Chapter 6
The Evolution of Industrial Networks in East Asia: Stylized Facts and Role of Trade Facilitation Policies

Hubert Escaith and Satoshi Inomata

Abstract 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 chapter is to provide a nontechnical introduction to the use of input–output analysis and graph theory for understanding trade in the global value chain 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 the People's Republic 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 policies from developing East Asian countries. These countries applied a series of trade facilitation measures 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 East Asia 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.

Keywords Global value chains • Multiregional input–output table • Average propagation length • Production networks

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6.1 Introduction

Often dubbed "Factory Asia," East Asia is probably the best-known example of a regional economic integration process initially driven by deepening industrial relations among the countries of the region, rather than by political agreements. The institutional or legal structures of regional integration in East Asia were put in place only afterward, in a "bottom–up" fashion. This is different from the economic integration process in North America, for example, where the ratification of the North American Free Trade Agreement (NAFTA) was a catalyst for the buildup of economic ties between the United States (US) and Mexico.

An important feature of East Asian integration is that deepening economic interdependency has not just been a spontaneous phenomenon, but has been carefully aided and facilitated by a 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, that is the focus of this chapter.

We make the case that understanding trade from a global value chain perspective is greatly enhanced by adapting analytical tools from network economics and the study of inter-industry or inter-country relationships. Analyzing the bilateral relationship between two nodes of a production network requires an understanding of the complementarity between these nodes, as well as with other partners in the network. International input–output (IIO) matrices are an effective way to describe and model the development of inter-industrial relationships in such a transnational context.

Facilitating trade is particularly important when international production networks crisscross several borders. When tariffs affect not only the domestic market price of final goods but also the cost of intermediate inputs, the appropriate analytical tool is the effective rate of protection. Derived by combining applied tariff schedules with input–output (I–O) matrices, they measure the impact of the overall tariff structure on the value-added of domestic industries. When considering trade facilitation from a supply chain perspective, the monetary dimension is not the sole determining factor: given the predominance of management models based on just-in-time production strategies, transport logistics and customs efficiency become important determinants of the comparative advantages of an economy.

6.2 Evolution of Regional Supply Chains in East Asia

6.2.1 A Network Approach to Mapping Value Chains in East Asia

Graphs are the most intuitive approach for mapping trade networks. Despite their apparent simplicity, graphs can be subjected to more advanced analysis, which allows us to measure the pivotal role that some trade partners play (Escaith 2014). A diachronic comparison of trade networks in two particular, distant years will also reveal the emergence of new key players and the relative decline of others. A trade network is best described as directed graphs, or digraphs, because it is made up of directed edges (imports from and exports to) connecting vertices (trade partners).

Trade in intermediate goods and services is of particular importance for mapping international supply chains. Such flows of intermediate products represent business-to-business (B2B) interactions that closely track the extent of the inter-industrial relationship between countries and sectors. Figure 6.1 shows the purchase of inputs by selected sectors in Asia and the Pacific, using data on trade in intermediate products estimated for 2000 and 2008 by the Institute of Developing Economies of the Japan External Trade Organization (IDE–JETRO) for the region (Inomata 2011). Note that a sector in any economy can also be a provider for the same sector

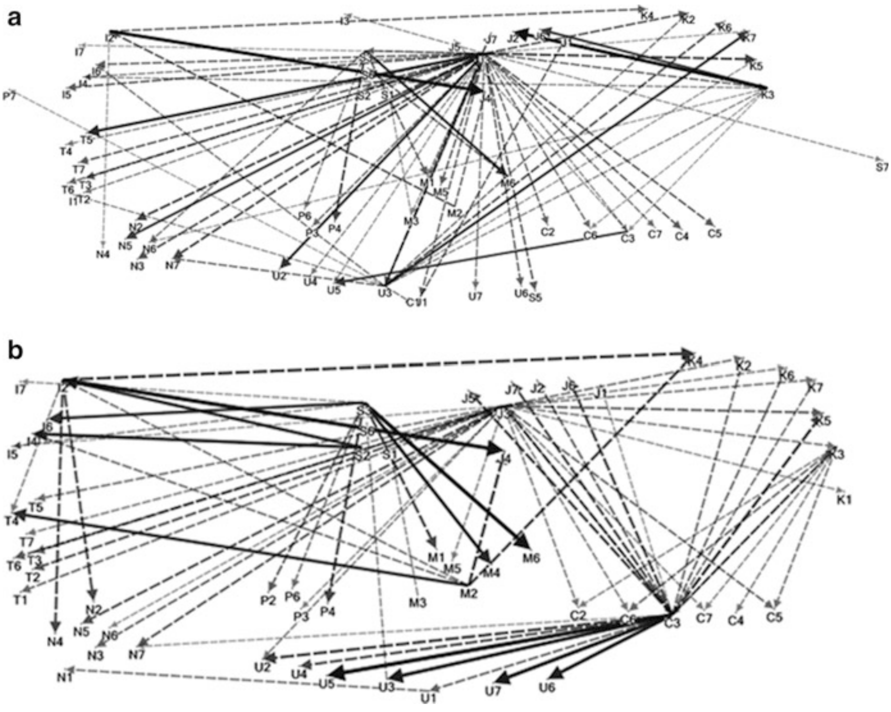


Fig. 6.1 Intersectoral trade in intermediate goods and services, Asia and the Pacific. (**a**) Intraregional flows of intermediate goods and services, 2000, (**b**) intraregional flows of intermediate goods and services, 2008. Notes: The arcs represent the inter-industrial trade of intermediate products between economies in Asia and the Pacific by origin and destination. The thickness of the arc relates to the relative contribution of the imports in the total imported inputs (excluding domestic ones) required for producing 100 units of sectoral output. Only flows greater than 20 % are considered, in order to simplify the graph and focus on main suppliers only. Letters denote the reporting economy (C: People’s Republic of China; I: Indonesia; J: Japan; K: Republic of Korea; M: Malaysia; N: Taipei,China; P: Philippines; S: Singapore; T: Thailand; U: United States) and numbers designate the industrial sectors (1: agriculture; 2: mining; 3: manufacturing; 4: electricity, gas, water; 5: construction; 6: trade and transport; 7: other services) (*Source*: Drawn by the authors, based on IDE-JETRO Asian International Input–Output Table)

in another economy, as trade partners can specialize in specific qualities of similar inputs. To simplify the graph, intermediate trade flows representing less than 20 % of the purchases of each sector were filtered out of the visual analysis. The strength of the trade relationship (i.e., the percentage of all traded inputs required for the production of the sectoral output that is imported from a given trade partner) is indicated by the thickness of the edge. The vertices in the graph were rearranged to facilitate readability and the length of the edges is not relevant for our analysis.

