	Portugal
AUT	Austria	ISL	Iceland	KOR	Rep. of Korea
AZE	Azerbaijan	IND	India	MDA	Rep. of Moldova
BOL	Bolivia	IDN	Indonesia	ROU	Romania
BRA	Brazil	IRL	Ireland	RUS	Russian Federation
BGR	Bulgaria	ISR	Israel	SAU	Saudi Arabia
CMR	Cameroon	ITA	Italy	SEN	Senegal
CAN	Canada	JAM	Jamaica	SGP	Singapore
CHL	Chile	JPN	Japan	SVK	Slovakia
CHN	China	KGZ	Kyrgyzstan	SVN	Slovenia
HKG	China, Hong Kong SAR	LVA	Latvia	ESP	Spain
COL	Colombia	LTU	Lithuania	SDN	Sudan
CRI	Costa Rica	MYS	Malaysia	SWE	Sweden
CIV	Cote d'Ivoire	MLI	Mali	CHE	Switzerland
HRV	Croatia	MLT	Malta	MKD	TFYR of Macedonia
CYP	Cyprus	MUS	Mauritius	THA	Thailand
CZE	Czech Rep.	MEX	Mexico	TUN	Tunisia
DNK	Denmark	MAR	Morocco	TUR	Turkey
ECU	Ecuador	NLD	Netherlands	UGA	Uganda
EGY	Egypt	NZL	New Zealand	UKR	Ukraine
SLV	El Salvador	NIC	Nicaragua	GBR	United Kingdom
EST	Estonia	NER	Niger	TZA	United Rep. of Tanzania
FIN	Finland	NGA	Nigeria	URY	Uruguay
FRA	France	NOR	Norway	USA	USA
GEO	Georgia	OMN	Oman	VEN	Venezuela
DEU	Germany	PAN	Panama	ZMB	Zambia
GHA	Ghana	PRY	Paraguay		

Figure A.1.1 – The share of active country-pair links: India's exports and imports



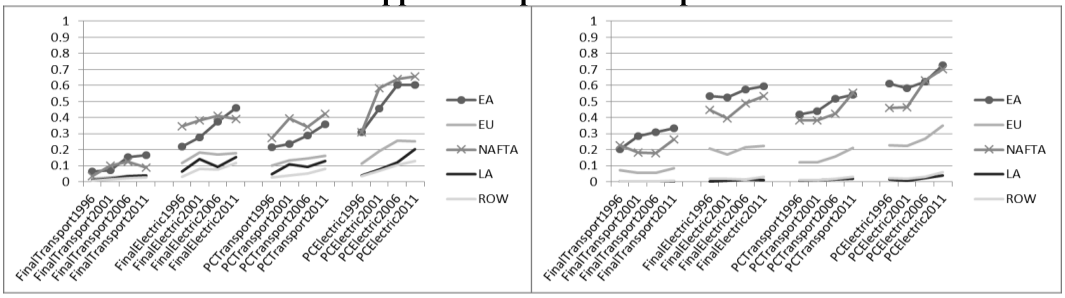
Source: Author's calculation using data from the UN Comtrade.

Figure A.1.2 – The share of active country-pair links: Hong Kong and Singapore's exports and imports



Source: Author's calculation using data from the UN Comtrade.

Figure A.1.3 – The share of active country-pair links: Indonesia, Malaysia, and Philippines's exports and imports



