Geometry of Global Value Chains in East Asia: The Role of Industrial Networks and Trade Policies

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Separata of a chapter published in:
"GLOBAL VALUE CHAINS IN A CHANGING WORLD"
Edited by Deborah K. Elms and Patrick Low
Fung Global Institute (FGI), Nanyang Technological University (NTU),
and World Trade Organization (WTO), 2013
ISBN: 978-92-870-3882-1

Summary: Deepening industrial interdependency in East Asia was not just a spontaneous phenomenon but it has been carefully aided and facilitated by the series of policies implemented by national governments. The objective of the paper is to provide a non-technical introduction to the use of input-output analysis and graph theory for understanding trade in the global value chains perspective. Applying these topological properties to the East Asian and Pacific context, we show that the inter-industry network moved from a simple hub and spokes cluster to a much more complex structure with the emergence of China and the specialization of several countries as secondary pivots. The densification of productive networks resulted from the coincidence of business strategies with the promotion of export-led growth strategies from developing East Asian countries. These countries applied a series of trade facilitation policies that lowered tariff duties and reduced other transaction costs. Tariff escalation was greatly reduced, lessening the anti-export bias attached to high effective protection rates and improving the competitiveness of second-tier national suppliers. The other axis of trade facilitation focused on improving logistics services and cross-border procedures. While the East Asia region is well ahead of the rest of developing Asia in this respect, there is still a wide margin of progress in order to close the gap with best international practices.

Key words: Global value chains, industrial networks, regional integration, East Asia, effective protection rate, trade facilitation.
JEL Classification: D57, F13, F14, F15, F23, O19, O24

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Geometry of global value chains in East Asia: the role of industrial networks and trade policies

Hubert Escaith and Satoshi Inomata

5.1. Introduction

East Asia is one of the best-known examples of a regional economic integration process that was initially driven by deepening industrial relations, rather than by political agreements, among countries of the region. The institutional or legal aspects of regional integration came only afterwards, in a typical “bottom-up” way. The situation differs from what has occurred in North America, where the ratification of the North America Free Trade Agreement (NAFTA) was a catalyst for the build-up of the US-Mexico economic ties.

What is important about East Asian integration, however, is that the deepening economic interdependency was not just a spontaneous phenomenon but it has been carefully aided and facilitated by the series of policies implemented by national governments. It is this interactive dimension of Asian integration, between industrial dynamics on the one hand and institutional development on the other, which presents the focus of this study.

In this line, the paper is structured as follows. The first part will show the evolution of regional supply chains in East Asia, using the information derived from international input-output (I-O) tables in order to map the dynamics of industrial linkages. The second part will demonstrate how trade and trade facilitation policies reduced the cost of doing business in the region and opened the way for further economic integration. The third part will conclude the discussion.

5.2. Evolution of regional supply chains in East Asia

In the modern production system, goods and services are processed through the progressive commitment of various industries in which a product of one industry is used as an intermediate input of others.

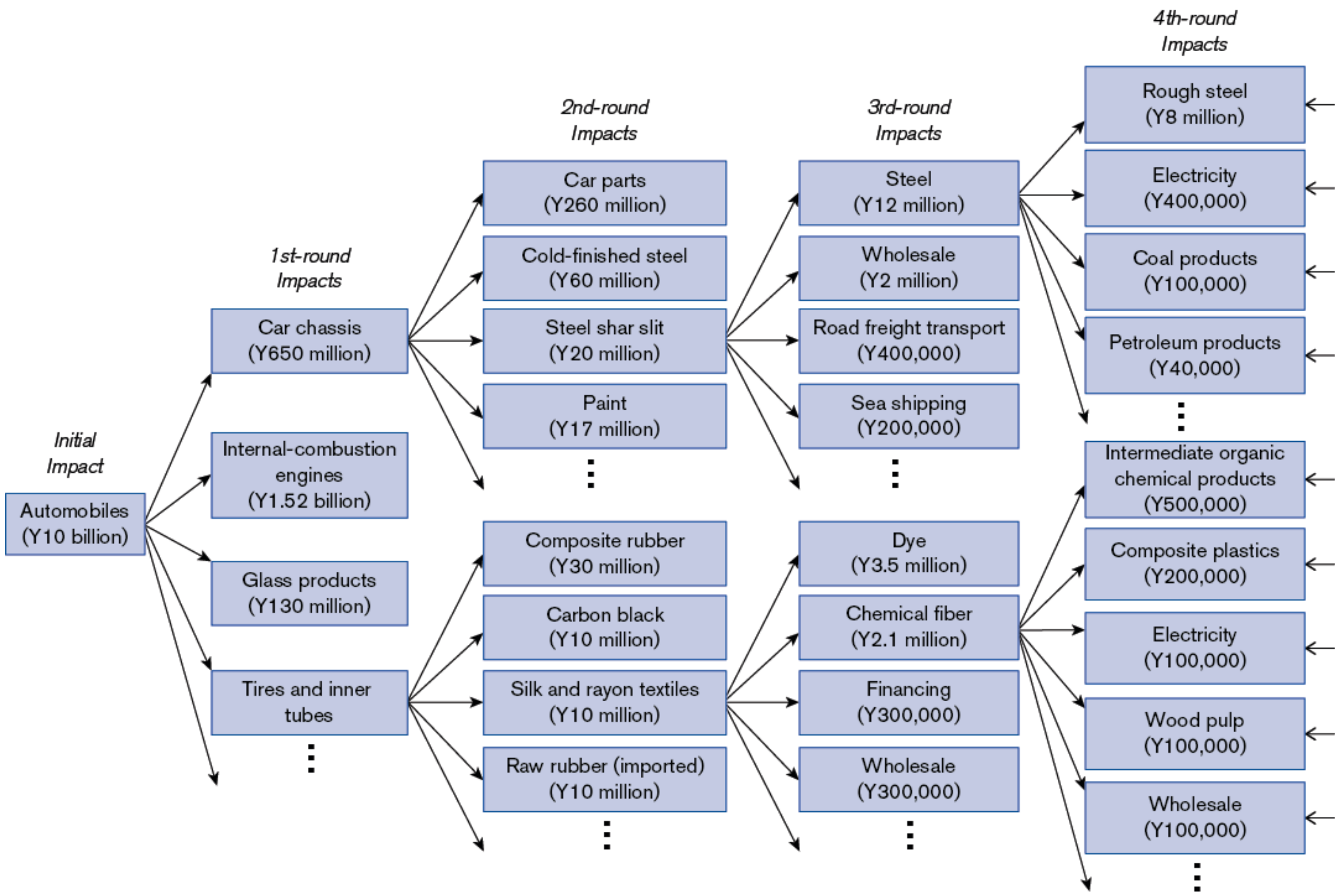
Input-output models and supply chains analyses

The conventional input-output approach to supply chains generally focuses on measuring interconnectedness, or "strength" of linkages among industries, based on the traditional demand-pull or cost-push impact models. Now, in addition to the strength of linkages, the increasing complexity of production networks due to the participation of the variety of industries requires measuring the "length" of linkages for mapping the geometry of supply chains. The strength of an input-output table, and what makes it special, is indeed its information of production linkages that are derived from supply-use relations between industries, which is totally absent in other types of data such as industrial statistics or foreign trade statistics.