Although the general geography of B2B relationships between 2000 and 2008 has not changed dramatically and the two graphs look more or less the same, a closer analysis shows variations in the degree of relative strength of the relationships. Unsurprisingly, the biggest change is related to the prominent role of the People's Republic of China (PRC) in 2008 as a provider of traded inputs, in particular with respect to the country's manufacturing sector (vertex C3 in the graph). The main provider of inputs is the manufacturing sector (coded 3 in the graph). The PRC (C), Japan (J), and the Republic of Korea (K) appear as the main sources of manufacturing inputs in 2008. Note also the role of Singapore (S), especially as a provider of manufacturing inputs to Malaysia (M).

In Fig. 6.2, the arcs (flows of intermediate inputs by origin and destination) that increased (decreased) in incidence between 2000 and 2008 are located above (below) the 45° diagonal. In contrast to Fig. 6.1, all trade flows in intermediate goods, irrespective of their size, are now represented. In the lower right quadrant of

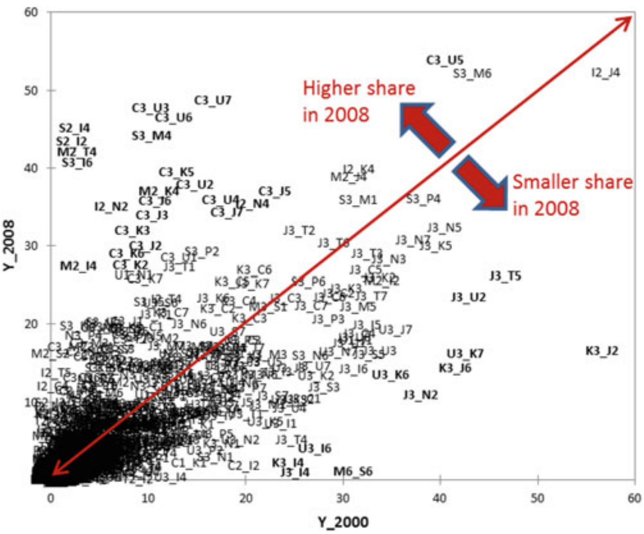


Fig. 6.2 Rise and fall of bilateral inter-industrial connections between 2000 and 2008. Notes: The axes of the scatterplot represent the percentage contribution of the imported inputs in the sectoral production requirements in 2000 and 2008, respectively; the observations are coded as "economy and sector of origin"_"economy and sector of destination" (see notes in Fig. 6.1 for more details on the alphanumeric coding) (*Sources*: Drawn by the authors, based on IDE-JETRO Asian International Input–Output Table)

the graph (lower share of sectoral inputs), we see trade flows originating from industrialized economies such as Japan (J) and the US (U). Imports of manufacturing inputs from the Republic of Korea by the Japanese mining sector (K3_J2) also lost some of their relevance between 2000 and 2008. It should be noted that data represent percentages and that actual trade flows may have increased in value even if their share shows a decrease.

Above the diagonal, the upper left quadrant plots the bilateral B2B relationship that increased in importance between 2000 and 2008. As already obvious from Fig. 6.1, inputs originating from the PRC's manufacturing sector (C3) are well represented. C3 is now more important as a provider of inputs to various US and Japanese industries (coded C3_U*x* and C3_J*x* in the graph). The growing role of Singapore and Malaysia as providers of mining inputs (coded S2_X*x* and M2_X*x* in the graph) is also evident.

Table 6.1 provides the main results of a more formal statistical analysis of the changes between 2000 and 2008, using an analysis of covariance (ANCOVA) approach, which allows regressing the value of trade in intermediate products in

Table 6.1 ANCOVA analysis of 2000–2008 changes in B2B trade flows

Variables[a]	Coefficient	Standard error	*t* statistics
B2B_Y2000 [b]	(0.45)	0.03	(15.13)
Origin-C3	0.48	0.03	17.91
Origin-S2	0.13	0.02	6.29
Origin-S3	0.16	0.03	5.98
Origin-M2	0.13	0.02	5.70
Origin-I2	0.14	0.02	5.64
Origin-K3	0.09	0.03	3.17
Origin-N3	0.07	0.03	2.45
Origin-T3	0.06	0.03	2.42
Origin-J3	0.07	0.03	2.11
Origin-M3	0.06	0.03	2.10
Origin-C6	0.05	0.03	1.94
Explained variable: B2B_Y2008[b]			
Observations: 1,676			
R^2: 0.39			

Source: Analysis of covariance based on IDE-JETRO Asian international input-output table
( )=negative value
B2B business to business
Notes
[a]Only the most significant variables are shown; the results are provided for illustration only, as they are contingent to the period 2000–2008 and may not be robust to changes in the sample size (see notes in Fig. 6.1 for more details on the alphanumeric coding of economy and sector of origin)
[b]Value of the inter-industrial bilateral trade flows in 2000, as a percentage of total import requirements of the sector of destination; the explained variable is the same value observed later in 2008

2008 against its value in 2000, and a set of qualitative variables represented by the sectoral origin of the trade flows.[1] The overall explanatory power of the analysis is quite low (less than 40 % of the variance), but provides some interesting results. First, the negative and highly significant sign of the 2000 value (Y_2000) indicates a clear tendency of regression to the mean. Large (small) values in 2000 tend to be lower (higher) in 2008. Second, some sectors appear to have significantly raised their share as exporters. Among them, the PRC's manufacturing industries (C3) are the most significant both in terms of statistics (highest t-statistics) and economic weight (highest coefficient value). With the notable exceptions of mining from Singapore and Malaysia and trade and transport services from the PRC, all significant contributors to intra-industry trade in intermediate products are manufacturing sectors (from Singapore; Republic of Korea; Taipei,China; Thailand; Japan; and Malaysia). It should be noted that a similar analysis using the destination sector instead of the origin sector did not produce any significant results: changes in the geometry of B2B trade responded more to changes on the supply side than to shifts in the structure of demand for intermediate products.