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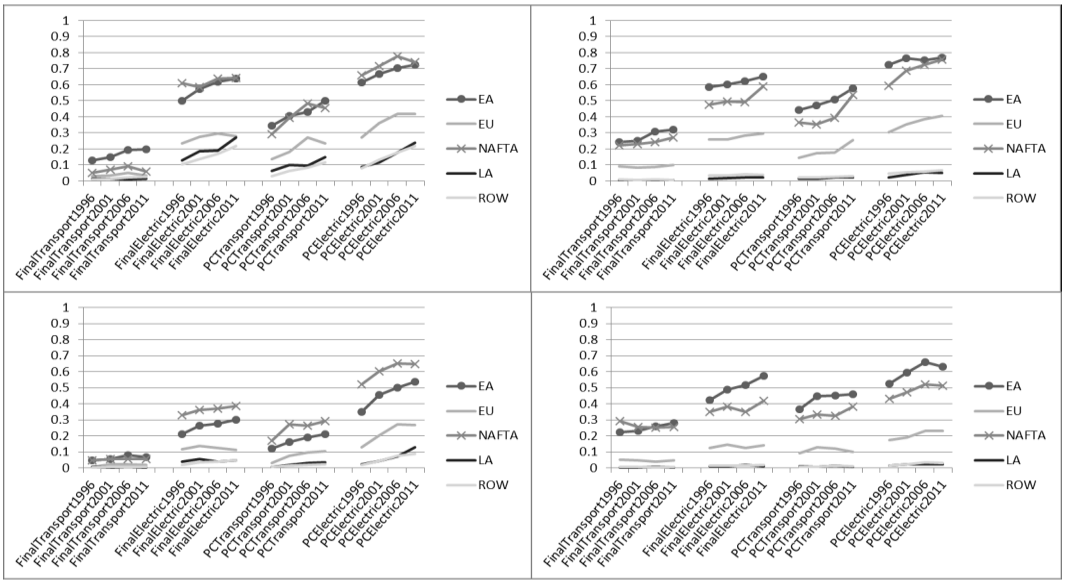
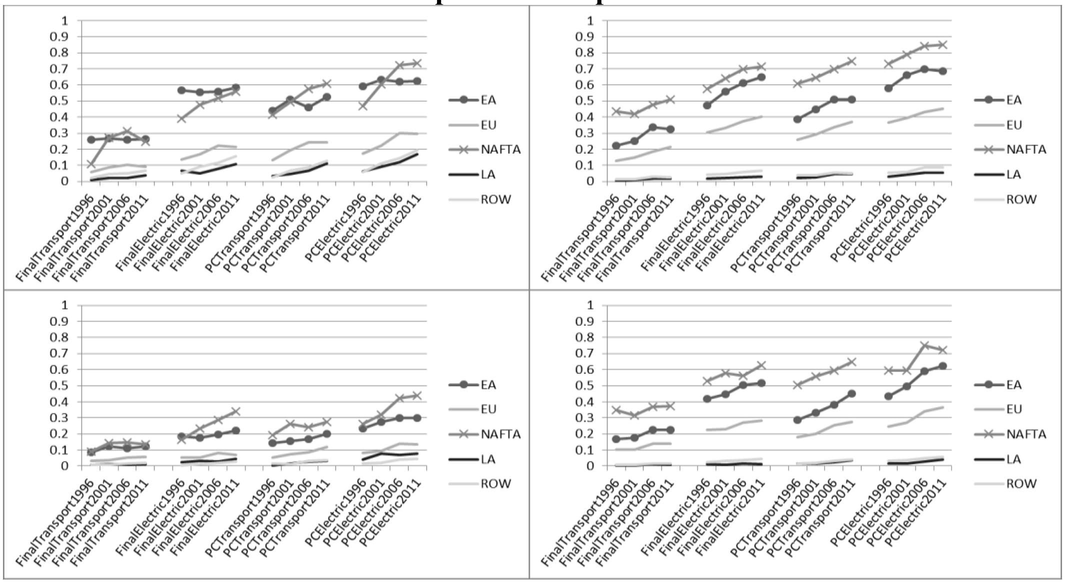


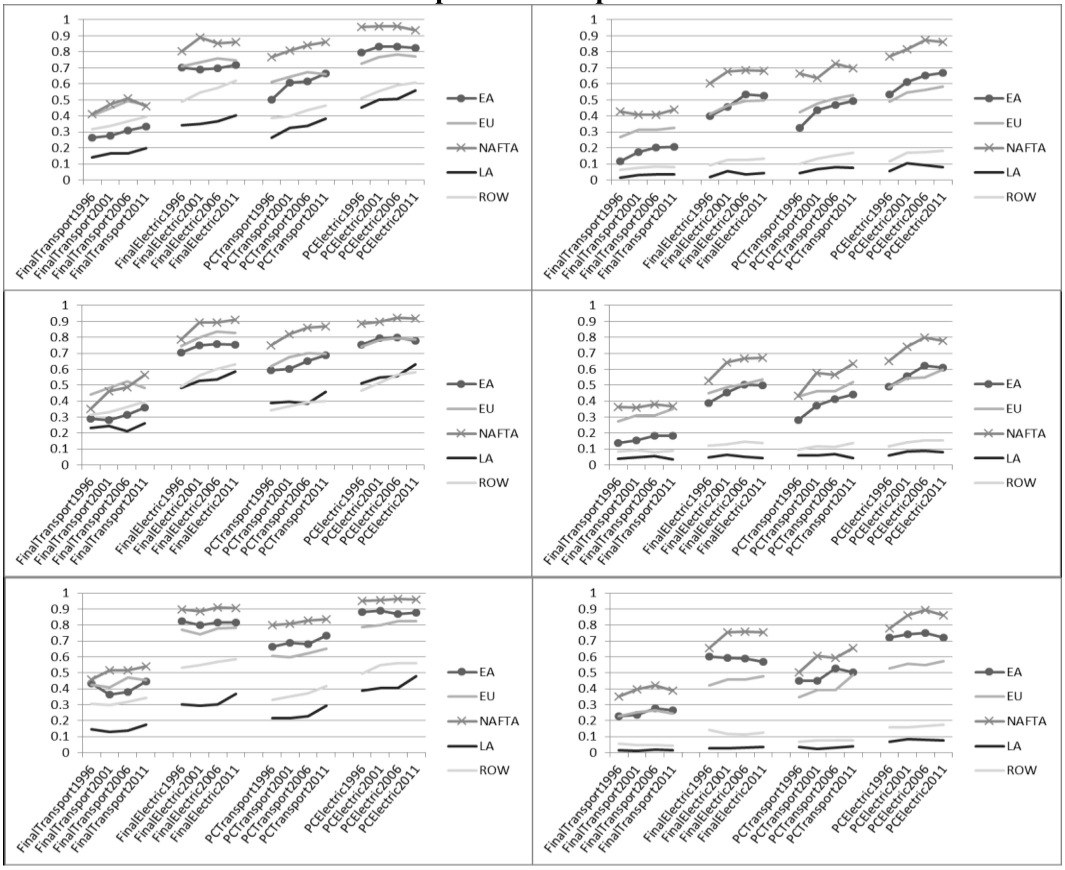
Source: Author's calculation using data from the UN Comtrade.