Suppose that there is an increase in the demand for cars by JPY 10 billion (Figure 5.1). The output expansion of cars brings about the secondary repercussion on the production of other products. Apparently, it increases the demand for car parts and accessories such as chassis, engines, front glass and tyres. The increase in production of these goods, however, further induces the demand for, and hence the supply of, their sub-parts and materials such as steel, paints and rubber. A change that occurs in one industry (say, an increase in demand for cars) will be amplified through the complex production networks and bring about a larger and wider impact on the rest of the economy.

The length is estimated using the concept of average propagation length (APL) developed in Dietzenbacher et al., (2005). As an illustrative example, consider the following hypothetical supply chains in Figure 5.2. If we want to measure the length of supply chains between Industry A and Industry E, we should look at the number of production stages of every branch of the supply chains. In this illustrative example, there are four paths leading from Industry A to Industry E. The path on the top involves two production stages. The second one has four stages, the third has three stages and the last one at the bottom has four stages.

FIGURE 5.1: **An image of demand propagation (automobile industry)**



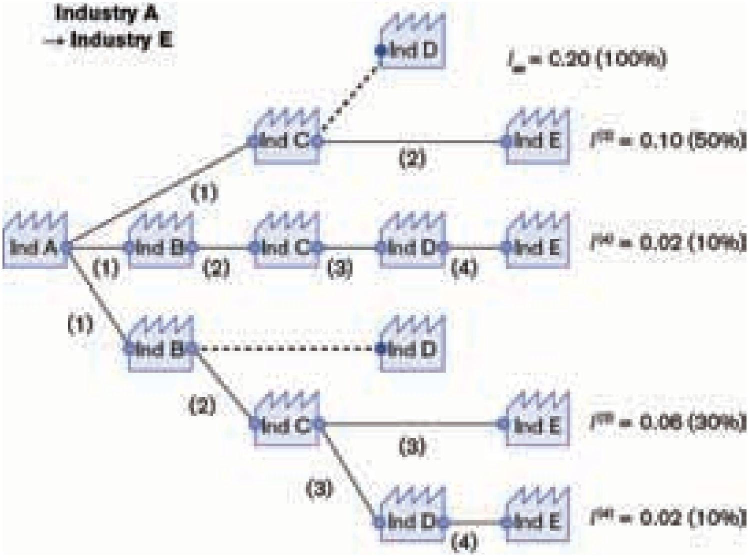
Source: Calculated and drawn by the authors.

Now, when the shares of a delivered impact for each path are calculated as given in parentheses at the ends of branches, the APL between Industry A and Industry E is derived as:

$$\mathrm{APL}_{(A\text{–}E)} = 1 \times 0\% + 2 \times 50\% + 3 \times 30\% + 4 \times (10 + 10)\% + 5 \times 0\% + \ldots = 2.7.$$

That is, APL is formulated as a weighted average of the number of production stages that an impact from Industry A to Industry E goes through, using the share of an impact at each stage as a weight.[1] It represents the average number of production stages lining up in every branch of all the given supply chains, or, in short, an industry's level of fragmentation. (For a formal description of the APL, see Technical Note.)

FIGURE 5.2: Calculation of average propagation length



Source: Drawn by the authors.

Motivations and previous studies

As already mentioned, the traditional input-output approach to supply chain analysis generally centred on the issue of measuring interconnectedness or "strength" of linkages among industries. Adding the "length" dimension of supply chains to the analysis of international production sharing basically responds to the following three motivations.

(1) As has just been demonstrated, it measures the degree of technological fragmentation and sophistication of particular supply chains.

(2) APL can be measured both in forward-looking and backward-looking ways. So, by comparing the lengths between the two for cross-national supply chains, we can identify the relative position of a country in the global production networks.

(3) If the production process is fragmented and shared among different countries, it increases the impact of trade policies on the volume and direction of international trade.

The relevance of the APL model to the issue of fragmentation was already suggested in the seminal paper of Dietzenbacher et al., (2005), although the paper did not explicitly used the term.[2] The APL model was applied at the international level in Dietzenbacher and Romero (2007), in which international linkage was analysed for major European economies using the international input-output table of 1985. The paper also employed the hypothetical extraction method to evaluate the influence of a single country on the APL of the chosen regional system, with the result of Germany being most influential. The international application of the APL model was brought into the Asian context by Inomata (2008a) with an extension to a time-series analysis using the Asian International Input-Output Table of 1990, 1995 and 2000. In particular, the paper proposed an index of geographical fragmentation based on the APL and compared its relative strength and weakness vis-à-vis the traditional measurements such as trade shares of intermediate products or the index of vertical specialization.

For the second motivation, Inomata (2008b) calculated the values of country's APL, again using the Asian International Input-Output Tables, in both forward and backward directions and by comparing these two values over time it elucidated the change in the relative positions of East Asian countries within the regional value chains. The idea was later extended in De Backer and Miroudot (2012) in a slightly different framework using the model of Fally (2011), which developed an index of "distance to final demand" based on the OECD's global input-output database covering 56 countries for the years 1995, 2000 and 2005.

The third point, the implication of the APL model for trade policies, was discussed in Diakantoni and Escaith (2012). As the production process is fragmented and shared by more countries, the intermediate products cross national borders more frequently, and hence the volume of traded products become more sensitive to the change in a country's trade policies. The detrimental effect of protectionist measures in an international production network becomes much larger than when the production process was relatively simple and taking place in a limited number of countries.