6.2.2 Input–Output Models and Supply Chain Analyses

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 for others. The strength of an I–O table—and what makes it special compared to a simple accounting of gross output—is indeed its information of production linkages that are derived from supply–use relations between industries, which is absent in other types of data such as industrial or foreign trade statistics.

Let us suppose the demand for cars increases by 10 billion yen (Fig. 6.3). The output expansion of cars has a secondary repercussion on the production of other products. It increases the demand for car parts and accessories such as chassis, engines, front glass, and tires. The increase in production of these goods, however, further induces demand for, and hence increases the supply of, their subparts and materials such as steel, paint, and rubber. A change that occurs in one industry (e.g., an increase in demand for cars) will be amplified through the complex production networks and will result in a larger and wider impact on the rest of the economy.

The conventional I–O approach to supply chains generally focuses on measuring interconnectedness, or the "strength" of linkages among industries, based on the

[1] The analysis of covariance (ANCOVA) uses the same conceptual framework as linear regression, but allows the inclusion of qualitative variables in the model. The explained variable is the change between 2000 and 2008 in bilateral B2B flows of intermediates. The explanatory variables mix a continuous quantitative variable (value observed in 2000) with qualitative factors indicating the industrial sector of origin. Here we use the analysis of variance as a data exploration tool rather than for formal statistical hypothesis testing.

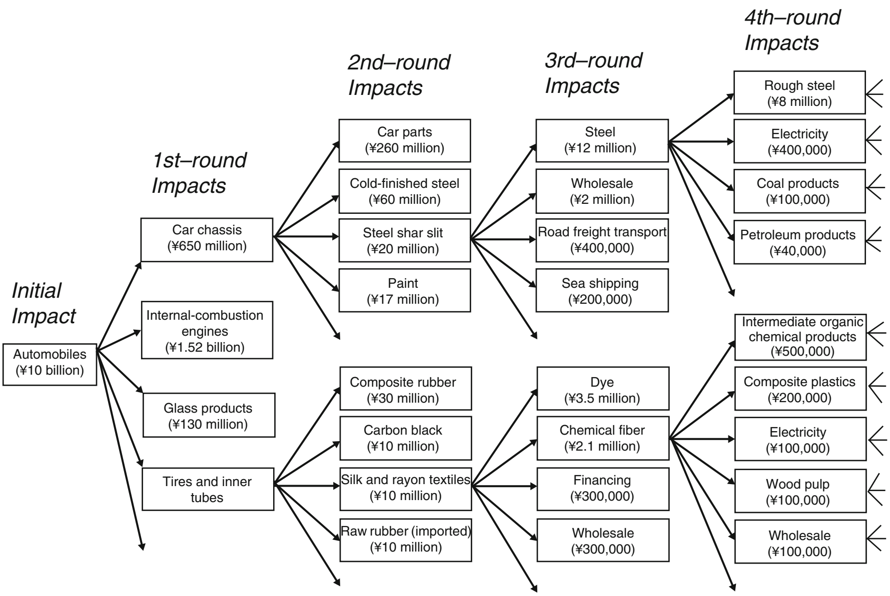


Fig. 6.3 An image of demand propagation (automobile industry) (*Source:* Drawn by the authors)

traditional demand–pull or cost–push impact models as shown in Fig. 6.3. In addition to the strength of linkages, the increasing complexity of production networks entails measuring the "length" of linkages to map the geometry of supply chains.

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 Fig. 6.4. 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 example, four paths lead from industry A to industry E. The path at the top has two production stages, the second one from the top has four stages, the third one from the top has three stages, and the one at the bottom has four stages.

When the shares of a delivered impact for each path are calculated, as given in parentheses at the end of branches, the APL between industry A and industry E is derived as[2]:

$$\mathrm{APL}_{(ae)} = 1 \text{ x } 0\% + 2 \text{ x } 50\% + 3 \text{ x } 30\% + 4 \text{ x } (10 + 10)\% + 5 \text{ x } 0\% + \ldots = 2.7. \tag{6.1}$$

That is, the 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 relative

[2] Note that in this example, there is no direct linkage between industry A and industry E, i.e., $l_{ae}^{(1)} = 0.00$ (0 %).

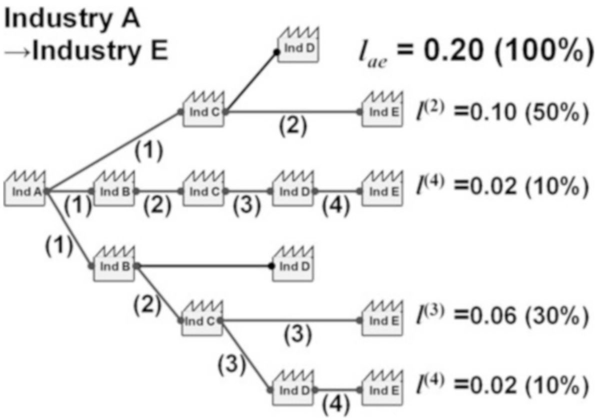


Fig. 6.4 Calculation of average propagation length (*Source:* Drawn by the authors)

strength of an impact at each stage as a weight.[3] 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, see Box 6.1).