Figure A.1.4 – The share of active country-pair links: Australia and New Zealand's exports and imports



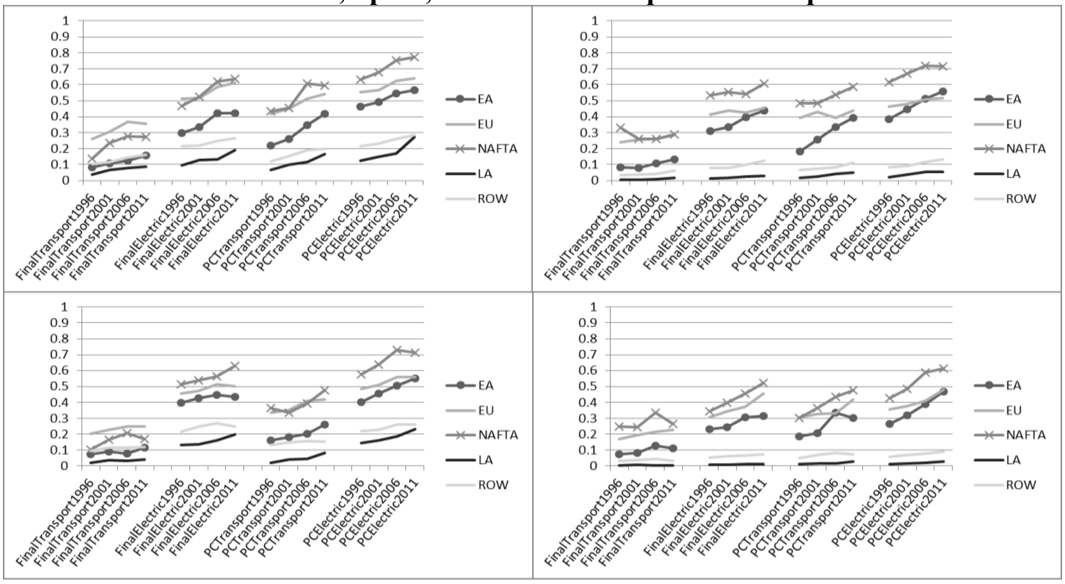
Source: Author's calculation using data from the UN Comtrade.

Figure A.1.5 – The share of active country-pair links: France, Italy, and United Kingdom's exports and imports



Source: Author's calculation using data from the UN Comtrade.

Figure A.1.6 – The share of active country-pair links: Austria, Denmark, Finland, Netherland, Spain, and Sweden's exports and imports



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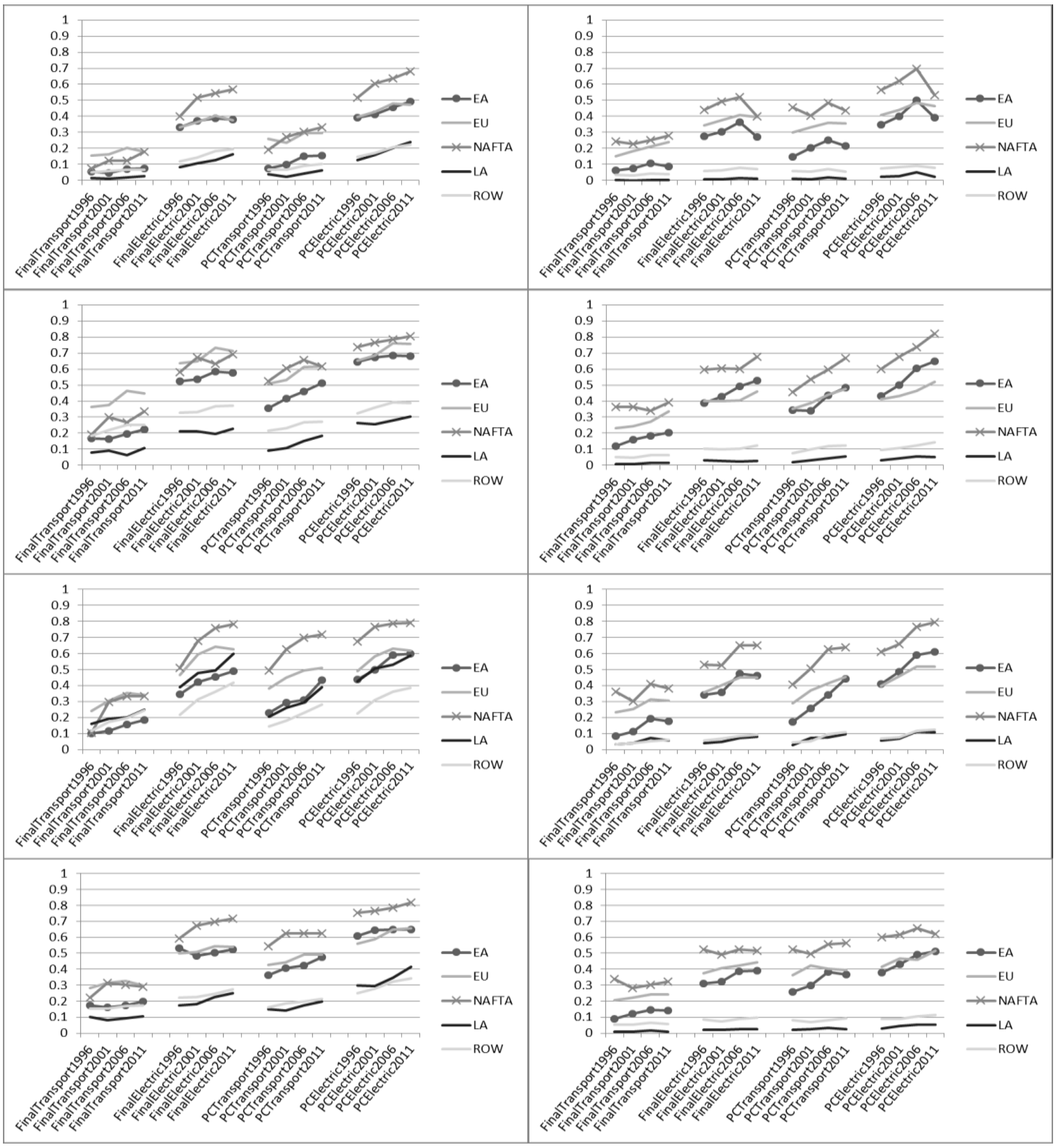
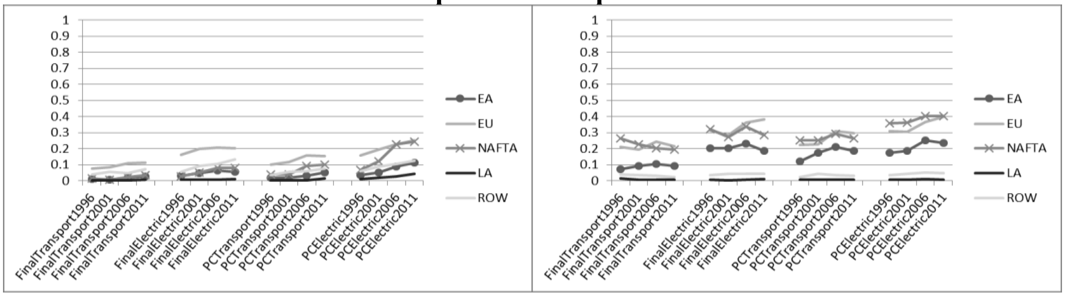