Analytical results

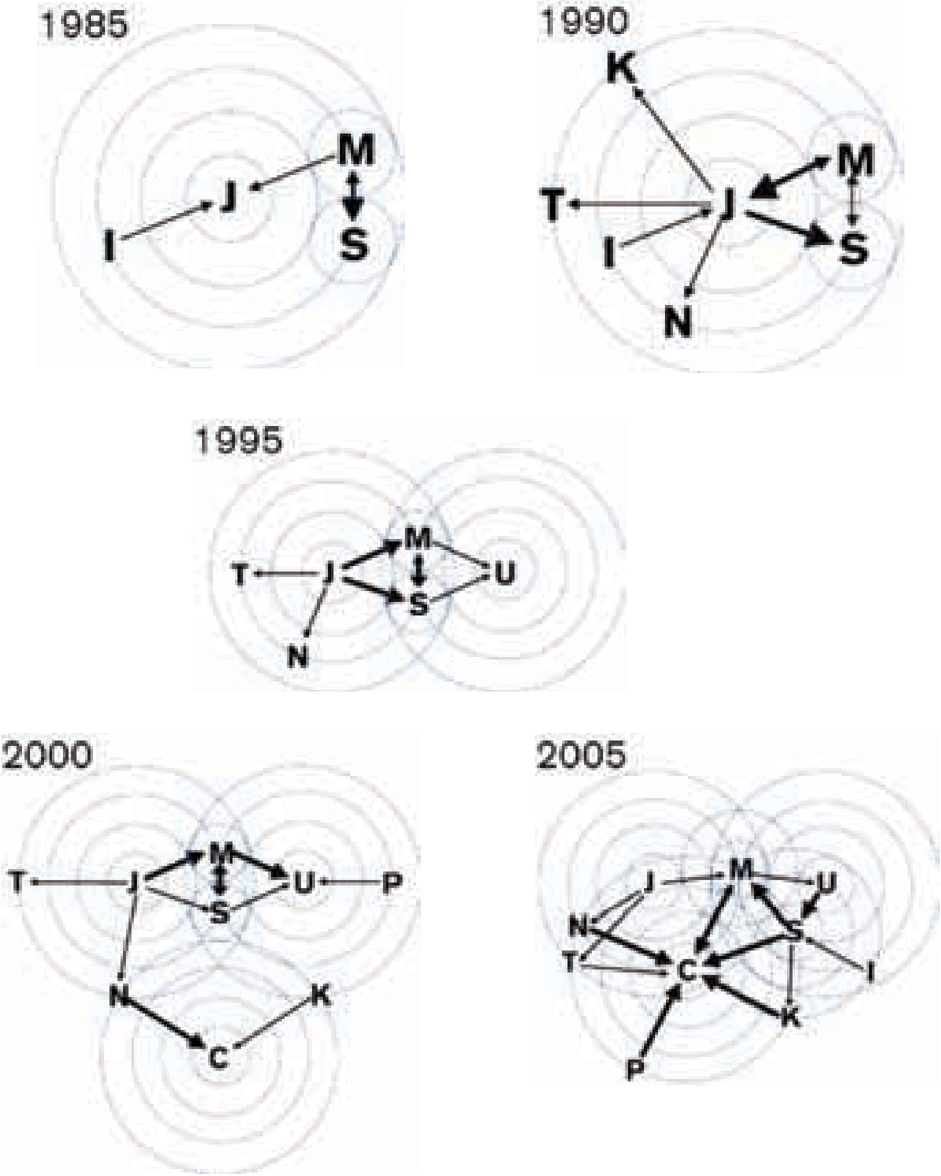
The diagram in Figure 5.3 traces the evolution of production networks in the Asia-US region over the last two decades. The visualization of the calculation results is based on the method presented in Dietzenbacher et al., (2005) with some graphical elaboration developed in Inomata (2008b). Arrows represent selected supply chains among the countries of the region with the direction of the arrows corresponding to the flow of intermediate products. Each arrow has two features: thickness and length. The thickness indicates the strength of linkages between industries, while the length, as measured against the ripple in the background, is given by APL. The number of rings that an arrow crosses represents the rounded value of APL, the average number of production stages, and thus indicates the level of technological fragmentation and sophistication of that particular supply chain.[3]

The analysis uses the Asian International Input-Output Tables for the reference years of 1985, 1990, 1995, 2000 and 2005, constructed by the Institute of Developing Economies, JETRO.[4] While conventional input-output analysis is usually concerned by a single country, the treatment is similar for international matrices. The table combines the national I-O tables of ten economies: China(C), Indonesia (I), Japan (J), Republic of Korea (K), Malaysia (M), Philippines (P), Singapore (S), Thailand (T), Chinese Taipei (N) and United States (U).

In 1985, there were only four key players in the region: Indonesia (I), Japan (J), Malaysia (M) and Singapore (S). The basic structure of the production network was that Japan built up supply chains from resource-rich countries like Indonesia and Malaysia. In this initial phase of regional development, Japan drew on a substantial amount of productive resources and natural resources from neighbouring countries to feed to its domestic industries.

By 1990 the number of key players had increased. In addition to the four countries already mentioned, Japan had extended its supply chains of intermediate products to the Republic of Korea (K), Chinese Taipei (N) and Thailand (T). While still relying

FIGURE 5.3: Evolution of regional supply chains in East Asia: 1985–2005



C: China, I: Indonesia, J: Japan, K: Rep. of Korea, M: Malaysia, N: Chinese Taipei, P: Philippines, S: Singapore, T: Thailand, U: United States

Source: Authors' calculation on the basis of IDE-JETRO Asian input-output matrix.

on the productive resources of Indonesia and Malaysia, Japan also started to supply products to other East Asian economies, especially to the group known as the Newly Industrialized Economies (NIEs). This is the phase when the relocation of Japanese production bases to neighbouring countries was accelerating, triggered by the Plaza Accord in 1985. It saw the building of strong linkages between core parts' suppliers in Japan and their foreign subsidiaries.

Then in 1995, the United States (U) came into the picture. It drew on two key supply chains originating in Japan, one via Malaysia and the other via Singapore. These two countries came to bridge the supply chains between East Asia and the United States. Also to be noted is the length of the arrows between Malaysia and Singapore. Compared to others, their shortness indicates that the supply chains involve fewer production stages, suggesting that the degree of processing is relatively low. It is considered that the product flows between these countries are distributional rather than value-adding.