Box 6.1 Note on Average Propagation Lengths

Suppose we have an economic system of n industrial sectors with a production structure defined by the input coefficient matrix $\mathbf{A}$ as shown in Fig. 6.5. 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 the value of the good or service i purchased for the production in industry j, and x_j is the total output of industry j. Thus, the coefficients represent the direct requirement of inputs for producing just one unit of output of industry j.

The vertical sequence of demand propagation can be depicted as follows. Let us consider the impact of demand for 100 units in industry 3 on 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

(continued)

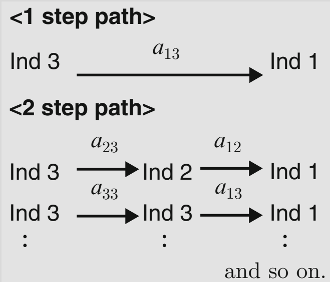
[3] The reasoning is as follows. If the share of a specific production stage in the overall magnitude of the impact is small, this implies that the corresponding path has a small contribution to the entire circuit of impact delivery, so this path is considered relatively insignificant in the supply chains and hence the number of production stages it has should be weighted less.

Box 6.1 (continued)

Fig. 6.5 Input coefficient matrix

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

Fig. 6.6 Impact delivery paths



through another industry, such as [3 → 2 → 1]. This is derived by two-stage multiplication, that is, 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 Fig. 6.6).

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 Δd**, into the input coefficient matrix, that is, $\mathbf{A} \times \mathbf{A}\, \mathbf{\Delta d} = \mathbf{A}^2\, \mathbf{\Delta d}$, where **Δd** is an initial demand injection. Similarly, the impact of three-step paths is given by $\mathbf{A} \times \mathbf{A}^2\, \mathbf{\Delta d} = \mathbf{A}^3\, \mathbf{\Delta d}$, that of four-step paths by $\mathbf{A} \times \mathbf{A}^3\, \mathbf{\Delta d} = \mathbf{A}^4\, \mathbf{\Delta d}$, and so on, which is evident from $[\mathbf{A}^2]_{ij} = \Sigma_k a_{ik} a_{kj}$, $[\mathbf{A}^3]_{ij} = \Sigma_k \Sigma_h a_{ik} a_{kh} a_{hj}$, etc. The amount of impact 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*th round steps or 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, that is, $\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1} = \mathbf{I} + \mathbf{A} + \mathbf{A}^2 + \mathbf{A}^3 + \mathbf{A}^4 + \ldots$, 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

(continued)

Box 6.1 (continued)
the following $\mathbf{A}^k$s are interpreted as progressive impacts of the initial demand when supply chains are sliced at the *k*th stage of the production process.

With this preliminary understanding, average propagation lengths are specified as:

$$\text{APL}_{(ji)} = 1^* a_{ij} / \left(l_{ij} - \delta_{ij}\right) + 2^* \left[\mathbf{A}^2\right]_{ij} / \left(l_{ij} - \delta_{ij}\right) + 3^* \left[\mathbf{A}^3\right]_{ij} / \left(l_{ij} - \delta_{ij}\right) + \ldots$$
$$= \sum_{k=1}^{\infty} k \left(\left[\mathbf{A}^{\mathbf{k}}\right]_{ij} / \sum_{k=1}^{\infty} \left[\mathbf{A}^{\mathbf{k}}\right]_{ij} \right),$$

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

The first term on the right side of the equation above shows that the impact delivered through one-step paths (k = 1), i.e. direct impact, amounts to a 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 a $[\mathbf{A}^2]_{ij}$ / $(l_{ij} - \delta_{ij})$ share, and three-step paths (k = 3) give a $[\mathbf{A}^3]_{ij}$/ $(l_{ij} - \delta_{ij})$ 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, the average propagation length 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.

6.2.3 Development of "Length" Analyses of Supply Chains

As noted, the traditional I–O approach to supply chain analysis generally centered on measuring interconnectedness or "strength" of linkages among industries. Adding the "length" dimension of supply chains basically responds to the following three motivations for the analysis of international production sharing:

(i) As demonstrated, it measures the degree of technological fragmentation and sophistication of particular supply chains.
(ii) The APL can be measured both in forward-looking and backward-looking ways. Thus, by comparing the lengths between the two for cross-national supply chains, we can identify the relative position of a country in global production networks.
(iii) If the production process is fragmented and shared among different countries, the impact of trade policies on the volume and direction of international trade increases.

The relevance of the APL model to the issue of fragmentation was first suggested in the seminal paper by Dietzenbacher et al. (2005), although the authors did not use the term "fragmentation" in their paper.[4] The APL model was applied at the international level in Dietzenbacher and Romero (2007), in which cross-national linkages were analyzed for major European economies using the IIO table of 1985. The study also employed the hypothetical extraction method to evaluate the influence of a single economy on the APL of the chosen regional system.

The international application of the APL model was adapted to cover developing economies by Inomata (2008a), with an extension to a time-series analysis using the Asian International Input–Output Tables of 1990, 1995, and 2000. In particular, the author proposed an index of geographical fragmentation based on the APL and compared its relative strengths and weaknesses 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 countries' APL, again using the Asian International Input–Output Tables, in both the forward and backward directions. Comparing the two values over time revealed the change in the relative positions of East Asian countries in the regional value chains.[5]

Fally (2011) developed a model with a philosophy similar to that of the APL model for the measurement of fragmentation. The major difference with the APL model is that the model, as well as its variation in Antras et al. (2012), captures the average number of production stages by pegging the end point of the sequence at the final consumption, which enables us to measure the "distance to final demand" or "upstreamness" of a product or industry along the supply chains. Both studies relied on national I–O tables of the United States (US) and other selected countries, but De Backer and Miroudot (2013) later applied Fally's model to the Organisation for Economic Co-operation and Development's Inter-country Input–Output Tables 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 multiple countries, intermediate products travel across national borders more frequently, and hence the volume of traded products becomes more sensitive to changes in a country's trade policies. The impact of protectionist measures on the international production system is magnified and becomes much more detrimental compared with when the production process was relatively simple and taking place in a smaller number of countries.

[4] 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 I–O tables estimated for 1978–2014.