Source: Author's calculation using data from the UN Comtrade.

Figure A.1.7 – The share of active country-pair links: Greece, Ireland, and Portugal's exports and imports



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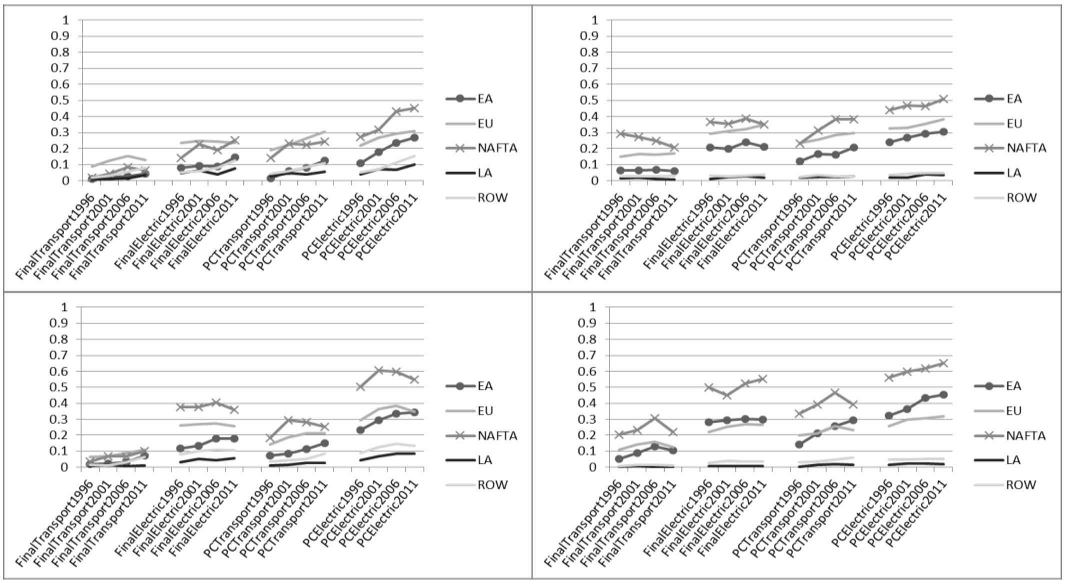
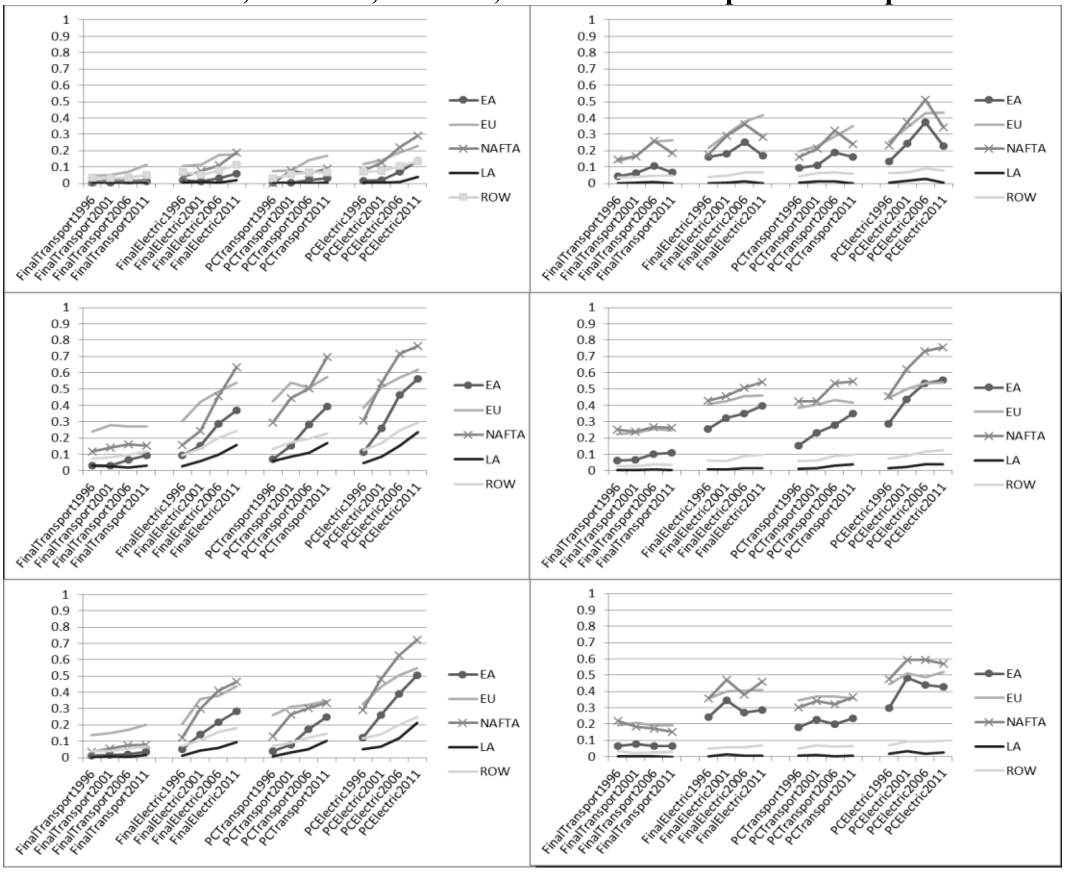