In the year 2000, on the eve of its accession to the WTO, China began to emerge as the third regional giant. The country entered the arena with strong production linkages to the Republic of Korea and Chinese Taipei. It then gained access to Japanese supply chains through the latter. The United States also brought a new supply chain from Philippines (P). So the basic structure of the tri-polar production network in the Asia-US region was thus completed.

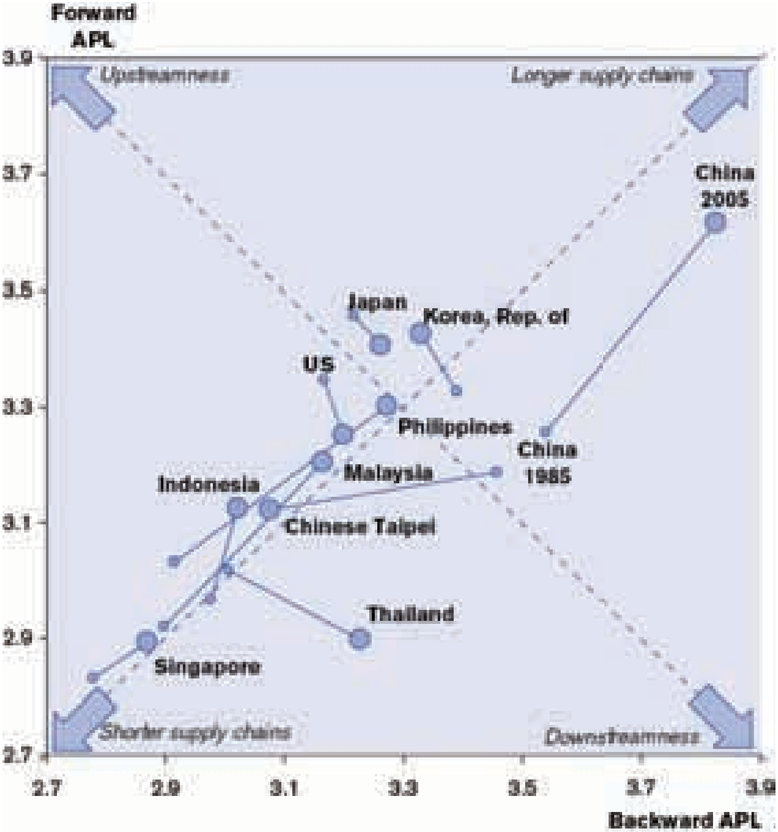
The regional production networks thereafter showed dramatic development. By 2005, the centre of the network had completely shifted to China, pushing the United States and Japan to the periphery. China became the core market for the products of the region from which final consumption goods were produced for export to the US and European markets. Also of note is the nature of the supply chains that China developed with others. The notable length of the arrows surrounding China indicates that the supply chains towards China are characterized by a high degree of fragmentation and sophistication, incorporating substantial amounts of value added from each country involved in the production networks. The competitiveness of Chinese exports, therefore, is not only attributable to its cheap labour force but also to the sophisticated intermediate products that the country receives from other East Asian economies, as embedded in goods labelled "Made in China".

The APL method can be used to measure separately the upstream and downstream length of average production linkages. Updating the methodology proposed by Inomata (2008b), Figure 5.4 presents the changes between 1985 and 2005 in the relative position of countries in Eastern Asia supply chains with respect to forward and backward APL.

The southwest-northeast diagonal presents the average length of supply chains that each country participates in. Most economies have moved towards the northeast corner, which means that they increased the length of supply chain linkages between 1985 and 2005. The exceptions to this trend are the United States and Chinese Taipei, while, Japan almost did not change; on the contrary, China demonstrates an outstanding increase in the length of supply chains. It is considered that inter-linking of its domestic supply chains with overseas production networks was accelerated by the country's accession to the WTO in 2001, as suggested by the big leap of the value from 1985 to 2005.

The northwest-southeast diagonal draws the relative position of each economy within the regional supply chains, as determined by the ratio of forward and backward APL. The United States and Japan, the most advanced economies in the region, are located

FIGURE 5.4: Change of relative positions in the regional supply chains, 1985–2005



Source: Based on Inomata (2008b) methodology and IDE-JETRO Asian input-output matrix.

in the upstream position, though the United States moved downwards during the period and swapped its position with the Republic of Korea. China stays in the downstream segment of the regional supply chains, which reflects the country's position as a "final assembler" of the regional products. The other economies more or less remain in the middle range spectrum, though the notable change is that Thailand went downstream to a large extent, and Chinese Taipei moved up into the middle cluster.

5.3. Tariffs, transport and trade facilitation

As shown above, international input-output matrices can be useful in revealing the topological characteristics of inter-industrial networks and their evolution. The present section aims at underlining some empirical characteristics of the bilateral trade "distance" that have a particular relevance from a network perspective. To quote Waldo Tobler: "everything is related to everything else, but near things are more related than distant things" (De Benedictis and Taglioni, 2011).

Understanding what defines the associativity between industrial sectors from a network perspective (or, symmetrically, the "distance" that lessens the possibility of interactions) would imply taking into consideration not only the bilateral relationship, but also associate it with the rest of the cluster of industries and countries that conforms the supply chain (Abbate et al., 2012). In the traditional trade perspective, transaction costs, including border costs and the cost of transporting goods from producers to users affects the volume, direction and pattern of trade. In a global value chain perspective, trade costs are part of the competitiveness of firms and determine in part their ability to participate in production networks.

More fundamentally, when trade takes place within a production network, the traditional bilateral approach to the role of transaction costs has to be abandoned to adopt a holistic method, where the intensity of bilateral trade depends also of the strength of the "trade-investment" nexus with all other network participants.[5] Connectedness with other trade partners becomes a central feature for explaining bilateral trade from a network perspective: bilateral "trade in tasks" depends not only, from the positive side, on the traditional attractors of industrial supply and demand between two countries, but also on the number of partners they have in common. At the extreme, no physical flow may appear between two closely-interconnected partners, A and B, because all trade in value-added transits through a third country, C, playing the role of a hub in the network.