[5] The analysis in the next section is a follow-up of this study using the latest dataset.

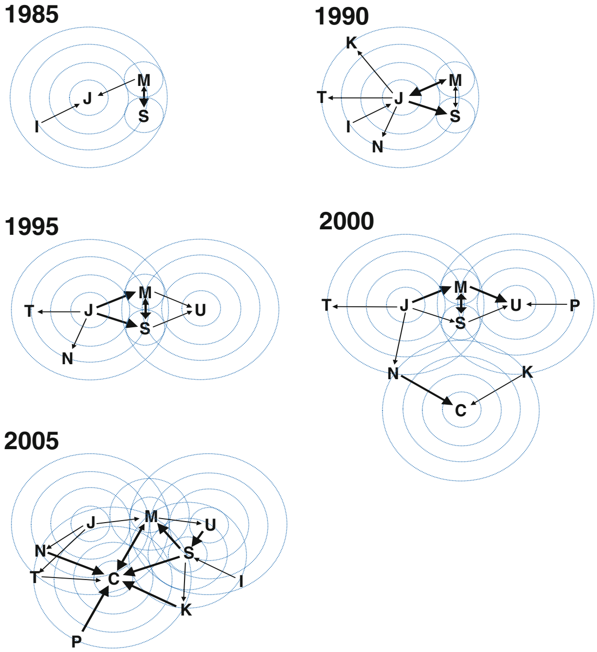


Fig. 6.7 Evolution of regional supply chains in East Asia, 1985–2005. Note: See notes in Fig. 6.1 for more details on the alphabetical coding of economies (*Source*: Authors' calculation based on IDE-JETRO Asian International Input–Output Table)

6.2.4 Analytical Results

The diagram in Fig. 6.7 traces the evolution of production networks in Asia and the US between 1985 and 2005. The visualization of the calculation results is based on the method presented in Dietzenbacher et al. (2005) with some graphical elaboration as 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 the APL. The number of rings an arrow crosses represents the rounded value of the APL, the average number of production stages, and thus indicates the level of technological fragmentation and sophistication of that particular supply chain.[6]

The analysis uses the Asian International Input–Output Tables for the reference years 1985, 1990, 1995, 2000, and 2005, constructed by IDE–JETRO. The IIO table is a major effort bringing together statistics taken from various national sources, and hence the results can be read exactly in the same manner as for national I–O tables. The major difference is that it explicitly presents international transactions between industries in the form of import and export matrices by trading partners,

[6] For a detailed explanation of the visualization method, see the annex of WTO and IDE–JETRO (2011).

which enables us to draw a comprehensive map of global production networks. The table in this analysis combines the national I–O tables of 10 economies: the PRC (C); Indonesia (I); Japan (J); the Republic of Korea (K); Malaysia (M); the Philippines (P); Singapore (S); Taipei,China (N); Thailand (T); and the US (U).

In 1985, the region had only four key players: Indonesia (I), Japan (J), Malaysia (M), and Singapore (S). The basic structure of the production network was determined by Japan having built up supply chains from resource-rich countries such as Indonesia and Malaysia. In this initial phase of regional development, Japan drew on large amounts of natural resources from neighboring countries to feed to its domestic industries.

By 1990, the number of key players had increased. In addition to the economies listed above, Japan extended its supply chains of intermediate products to the Republic of Korea (K); Taipei,China (N); and Thailand (T). While still relying on the productive resources of Indonesia and Malaysia, Japan also started supplying products to other East Asian economies, especially to the group known as the newly industrialized economies (NIEs). Triggered by the Plaza Accord of 1985, this phase was marked by a relocation of Japanese production bases to neighboring countries, resulting in the development of strong linkages between core parts suppliers in Japan and Japanese multinationals' foreign subsidiaries.

In 1995, the US (U) entered the picture. It drew on two key supply chains originating in Japan, one via Malaysia and the other via Singapore, so these two countries came to bridge the supply chains between East Asia and the US. The relatively short length of the arrows between Malaysia and Singapore indicates that the supply chains involve fewer production stages, suggesting that the degree of processing is relatively low. The product flows between these countries are considered to be distributional rather than value-adding.

In 2000, on the eve of its accession to the World Trade Organization (WTO), the PRC began to emerge as the third regional giant. The country entered the arena with strong production linkages to the Republic of Korea and Taipei,China, and gained access to Japanese supply chains through Taipei,China. And with the US adding a new supply chain from the Philippines (P), the basic structure of the tripolar production network in Asia and the US had taken shape.

The regional production networks thereafter showed dramatic development. By 2005, the center of the network had completely shifted to the PRC, pushing the US and Japan to the periphery. The PRC became the core market for the intermediate products of the region, from which final consumption goods were produced for export to the US and European markets. The nature of the supply chains that the PRC developed with others is also worth noting. The relatively long arrows surrounding the PRC indicate that the supply chains toward the PRC are characterized by a high degree of fragmentation and sophistication, incorporating substantial amounts of value-added from each economy involved in the production networks. Hence, the competitiveness of PRC exports is attributable not only to its cheap labor force, but also to the sophisticated intermediate products the country receives from other East Asian economies, as embodied in goods with a "Made in China" label.