Source: Author's calculation using data from the UN Comtrade.

Figure A.1.8 – The share of active country-pair links: Bulgaria, Czech Republic, Hungary, Lithuania, Romania, Slovakia, and Slovenia's exports and imports



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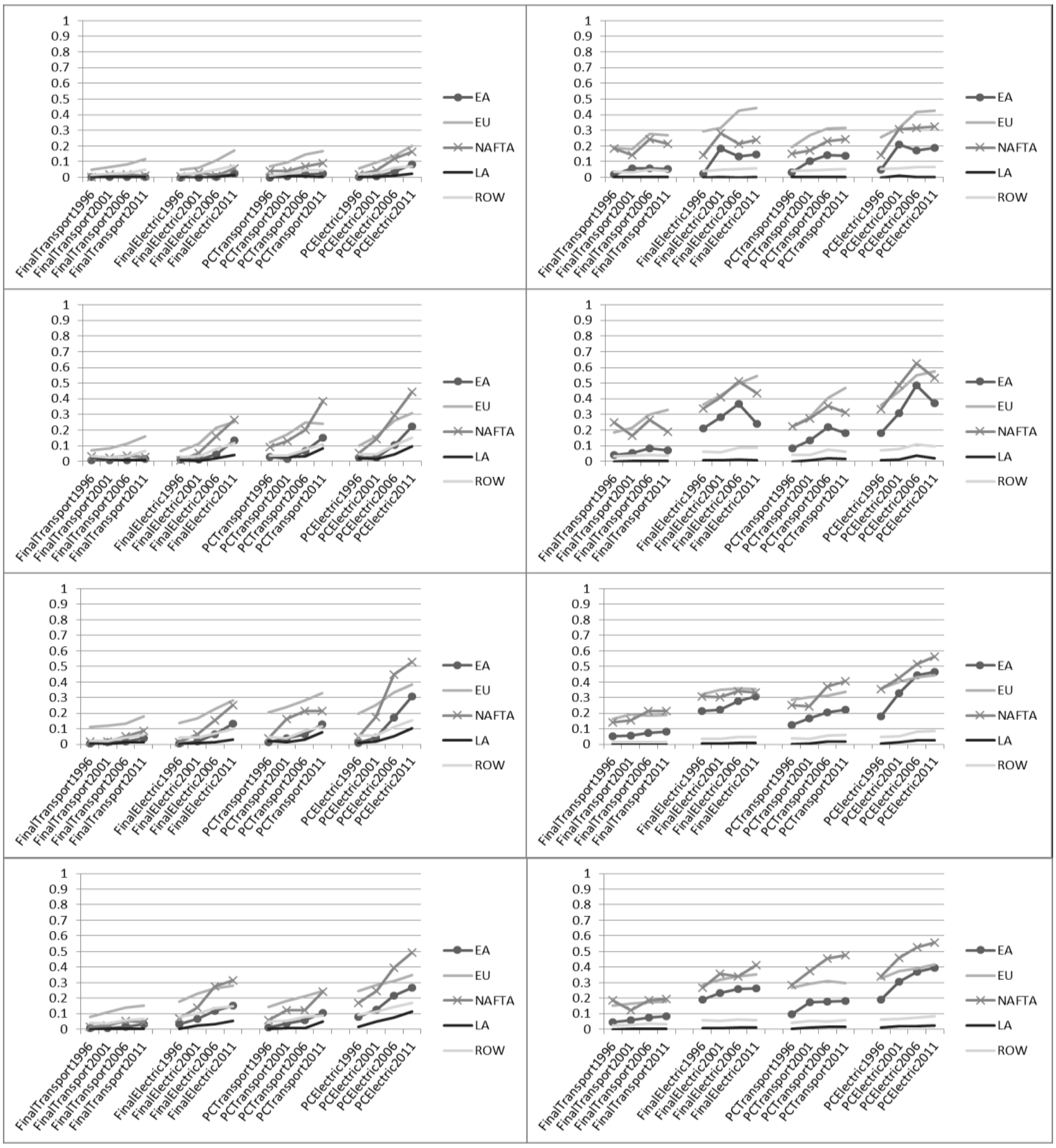
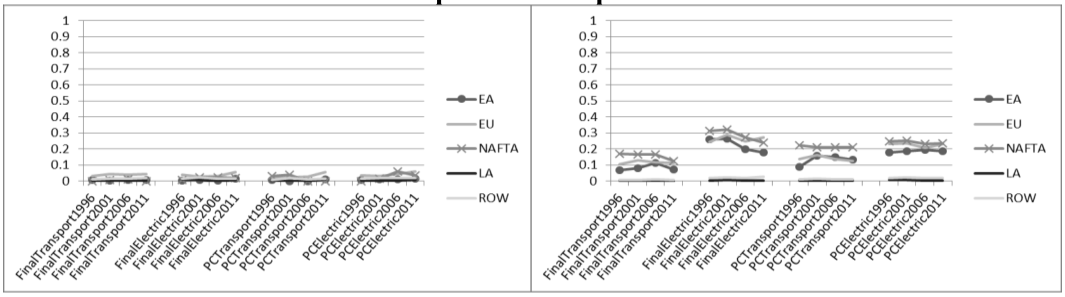