Cascading transaction costs in production networks

The limited evidence available highlights very marked non-linearity in the way in which transaction costs negatively affect trade-flows in a trade in task perspective, where goods have to travel through several nodes before reaching their final destination. Yi (2003) shows that a small decrease in tariffs can induce a tipping point at which vertical specialization (trade in tasks) kicks in, while it was previously non-existent. When tariffs decrease below this threshold, there is a large and non-linear increase in international trade. The cascading and non-linear impact of tariff duties when countries are vertically integrated can be extended to other components of the transaction cost. When supply chains require that semi-finished goods cross international borders more than once, the effect of a marginal variation in trade costs everywhere in the supply chain is much larger than would be the case if there were a single international transaction.

Ferrantino (2012) shows that, when trade costs apply in proportion to the value of the good, the total cost of delivering the product to the final consumer increases exponentially with the number of production stages.[6] For example, if the average *ad valorem* transaction cost is ten per cent, accumulated transaction costs in a five-stage supply chain lead to an *ad valorem* tariff equivalent of 34 per cent. Doubling the number of stages by slicing up the supply chain more than doubles the total delivery costs, as the tariff equivalent is 75 per cent. All this indicates the critical role of low transaction costs including tariff duties and non-tariff measures in facilitating trade in a “trade in tasks” perspective.

Moreover, as we shall see, some features of these transaction costs such as tariff schedule escalating in function of the processing stage may be particularly harmful to trade in tasks. It is therefore necessary for a supply chain strategy to be successful, as was the case in East Asia, so that these transaction costs both physical and government-induced be minimized.[7] Reducing these costs from a regional perspective is particularly important, as many supply chains are regionally-based, as is observed in North America, Europe or in East Asia. The following sections will review how they have changed across time in order to accommodate and facilitate the development of regional production networks.

Tariff duties and effective rate of protection

Among all cross-border transaction costs, nominal tariffs are certainly the most visible. Tariff duties increase the domestic price of tradable goods by adding a tax to their international, or free market price. From a "trade in tasks" perspective, not only the value of nominal tariffs, but also their distribution between unprocessed and processed goods – a feature of nominal schedules known as tariff escalation – have a particular importance. By increasing the domestic prices of finished goods more than intermediary ones, tariff escalation creates a significant anti-export bias when value-added is the traded "commodity", as is made clear when looking at effective protection rates (EPRs).

Effective protection compares the nominal protection received on one unit of output produced by an industry and sold on the domestic market (at a price higher than the free market because of the duty charged on competitive imports) with the additional production cost the producer had to pay because of the tariff charged on the importable inputs required for producing this unit of output. Note that the value of one unit of output minus the value of the intermediate inputs required is equal to the rate of value added at domestic prices.

Tariff duties do influence the domestic price of all inputs, including domestically produced ones. Domestic suppliers of tradable goods will be able to raise their own prices up to the level of the international price plus the tariff duty, without running the risk of being displaced by imports. If the tariff schedule is flat (all tariffs are equal), the effective protection on the value added is equal to the nominal protection. In the presence of tariff escalation, downstream industries producing final goods will benefit from a higher effective protection. Upstream industries producing inputs will have, on the contrary, a lower protection and possibly a negative one if the sum of duty taxes paid on the inputs is higher than the taxes collected on the output.

As shown in Appendix 5.2, EPR is a ratio comparing the value added per unit of output at domestic prices – tariffs applying on both output and inputs – with the value added the industry would have gained if operating at international prices (without tariff duties). It has been known for years that high EPRs discourage benefiting firms from exporting their output. This anti-export bias is even more relevant when analysing trade policy from a "trade in value added" perspective (Diakantoni and Escaith, 2012).

One option chosen by countries suffering from high and differentiated tariff schedules has been to establish duty-free export processing zones (EPZs). Another option is to implement draw-back schemes where domestic firms can have the duty taxes paid on inputs reimbursed when they export their products. Nevertheless, as we shall see, this mitigating strategy is clearly insufficient in the case of fragmented production network.

It is easy to show (Appendix 5.2) that EPZs or duty draw-back schemes will benefit the lead exporting firm only if it uses imported inputs, and will price out domestic ones. The national suppliers of these firms, because they sell on their own market, will not be able to draw back the duties they had to pay on their own inputs. Even if they were able to do so, through a somewhat complicated administrative mechanism, domestic suppliers using non-imported inputs would still be put at a disadvantage because nominal protection raised the domestic price of all tradable products, be they actually imported or not.

In other words, high EPRs lower the competitiveness of domestic suppliers by increasing the "country cost" in the same way as an overvalued exchange rate does. Countries willing to actively participate in global value chains should therefore pursue tariff policies aimed at: (i) lowering nominal tariffs, in order to reduce transaction costs below the tipping point at which vertical specialization is profitable, as mentioned in Yi (2003), and (ii) reducing tariff escalation and effective protection rates in order to reduce the anti-export bias of the tariff schedule and its inflationary impact on the "country costs".

East Asian developing countries did follow the expected policy, as shown in Table 5.1. Not only did nominal protection drop, but the dispersion of duties – the main source

TABLE 5.1: Nominal protection and effective protection rates in East Asia and the Pacific, 1995–2005 (percentage, *ad valorem*)

	Developing countries				Developed countries			
	Agriculture		Manufacture		Agriculture		Manufacture	
	1995	2005	1995	2005	1995	2005	1995	2005
Nominal Protection								
– Median	6.5	3.9	9.2	6.2	1.3	1.9	2.3	1.3
– Average	27.2	11.9	15.9	7.8	2.0	2.1	4.0	2.9
Effective Protection								
– Median	4.9	2.6	14.7	10.6	0.9	3.1	3.5	1.8
– Average	29.6	15.5	26.3	16.6	1.1	3.9	8.3	5.8

Source: Diakantoni and Escaith (2012) based on ten countries IDE-JETRO Asian input-output matrix and WTO tariff data.

Note: NP: nominal protection; EPR or effective protection rate.

of variance in EPRs – was also lower as can be observed from the steeper drop in the NP average than in the median. As a result, EPRs decreased in both agriculture and manufacture sectors. In developed countries which had already low tariffs in 1995, the reduction in the protection of domestic manufacture was less impressive in absolute value but still important in relative terms. On the contrary, nominal protection of agriculture remained stable or even increased when weighted for trade flows. As the protection on industrial inputs purchased by farmers decreased, they benefited from higher EPRs.