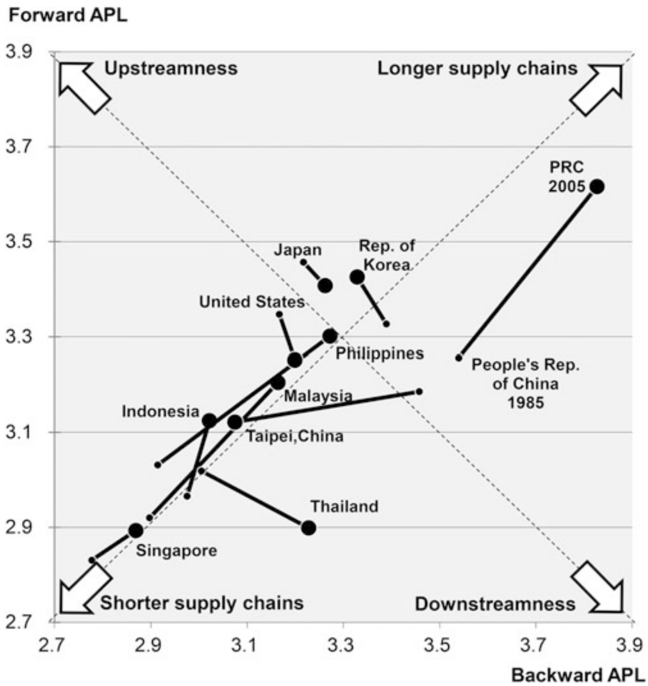


Fig. 6.8 Change of relative positions in the regional supply chains, 1985–2005. *APL* average propagation length; *PRC* People's Republic of China (*Source*: Authors' drawing based on the Inomata (2008b) methodology and IDE-JETRO Asian International Input–Output Table)

The APL method can also be used to measure separately the upstream and downstream average lengths of production linkages. Updating the methodology proposed by Inomata (2008b), Fig. 6.8 presents the changes between 1985 and 2005 in the relative positions of economies in East Asian supply chains with respect to forward and backward APLs.

Reading the chart from bottom left to top right, it presents the entire length of supply chains in which each economy participates. Most economies have moved toward the top right, which means they increased the length of their supply chains between 1985 and 2005. The exceptions to this trend are the US and Taipei,China, while Japan's change in this direction was very small. In contrast, the PRC's supply chains saw a sharp increase in length. It is considered that the country's accession to the WTO in 2001 accelerated the interlinking of its domestic supply chains with overseas production networks, as suggested by the big leap in the value from 1985 to 2005.

The diagonal running from the top left to the bottom right draws the relative position of each economy within the regional supply chains, as determined by the ratio of forward and backward APLs. The US and Japan, the most advanced economies in Asia and the Pacific, are located in the upstream position, though they lowered their "upstreamness" between 1985 and 2005, and the US has swapped its position with the Republic of Korea. The PRC remains in the downstream segment of the regional supply chains, which reflects its position as a "final assembler" of regional products.

The other economies remain more or less in the middle spectrum, though Taipei,China moved up into the middle cluster and Thailand moved largely downstream. These changes clearly reflect the development of the roles of these two economies in the region. Taipei,China significantly increased its electronics manufacturing service and became a major parts supplier to big computer multinationals, while there was a massive inflow of Japanese car assembly plants into Thailand, which later led to the country being referred to as the "Asian Detroit."

Figure 6.9 maps the previous diagram into a one-dimensional schematization of the relative position of countries within the regional supply chains. From 1985 to 2005, upstream economies were more or less clustered, while the PRC and Thailand became downstream stand-alones. It was a period marked by bipolarization between parts suppliers and final assemblers.

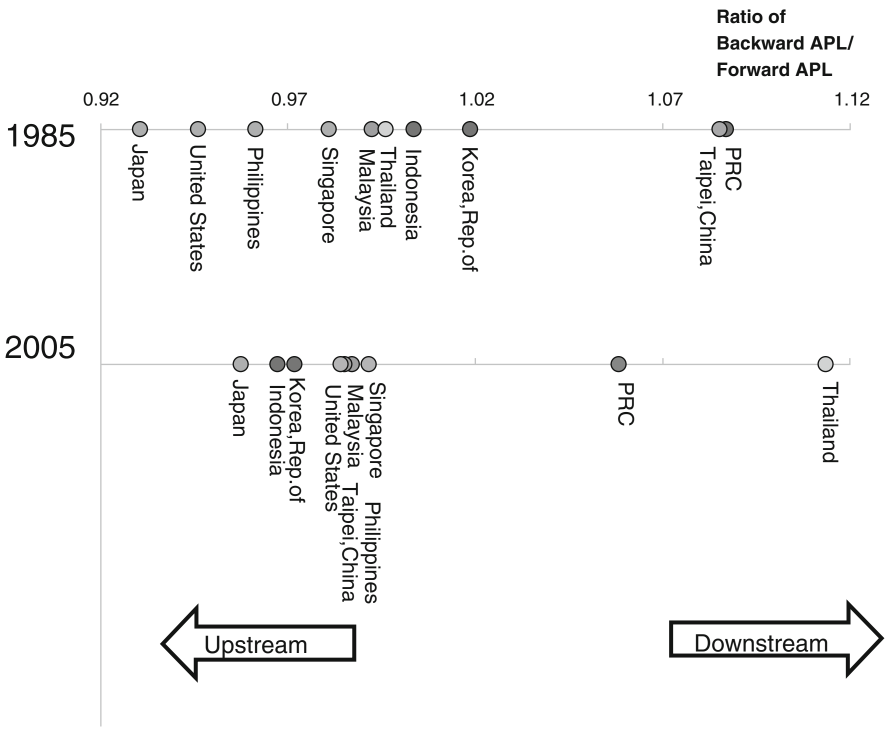


Fig. 6.9 One-dimensional schematization of the relative positions in the regional supply chains, 1985–2005. *APL* average propagation length; *PRC* People's Republic of China (*Source*: Authors' drawing based on the Inomata (2008b) methodology and IDE-JETRO Asian International Input–Output Table)

6.3 Tariffs, Transport, and Trade Facilitation

As shown above, graph analysis and IIO matrices can be useful in revealing the topological characteristics of inter-industrial networks and their evolution. This section describes some empirical characteristics of bilateral trade "distance" that have a particular relevance from a production network perspective.