Source: Author's calculation using data from the UN Comtrade.

Figure A.1.9 – The share of active country-pair links: Cyprus, Estonia, Latvia, and Malta's exports and imports



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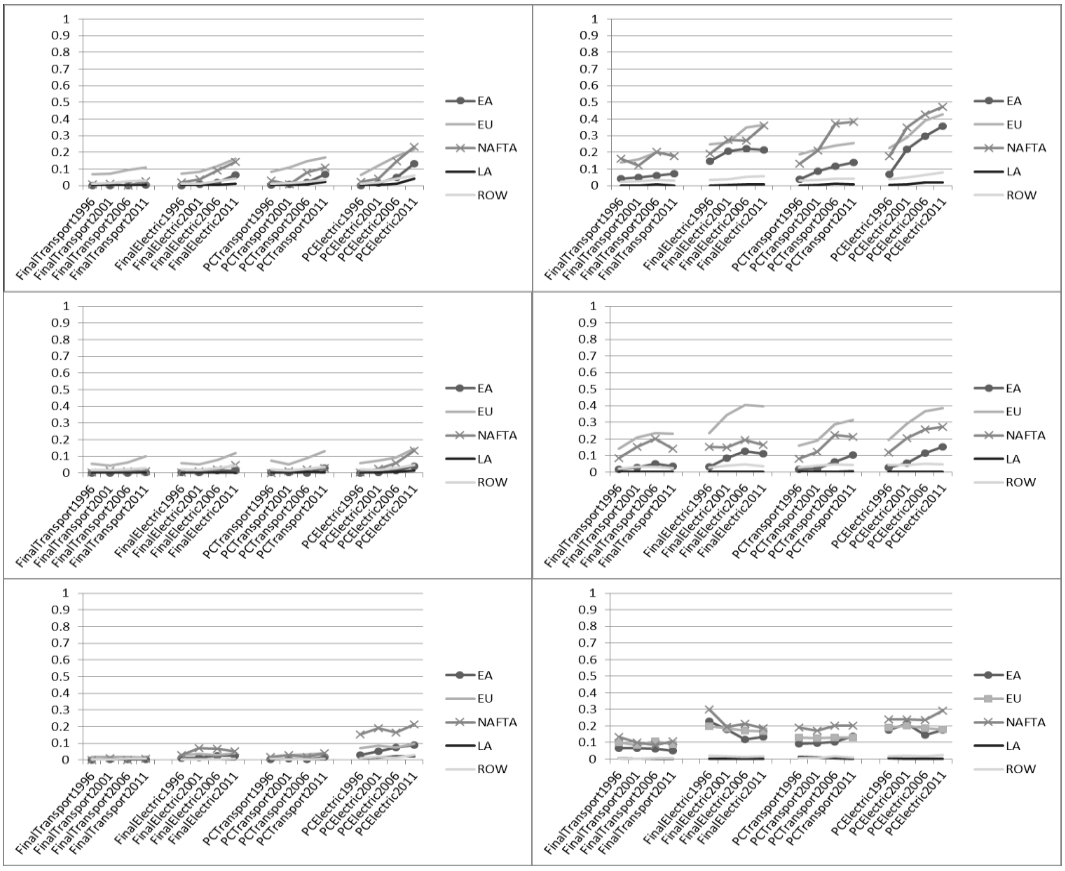
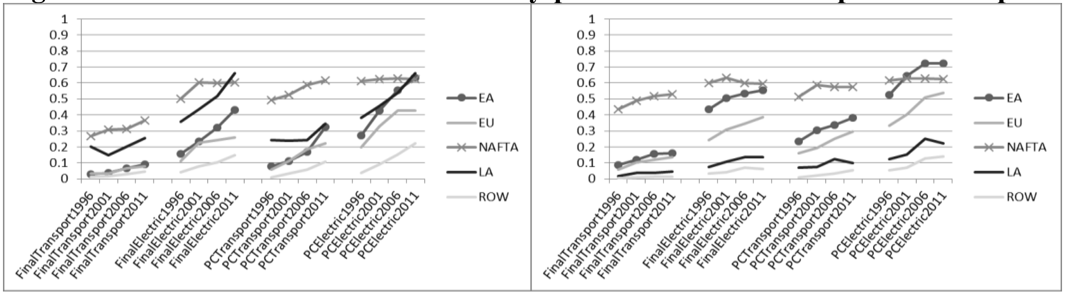