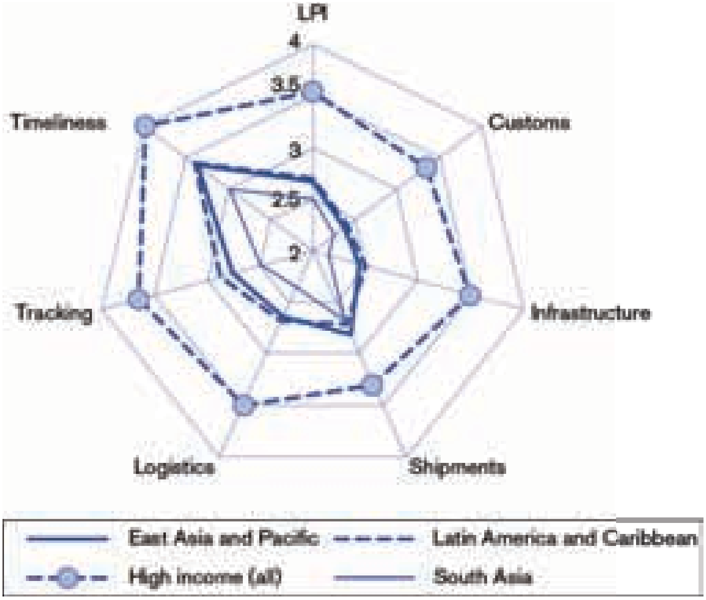
Transport and trade facilitation

As for tariffs, costs incurred for transport and customs procedures are magnified in international supply chains, because goods for processing cross several borders and these costs have to be paid twice, first on the imported component and then on the processed good. The social cost is much higher than the monetary implications of maintaining large inventories and immobilizing transport equipment for long periods of time. The cumulative effect of such barriers creates delays in delivery and uncertainty that may entirely disqualify domestic firms from competing for the higher value-added portion of the value chain, where flexibility, reactivity and just-in-time delivery are a prerequisite. Leaving aside inspection and certification requirements related to technical and safety standards, this section focuses on transport and administrative procedures.

To advance their export-led growth agenda, East Asian countries invested in improving transport infrastructure. They also put in place schemes aimed at alleviating administrative burdens and encouraging processing trade in order to take full advantage of GVCs. As shown in Duval and Utoktham (2011), the non-tariff cost of trade in goods was 53 per cent of the value of goods for intraregional trade among South-East Asian countries in 2007, compared to a prohibitive 282 per cent within South and Central Asia. These authors show that natural factors linked to geographical characteristics were only partially to blame for these additional transaction costs. Distinguishing between natural and non-tariff policy-related trade costs, they rank Malaysia, followed by the United States, China, Republic of Korea and Thailand as the top five trade facilitators. Singapore and Hong Kong, China could not be included in the ranking but would have probably been among the top performer.[8] Similarly, WTO and IDE-JETRO (2011) highlight the role of transport and logistics in fostering the development of GVCs in the East Asia region by stating that, in 2009, of the top ten leading world ports in terms of container traffic, five were located in China and one each in Hong Kong, China; Republic of Korea and Singapore. These four economies represent 38 per cent of the world's container port traffic.

Figure 5.5 shows that, despite the high efficiency of the Asian hubs (Singapore ranks second after Germany on the World Bank's logistics index, while Japan is 7th and Hong Kong, China 13th, all ahead of the United States and Canada), there is still room for improvement in most of the region's countries. In particular, the region is still far from having the best practices in customs procedures found in high-income countries. Unlike with improving trade and transport-related infrastructure, which requires costly investment in ports, railroads, roads and information technology, improving efficiency in customs procedures is a relatively cost-free matter of introducing administrative reform.

FIGURE 5.5: Trade, logistics and transportation – East Asia in perspective



Source: Elaborated on the basis of World Bank LPI, 2012.

Note: Logistics Performance Index (LPI), weighted average on the six key dimensions.

Regional production networks and shock transmission

When trade partners are closely interconnected in production networks, as is the case in East Asia, a sudden change in one country (a tariff hike or a bottleneck in production or logistics) will generate a supply shock through the entire supply chain. The shock may increase the cost of the related product or stop production chains, if it is disruptive. The damaging impact will be greater the larger the volume of vertical trade processed in the originating country (size effect) and the more connected it is with other partners (network effect). As mentioned previously, in an input-output setting, a rough measure of the depth and length of supply shocks along production chains is given by the average propagation length (APL) of this shock.

Table 5.2 presents a modified version of APL (Diakantoni and Escaith, 2012) calculated for 2005 using the aggregated 26-sector IDE-JETRO's Asian Input-Output. From a country perspective, China is the main hub for inter-industrial connections, when both

TABLE 5.2: Sectoral average propagation length in East Asia, 2005 (selected cases)

	China	Japan	United States	Korea, Rep. of	Taipei, Chinese	Average
Metals and metal products	75.8	100.0	27.3	31.6	17.8	27.5
Chemical products	40.7	66.8	45.0	27.3	23.5	24.1
Computers and electronic equipment	25.2	43.1	19.3	18.1	20.3	16.5
Petroleum and petrol products	22.5	11.3	9.7	12.9	10.7	11.7
Other electrical equipment	25.2	25.7	23.2	8.4	8.5	10.7
Crude petroleum and natural gas	11.5	0.3	17.5	1.3	0.1	6.8
Industrial machinery	20.7	23.1	9.5	3.8	2.6	6.8
Transport equipment	10.5	29.0	10.4	3.8	0.6	6.4
Other manufacturing products	18.1	17.6	8.4	3.8	3.0	5.9
Food, beverage and tobacco	9.6	4.6	6.9	1.7	0.6	4.1
Textile, leather, and other	18.5	4.2	2.3	3.7	3.7	3.9
Paddy	1.2	0.4	0.0	0.3	0.0	0.4
Average	16.9	17.0	10.0	6.0	4.7	7.0
Median	11.5	4.6	6.9	2.1	0.7	4.3

Source: based on Diakantoni and Escaith, 2012.

Note: Results exclude domestic impacts and were rescaled to 100 for maximum value.

intensity and length are pondered. Japan comes a close second in terms of average APL indexes due to the high value of some sectors (metals, chemical products and computers). The United States comes in third. From a sectoral perspective, chemical products and metals and metal products are by far the sectors generating most of the depth in inter-industrial connections, Computers and electronic equipment are also highly interconnected.

5.4. Conclusions

Understanding trade in the global value chain perspective is greatly enhanced by adapting analytical tools derived from network economics and the study of inter-industry or inter-country relationships. Analysing the bilateral relationship between two nodes of a production network requires understanding the complementarity between them as well as with other partners in the network, as well as the factors that may explain the strength of the edges between them. International input-output (IIO) matrices are an effective way of describing and modelling the development of inter-industrial relationships in such a transnational context.