Understanding what defines the associativity between industrial sectors from a network perspective (or, symmetrically, the "distance" that lessens the possibility of interactions) would imply not only taking into consideration the bilateral relationship, but also associating it with the rest of the cluster of industries and economies that comprise the supply chain (Abbate et al. 2012). According to the traditional trade perspective, transaction costs, including border costs and the cost of transporting goods from producers to users, affect the volume, direction, and pattern of trade. To quote Waldo Tobler: "everything is related to everything else, but near things are more related than distant things" (De Benedictis and Taglioni 2011, p. 75). From a global value chain perspective, associativity between trade partners becomes more complex as defining comparative advantages goes beyond the simple bilateral relationship. When trade takes place within a production network, it is necessary to adopt a holistic method, as the intensity of bilateral trade depends also on the B2B nexus with all other network participants (Noguera 2012). For example, the capacity of a supplier to join a supply chain will depend on its location relative to its upstream and downstream partners. More than in traditional trade, transaction costs (border and behind-the-border costs of trade) are a crucial factor in the competitiveness of firms and determine in part their ability to participate in production networks. This is one of the reasons that implementing the WTO's Bali Agreement on Trade Facilitation (December 2013) is expected to have a strong multiplier effect on trade.

Connectedness with other trade partners is central to explaining bilateral trade from a network perspective: bilateral "trade in tasks" depends not only on the traditional complementarity factors helping to match industrial supply and demand between two countries, but also on the number of partners they have in common. It is possible that no physical flow can be seen between two closely interconnected partner economies, because all trade in value-added transits through a third country that plays the role of a hub in the network.

6.3.1 Cascading Transaction Costs in Production Networks

The limited evidence available so far (Yi 2003; Ferrantino 2012) has highlighted a very marked nonlinearity in the way transaction costs negatively affect trade flows from a "trade in tasks" perspective, with goods having to travel through several nodes before reaching their final destination. Yi (2003) showed that a small decrease in tariffs can induce a tipping point at which previously nonexistent vertical specialization (trade in tasks) kicks in. When tariffs fall below this threshold, a large and nonlinear increase in international trade can be observed. The cascading and nonlinear impact of tariff duties when countries are vertically integrated can be extended to other components of transaction costs. When supply chains require that semi-finished goods cross international borders more than once, the ultimate effect of a marginal variation in trade costs anywhere in the supply chain is much larger than in the case of only one international transaction.

Ferrantino (2012) showed that when transaction costs (tariff duties, etc.) apply in proportion to the value of the good, the total cost of delivering the product to the final consumer increases exponentially as the number of international production stages increases.[7] For example, if the average ad valorem transaction cost is 10 %, accumulated transaction costs in a five-stage supply chain lead to an ad valorem tariff equivalent of 34 %. Doubling the number of stages by slicing up the supply chain increases total delivery costs more than twofold, as the tariff equivalent is 75 %. This underlines the critical role of low transaction costs, including tariff duties and non-tariff measures, in facilitating trade from a “trade in tasks” perspective.

Moreover, as we will see, some features of these transaction costs, such as tariff schedules escalating as a function of the number of processing stages, may be particularly harmful to trade in tasks. For a supply chain strategy to be successful, as was the case in East Asia, it is necessary, therefore, that these transaction costs, both physical and government-induced, are minimized.[8] Reducing these costs from a regional perspective is particularly important as many supply chains are regionally based, as has been observed in North America, Europe, and East Asia. The following sections will review how the transaction costs have changed over time to accommodate and facilitate the development of regional production networks.

6.3.2 Tariff Duties, Effective Rate of Protection, and Tax on Domestic Value Added

Of all cross-border transaction costs, nominal tariffs are the most visible. Tariff duties increase the domestic price of tradable goods by adding a tax to their international, or free market, price. These effects, known since the late 1960s, take on a new dimension when analyzed from the perspective of global value

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

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

chains. From a "trade in tasks" perspective, not only is the value of nominal tariffs particularly important, but also their distribution between unprocessed and processed goods—a feature of nominal schedules known as tariff escalation. By effecting a larger increase of the domestic prices of finished goods compared to those of intermediary ones, tariff escalation creates a significant anti-export bias on complex manufactured goods when value-added is the traded "commodity," as becomes clear when effective protection rates (EPRs) are calculated.

EPRs deduct the additional production cost the producer had to pay because of the tariff charged on the importable inputs from the nominal protection received on one unit of output produced by an industry and sold on the domestic market (at a price higher than in the free market because of the duty charged on competitive imports). The result is compared with the hypothetical value-added that would have resulted from the operation had no custom duties been levied.

More formally, the EPR for sector j is the difference between the nominal protection enjoyed on the output minus the weighted average of the tariff paid on the required inputs, divided by value-added at free-trade prices:

$$EPR_j = \frac{t_j - \sum_i (t_i \, . \, a_{ij})}{1 - \sum_i a_{ij}} \tag{6.2}$$

where

a_{ij} = elements of the matrix **A** of technical coefficients in an I–O matrix
t_j = nominal tariff on sector j
t_i = nominal tariff on inputs purchased from sector i.

Sector i can be equal to sector j when a firm purchases inputs from other firms of the same sector of activity. In an inter-country framework, i includes an additional trade partner dimension [c], as inputs from sector i might be domestic or imported.

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, however, will have a lower protection, and possibly a negative one if the sum of duty taxes paid on inputs is higher than the taxes collected on output.

6.3.2.1 Effective Protection Rates and Trade in Value-Added

Noting that $\left[1 - \sum_i a_{ij}\right]$ 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), the EPR can be interpreted as the ratio of value-added per unit of output at domestic prices—tariffs applying on both outputs and inputs—to the value-added the industry would have gained if operating at international prices (without tariff duties).

A high EPR, resulting, for example, from high nominal duties and a steep tariff escalation, reduces the incentive for protected sectors to export, as their rate of return on the domestic market is higher than what they can expect on the international market. Similarly, an exporting firm will be at a disadvantage vis-à-vis a foreign competitor operating in a free trade environment, as its value-added when selling at world prices (left side of Eq. 6.3) is lower than that of its free trade competitor (right side):

$$\left(1_j - \sum_i (t_i \, . \, a_{ij})\right) < \left(1 - \sum_i a_{ij}\right). \tag{6.3}$$

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 analyzing trade policy from a "trade in value added" perspective (Diakantoni and Escaith 2012). This is one of the reasons developing countries with high tariff duties establish their export-oriented activities in export processing zones where inputs can be imported duty-free. Nevertheless, as we will show, this strategy may initially be relevant for joining a supply chain, but falls short of policy makers' expectations when it comes to fostering upgrading by incorporating more domestic tasks in the production process.