Source: Author's calculation using data from the UN Comtrade.

Figure A.1.10 – The share of active country-pair links: Mexico's exports and imports



Source: Author's calculation using data from the UN Comtrade.

Table A.2.1 – Gravity model estimation for transport equipment trade with EA and LA dummies

	1996		2001		2006		2011	
	Final	P&C	Final	P&C	Final	P&C	Final	P&C
				Exports				
EA	0.38	0.25	0.39	0.17	0.54^{**}	0.43^{***}	0.11	0.22
	(0.25)	(0.27)	(0.27)	(0.23)	(0.24)	(0.17)	(0.19)	(0.17)
LA	-0.68^{**}	-0.16	-0.27	-0.41^{**}	-0.06	-0.24	-0.56	-0.86^{**}
	(0.34)	(0.32)	(0.31)	(0.20)	(0.25)	(0.25)	(0.38)	(0.41)
Observations	7832	7832	7832	7832	7832	7832	7832	7832
R^2	0.602	0.753	0.695	0.841	0.617	0.779	0.602	0.614
				Imports				
EA	-0.01	-0.07	-0.73^{***}	-0.34^{*}	-0.49^{**}	-0.08	-0.24	-0.22
	(0.23)	(0.27)	(0.26)	(0.19)	(0.20)	(0.17)	(0.20)	(0.19)
LA	-0.02	-0.31	-0.24	-0.28	-0.17	-0.19	0.22	-0.13
	(0.23)	(0.28)	(0.23)	(0.19)	(0.21)	(0.19)	(0.20)	(0.19)
Observations	7832	7832	7832	7832	7832	7832	7832	7832
R^2	0.577	0.75	0.700	0.847	0.608	0.773	0.615	0.628

Given a restriction of space, the coefficients of secondary variables are omitted. Robust standard errors in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.3.1 Country List by Regions

Region	ISO-3	Country	Region	ISO-3	Country
LA	ARG	Argentina	ROW	FRA	France
LA	BRA	Brazil	ROW	DEU	Germany
LA	COL	Colombia	ROW	GRC	Greece
LA	CRI	Costa Rica	ROW	HUN	Hungary
LA	CHL	Chile	ROW	ISL	Iceland
LA	MEX	Mexico	ROW	IND	India
LA	PER	Peru	ROW	IRL	Ireland
NA	CAN	Canada	ROW	ISR	Israel
NA	USA	United States	ROW	ITA	Italy
EA	BRN	Brunei Darussalam	ROW	LVA	Latvia
EA	CHN	China	ROW	LTU	Lithuania
EA	IDN	Indonesia	ROW	LUX	Luxembourg
EA	HKG	China, Hong Kong	ROW	MLT	Malta
EA	JPN	Japan	ROW	MAR	Morocco
EA	KHM	Cambodia	ROW	NLD	Netherlands
EA	KOR	Korea	ROW	NZL	New Zealand
EA	MYS	Malaysia	ROW	NOR	Norway
EA	PHL	Philippines	ROW	POL	Poland
EA	SGP	Singapore	ROW	PRT	Portugal
EA	THA	Thailand	ROW	ROW	Rest of the world
EA	TWN	Chinese Taipei	ROW	ROU	Romania
EA	VNM	Viet Nam	ROW	RUS	Russian Federation
ROW	AUS	Australia	ROW	SAU	Saudi Arabia
ROW	AUT	Austria	ROW	SVK	Slovak Republic
ROW	BEL	Belgium	ROW	SVN	Slovenia
ROW	BGR	Bulgaria	ROW	ZAF	South Africa
ROW	HRV	Croatia	ROW	ESP	Spain
ROW	CYP	Cyprus	ROW	SWE	Sweden
ROW	CZE	Czech Republic	ROW	CHE	Switzerland
ROW	DNK	Denmark	ROW	TUN	Tunisia
ROW	EST	Estonia	ROW	TUR	Turkey
ROW	FIN	Finland	ROW	GBR	United Kingdom