Thanks to a close relationship between input-output analysis and graph theory, diachronic IIOs serve also to map and visualize the evolution of productive networks and identify their main clusters. Applying these topological properties to the East Asian and Pacific context, we show that the inter-industry network moved from a simple hub and spokes cluster, centered on Japan in 1995, to a much more complex structure in 2005 with the emergence of China but also the specialization of several countries, such as Singapore or Malaysia, as secondary pivots.

The rise of “factory Asia” and its present topology were determined by specific policies. The densification of production networks in East Asia resulted from the coincidence of business strategies, linked to the widespread adoption of international supply chain management by lead firms in Japan and the United States, with the promotion of export-led growth strategies from developing East Asian countries. These countries applied a series of trade facilitation policies that lowered not only tariff duties, but also reduced other transaction costs.

We show that tariff escalation was greatly reduced in developing East Asia between 1995 and 2005, reducing the dissuasive anti-export bias attached to high effective protection rates and improving in the process the competitiveness of second-tier national suppliers. The other axis of trade facilitation focused on improving logistics services and cross-border procedures. While the East Asia region is well ahead of the rest of developing Asia in this respect, there is still a wide margin of progress in order to close the gap with best international practices, particularly in terms of administrative arrangements.

Appendix 5.1. Technical note on average propagation length

Suppose an n-industrial sector economy with a production structure defined by the input coefficient matrix **A** shown in Figure a. Input coefficients a_{ij} are calculated from an input-output table by dividing input values of goods and services used in each industry by the industry's corresponding total output, i.e. $a_{ij} = z_{ij} / X_j$ where z_{ij} is a value of good/service i purchased for the production in industry j, and X_j is the total output of industry j. So, the coefficients represent the direct requirement of inputs for producing just one unit of output of industry j.

Figure a An input Coefficient Matrix

$$\mathbf{A} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \cdots & a_{2n} \\ a_{31} & a_{32} & a_{33} & \cdots & a_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & a_{n3} & \cdots & a_{nn} \end{bmatrix}$$

Figure b Impact delivery paths

<1 step path>

Ind 3 $\xrightarrow{a_{13}}$ Ind 1

<2 step paths>

Ind 3 $\xrightarrow{a_{23}}$ Ind 2 $\xrightarrow{a_{12}}$ Ind 1
Ind 3 $\xrightarrow{a_{33}}$ Ind 2 $\xrightarrow{a_{13}}$ Ind 1
. . .
. . .

and so on.

The vertical sequence of demand propagation can be depicted as follows. Let us consider the impact of demand for 100 units in industry 3 upon the output of industry 1. The simplest form of all is given by the direct linkage [3→1], which is calculated as a product of multiplying 100 units by input coefficient a_{13}. This is because a_{13}, by definition of an input coefficient, represents an immediate amount of products of industry 1 required for producing just one unit of products of industry 3. Alternatively, there is a two-step path going through another industry, say, [3→2→1]. This is derived by two-stage multiplication, i.e. 100 units by a_{23}, and then by a_{12}. There can also be a two-step path going through the same industry, such as [3→3→1] or [3→1→1] which would be derived respectively as "$100 \times a_{33} \times a_{13}$" and "$100 \times a_{13} \times a_{11}$" (see Figure b).

The exercise reveals that the impact of any two-step path, whatever the sequence of industries, can be given by feeding back a set of direct impacts, **A**, into the input coefficient matrix, i.e. $\mathbf{A} \times \mathbf{A} = \mathbf{A}^2$. Similarly, the impact of three-step paths is given by $\mathbf{A} \times \mathbf{A}^2 = \mathbf{A}^3$, that of four-step paths by $\mathbf{A} \times \mathbf{A}^3 = \mathbf{A}^4$ and so on, which is evident from $[\mathbf{A}^2]_{ij}=\Sigma_k a_{ik} a_{kh}$, $[\mathbf{A}^3]_{ij}=\Sigma_k \Sigma_h a_{ik} a_{kh} a_{hj}$, etc. The amount of impacts shown in each layer of $\mathbf{A}^k$s (k=1, 2, 3,...,) is a result of the initial demand injection passing through all k-step paths. It captures the effect of every direct and indirect linkage that undergoes exactly the k-round steps/stages of the production process.

Meanwhile, it is mathematically known that the Leontief inverse matrix **L**, which shows the total amount of goods and services required for the production of one unit of output, can be expanded as an arithmetic series, i.e. $\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1} = \mathbf{I} + \mathbf{A} + \mathbf{A}^2 + \mathbf{A}^3 + \mathbf{A}^4 + \ldots$, where **I** is an identity matrix (with "1" in diagonal elements and "0" elsewhere). From what we saw above, it is immediately clear that the equation represents the decomposition of the total impact on output into its constituent layers according to the number of production stages involved. Matrix **I** corresponds to an initial (unit) demand injection and the following $\mathbf{A}^k$s are regarded as progressive impacts of the initial demand when supply chains are sliced at the kth stage of the production process.

With this preliminary understanding, Average Propagation Lengths are specified as:

$$\mathrm{APL}_{(j\text{-}i)} = 1^* a_{ij} / (l_{ij} - \delta_{ij}) + 2^*[\mathbf{A}^2]_{ij} / (l_{ij} - \delta_{ij}) + 3^*[\mathbf{A}^3]_{ij} / (l_{ij} - \delta_{ij}) + \ldots$$

$$= \sum_{k=\mathbf{1}}^{\infty} k \left(\left[\mathbf{A}^k \right]_{ij} \Big/ \sum_{k=\mathbf{1}}^{\infty} \left[\mathbf{A}^k \right]_{ij} \right) \qquad [2]$$

where **A** is an input coefficient matrix, a_{ij} is its elements, l_{ij} is Leontief inverse coefficients, δ_{ij} is a Kronecker delta which is $\delta_{ij}=1$ if i=j and $\delta_{ij}=0$ otherwise, and k is a number of production stages along the path. We also define $\mathrm{APL}_{(j\text{-}i)}=0$ when $(l_{ij} - \delta_{ij}) = 0$.

The first term in the right-hand side of the upper equation shows that the impact delivered through one-step paths (k=1), i.e. direct impact, amounts to $a_{ij} / (l_{ij} - \delta_{ij})$ share of the total impact given by the Leontief inverse coefficients (less unity for diagonal elements). Similarly, two-step paths (k=2) contribute $[\mathbf{A}^2]_{ij} / (l_{ij} - \delta_{ij})$ share, and three-step paths (k=3) give $[\mathbf{A}^3]_{ij} / (l_{ij} - \delta_{ij})$ share of the total impact. This is evident from $\mathbf{L} = \mathbf{I} + \mathbf{A} + \mathbf{A}^2 + \mathbf{A}^3 + \ldots$ which is rearranged as $\mathbf{L} - \mathbf{I} = \mathbf{A} + \mathbf{A}^2 + \mathbf{A}^3 + \ldots$, and hence $(\mathbf{L} - \mathbf{I})_{ij} = (l_{ij} - \delta_{ij}) = \mathbf{A}_{ij} + [\mathbf{A}^2]_{ij} + [\mathbf{A}^3]_{ij} + \ldots$.

That is, Average Propagation Lengths is formulated as a weighted average of the number of production stages which an impact from industry j goes through until it ultimately reaches industry i, using the share of an impact at each stage as a weight.

Appendix 5.2. Effective protection rates and anti-export bias

EPR for sector "j" is the difference between the nominal protection enjoyed on the output minus the weighted average of tariff paid on the required inputs.

It is given by:

$$EPR_j = \frac{t_j - \Sigma_i (t_i . a_{ij})}{1 - \Sigma_i a_{ij}} \qquad [3]$$

With a_{ij} : elements of the matrix A of technical coefficients in an input-output matrix,

t_j : nominal tariff on sector "j",

t_i : nominal tariff on inputs purchased from sector "i". "i" can be equal to "j" when a firm purchases inputs from other firms of the same sector of activity. In an inter-country framework, "i" includes also the partner dimension [c] as inputs from sector "i" might be domestic or imported.

Note that $[1 - \Sigma_i a_{ij}]$ is the rate of sectoral value added per unit of output when there is no tariff and the domestic prices of tradable goods are similar to the international ones (free trade). Therefore, EPRs are the ratio of the value added obtained considering the given (applied) tariff schedules compared to a situation of free trade and no tariff. It can be negative when firms pay a high tariff on their inputs but have a low nominal protection on their output.

Tariff duties influence the domestic price of all inputs, including domestically produced. Domestic suppliers of tradable goods will be able to raise their own prices up to the level of the international price plus the tariff duty, without running the risk of being displaced by imports. Distinguishing between domestic and foreign inputs, EPR can therefore be written as:

$$EPR_j = \frac{t_j - \left[\Sigma_i (t_i . a^f{}_{ij}) + \Sigma_i (t_i . a^h{}_{ij}) \right]}{1 - \Sigma_i a_{ij}} \qquad [4]$$

With a^f_{ij} and a^h_{ij} the intermediate consumption “i” from, respectively, foreign and home country required to produce one unit of output “j”.

From a “trade in tasks” perspective, we can deduce two important conclusions from equation [4]:

(i) A high positive EPR reduces protected sectors’ incentive to export, as their rate of return on the domestic market is higher than what they can expect on the international one. Similarly, an exporting firm will be in an inferior position vis à vis a foreign competitor operating in a free trade environment, as its value-added when selling at world price is lower than its free-trade competitor, as shown in [5].

$$\frac{1-\left[\Sigma_i(t_i.a^f{}_{ij})+\Sigma_i(t_i.a^h{}_{ij})\right]}{1-\Sigma_i a_{ij}}<1 \qquad [5]$$

(ii) When duty draw-backs or tariff exemption (as in export processing zones) correct for this bias and allow domestic producers to purchase inputs at international prices, export-oriented firms still have a disincentive to purchase inputs internally as their second-tier domestic suppliers won’t be able to benefit from the duty exemption (see [6]).[9]

$$\frac{1-\left[\Sigma_i a^f{}_{ij}+\Sigma_i(t_i.a^h{}_{ij})\right]}{1-\Sigma_i a_{ij}}<1 \qquad [6]$$

While the anti-export bias [5] is a well-known result from a traditional trade in final goods perspective, new corollary [6] is relevant only from a vertical specialization perspective, where a “buy” decision arising from a “make or buy” assessment implies arbitraging between domestic and foreign suppliers.

Endnotes

1 The reason for using the impact shares as weights is as follows. If a calculated share is small, this implies that the corresponding path has a small contribution to the overall circuit of impact delivery; so this path is considered relatively insignificant in the supply chains and hence the number of production stages it has should be weighted less.

2 A more extensive analysis was carried out in Romero et al. (2009), in which the effects of fragmentation on the complexity of the Chicago economy were studied from a set of input-output tables estimated for the period 1978–2014.

3 For a detailed explanation of the visualization method, see Annex of WTO – IDE JETRO (2011).

4 The 2005 table is a preliminary table.

5 In a gravity model, bilateral trade is proportional to the size of the attractors – supply and demand – and inversely related to their economic distance (transaction and transportation costs). The influence of the 'distance' to other trade partners – or multilateral resistance – has been acknowledged in traditional trade analysis, but mainly as a statistical issue when estimating gravity model. Analysing complex interdependence in trade relations is still in its infancy. For a review, see Abbate et al (2012) and Noguera (2012) for an application to the case of trade in value-added.

6 More formally, the total cost of delivering the product to the final consumer after (n) production stage is: $\mathbf{C}(n) = \Sigma_{i=\mathbf{1}}^{n} \frac{\mathbf{1}}{n} \mathbf{(1} + t\mathbf{)}^{i}$ where C(n) : total cost of delivering the product as a proportion of the production cost, t : *ad valorem* transaction cost at each stage, N: number of stages in the supply chain.

7 Transaction costs – besides tariff duties and non-tariff measures – are usually defined as function of the geographical features of the respective countries, infrastructure and transportation services (including their regulatory regime and competition policies), custom procedures and other cross-border formalities, technological innovations and fuel costs.

8 Bilateral "natural" trade costs between trade partners are found to account for nearly one third of non-tariff trade costs explained by the authors. While significant, this incompressible share leaves a lot of space for transport and trade facilitation policies.

9 Unless firms substitute high-tariff domestic inputs for lower ones (negative correlation between changes in t_i and a^h_{ij}) but Diakantoni and Escaith (2012) show that almost no substitution took place in East Asia.

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