Table A.4.1 Country List by Regions

Region	Name	Region	Name	Region	Name
North America	Canada	EU	Netherlands	ROW	Cote d'Ivoire
North America	USA	EU	Poland	ROW	Croatia
China	China	EU	Portugal	ROW	Egypt
China	China, Hong Kong	EU	Romania	ROW	Georgia
EA	Australia	EU	Slovakia	ROW	Ghana
EA	India	EU	Slovenia	ROW	Iceland
EA	Indonesia	EU	Spain	ROW	Israel
EA	Japan	EU	Sweden	ROW	Jamaica
EA	Malaysia	EU	United Kingdom	ROW	Kyrgyzstan
EA	New Zealand	LA	Argentina	ROW	Mali
EA	Philippines	LA	Bolivia	ROW	Mauritius
EA	Rep. of Korea	LA	Brazil	ROW	Morocco
EA	Singapore	LA	Chile	ROW	Niger
EA	Thailand	LA	Colombia	ROW	Nigeria
EU	Austria	LA	Costa Rica	ROW	Norway
EU	Bulgaria	LA	Ecuador	ROW	Oman
EU	Czech Rep.	LA	El Salvador	ROW	Rep. of Moldova
EU	Cyprus	LA	Guatemala	ROW	Russian
EU	Denmark	LA	Honduras	ROW	Saudi Arabia
EU	Estonia	LA	Mexico	ROW	Senegal
EU	Finland	LA	Nicaragua	ROW	Sudan
EU	France	LA	Panama	ROW	Switzerland
EU	Germany	LA	Paraguay	ROW	Rep. of Macedonia
EU	Greece	LA	Peru	ROW	Tunisia
EU	Hungary	LA	Uruguay	ROW	Turkey
EU	Ireland	LA	Venezuela	ROW	Uganda
EU	Italy	ROW	Albania	ROW	Ukraine
EU	Latvia	ROW	Algeria	ROW	Tanzania
EU	Lithuania	ROW	Azerbaijan	ROW	Zambia
EU	Malta	ROW	Cameroon		

Table A.4.2 List of Latin American preferential trade agreements

Agreement	Year that entered in force	Type	Number of enforceable provisions
Panama-Chile	2008	FTA & EIA	12
CAN	1988	CU	15
Chile-Costa Rica	2002	FTA & EIA	16
MERCOSUR	1991	CU & EIA	17
Central American Common Market (CACM)	1961	CU	18
Chile-Honduras	2008	FTA & EIA	18
Chile-Guatemala	2010	FTA & EIA	18
Chile-El Salvador	2002	FTA & EIA	19
CAFTA-DR	2006	FTA & EIA	19
Mexico-Uruguay	2004	FTA & EIA	21
Panama-El Salvador	2003	FTA & EIA	22
Panama-Costa Rica	2008	FTA & EIA	22
Colombia-Northern Triangle	2009	FTA & EIA	22
Panama-Guatemala	2009	FTA & EIA	22
Panama-Honduras	2009	FTA & EIA	22
Peru-Chile	2009	FTA & EIA	22
Chile-Mexico	1999	FTA & EIA	24
El Salvador-Honduras	2008	FTA & EIA	24
Panama-Nicaragua	2009	FTA & EIA	24
Chile-Colombia	2009	FTA & EIA	25
Colombia-Mexico	1995	FTA & EIA	27

Table A.5.1 – Country List by Regions

Region	Name	Region	Name	Region	Name
NAFTA	Canada	EU	Malta	ROW	Cote d'Ivoire
NAFTA	Mexico	EU	Netherlands	ROW	Croatia
NAFTA	USA	EU	Poland	ROW	Egypt
East Asia	Brunei Darussalam	EU	Portugal	ROW	Georgia
East Asia	Cambodia	EU	Romania	ROW	Ghana
East Asia	China	EU	Slovakia	ROW	Iceland
East Asia	China, Hong Kong	EU	Slovenia	ROW	India
East Asia	Indonesia	EU	Spain	ROW	Israel
East Asia	Japan	EU	Sweden	ROW	Jamaica
East Asia	Malaysia	EU	United Kingdom	ROW	Kyrgyzstan
East Asia	Myanmar	Latin America	Argentina	ROW	Mali
East Asia	Philippines	Latin America	Bolivia	ROW	Mauritius
East Asia	Rep. of Korea	Latin America	Brazil	ROW	Morocco
East Asia	Singapore	Latin America	Chile	ROW	New Zealand
East Asia	Thailand	Latin America	Colombia	ROW	Niger
East Asia	Vietnam	Latin America	Costa Rica	ROW	Nigeria
EU	Austria	Latin America	Ecuador	ROW	Norway
EU	Bulgaria	Latin America	El Salvador	ROW	Oman
EU	Czech Rep.	Latin America	Guatemala	ROW	Rep. of Moldova
EU	Cyprus	Latin America	Honduras	ROW	Russian
EU	Denmark	Latin America	Nicaragua	ROW	Saudi Arabia
EU	Estonia	Latin America	Panama	ROW	Senegal
EU	Finland	Latin America	Paraguay	ROW	Sudan
EU	France	Latin America	Peru	ROW	Switzerland
EU	Germany	Latin America	Uruguay	ROW	Rep. of Macedonia
EU	Greece	Latin America	Venezuela	ROW	Tunisia
EU	Hungary	ROW	Albania	ROW	Turkey
EU	Ireland	ROW	Algeria	ROW	Uganda
EU	Italy	ROW	Australia	ROW	Ukraine
EU	Latvia	ROW	Azerbaijan	ROW	Tanzania
EU	Lithuania	ROW	Cameroon	ROW	Zambia

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