6.3.2.2 Effective Protection Rates, Trade in Value-Added, and the Densification of Domestic Industrial Networks

The negative impact of high EPRs on second-tier domestic suppliers occurs because tariff duties influence the domestic price of all inputs, including those produced domestically. Domestic suppliers of tradable goods are able to raise their prices up to the level of the international price plus the tariff duty, without the risk of being displaced by imports.

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 drawback schemes, allowing domestic firms to have the duty taxes paid on inputs reimbursed when exporting their products. But as shown below, this mitigating strategy is clearly insufficient in the case of a fragmented production network.

To distinguish between the costs of domestic and foreign inputs, the EPR can therefore be written as:

$$EPR_j = \frac{t_j - \left[\sum_i (t_i \, . \, a^f{}_{ij}) + \sum_i (t_i . \, a^h{}_{ij})\right]}{1 - \sum_i a_{ij}} \tag{6.4}$$

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.

When duty drawbacks or tariff exemptions (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 (represented by the sum $\sum_i \left(t_i . a_{ij}^h\right)$ in Eq. 6.4) will not be able to benefit from the duty exemption. Thus, despite drawbacks, the first-tier suppliers will be at a disadvantage compared with their free trade competitors (right side of Eq. 6.5) if they source some of their inputs from other local suppliers or outsource part of their tasks to them[9]:

$$\left(1 - \left[\sum_i a^f{}_{ij} + \sum_i \left(t_i . a_{ij}^h\right)\right]\right) < \left(1 - \sum_i a_{ij}\right) \tag{6.5}$$

EPZs or duty drawback schemes will benefit the lead exporting firm only if it uses imported inputs, but such a strategy will price out domestic suppliers if nominal tariffs are high. The national suppliers of these firms, because they sell in 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 nonimported inputs would still be at a disadvantage because nominal protection would raise the domestic price of all tradable products, irrespective of whether they are in fact imported. Moreover, nominal protection indirectly affects the production cost of services, many of them playing an important role in defining the international competitiveness of firms from a global value chain perspective (Diakantoni and Escaith 2014).

While the anti-export bias (Eq. 6.3) is a well-known result from a "traditional trade in final goods" perspective, the new corollary (Eq. 6.4) is relevant only from a vertical specialization perspective, according to which a "buy" decision arising from a "make or buy" assessment implies arbitraging between domestic and foreign suppliers.

High EPRs lower the competitiveness of domestic suppliers by increasing the "country cost" in the same way 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 to reduce transaction costs below the tipping point at which vertical specialization is profitable, as suggested in Yi (2003); and (ii) reducing tariff escalation and EPRs to reduce the anti-export bias of the tariff schedule and its inflationary impact on the "country costs."

Developing economies in East Asia did follow the policy of lowering EPRs, as shown in Table 6.2. Not only did nominal protection drop, but the dispersion of duties—the main source of variance in EPRs—was also lower, as can be observed from the steeper drop in the nominal protection average than in the median. As a result, EPRs decreased in both the agriculture sector and the manufacturing sector.

[9] This is the case unless firms substitute high-tariff domestic inputs for lower ones (negative correlation between changes in t_i and $a^h{}_{ij}$). Diakantoni and Escaith (2012), however, show that almost no substitution took place in East Asia.

Table 6.2 Nominal protection and effective protection rates in East Asia and the Pacific, 1995–2005 (percentage, ad valorem)

	Developing countries				Developed countries			
	Agriculture		Manufacturing		Agriculture		Manufacturing	
	1995	2005	1995	2005	1995	2005	1995	2005
NP median	6.5	3.9	9.2	6.2	1.3	1.9	2.3	1.3
NP average	27.2	11.9	15.9	7.8	2.0	2.1	4.0	2.9
EPR median	4.9	2.6	14.7	10.6	0.9	3.1	3.5	1.8
EPR average	29.6	15.5	26.3	16.6	1.1	3.9	8.3	5.8

Source: Diakantoni and Escaith (2012) based on 10 economies in IDE-JETRO's Asian international input–output table and World Trade Organization tariff data
EPR effective protection rate, *NP* nominal protection

For the developed countries that already had low tariffs in 1995, the reduction in the protection of domestic manufacturing was less impressive in absolute values, but still important in relative terms. By contrast, nominal protection of agriculture remained stable, or even increased, when weighting for trade flows. As the protection on industrial inputs purchased by farmers decreased, they benefited from higher EPRs. It should be noted that the new light shed on EPRs by the observed impact of tariffs on global value chains motivated advanced countries such as Canada to apply duty-free treatment for all intermediate goods with the objective of "being the first G20 country to become a tariff-free zone for manufacturers."[10]

6.3.3 Transport and Trade Facilitation

As for tariffs, the costs for transport and customs procedures are magnified in international supply chains, because goods for processing cross several borders and these costs are incurred twice—first on imported components and then on the processed good. The cumulative effect of such barriers creates delays in delivery and uncertainty that may make it impossible for domestic firms to compete for the higher value-added portion of the value chain, where flexibility, reactivity, and just-in-time delivery are essential. The social cost in terms of lost jobs and business opportunities due to loss of competitiveness is much higher than the financial cost of maintaining large inventories and immobilizing transport equipment for long periods of time. 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 economies invested in improving transport infrastructure. They also put in place schemes aimed at alleviating administrative burdens and encouraging processing trade to take full advantage of global value chains. As shown in Duval and Utoktham (2011), the non-tariff

[10] Former Canadian Finance Minister Jim Flaherty quoted in *The Globe and Mail* (2010).

cost of trade in goods was 53 % of the value of goods for intraregional trade within Southeast Asia in 2007, compared with a prohibitive 282 % within South and Central Asia. The 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 as the top trade facilitator, followed by the US, the PRC, the Republic of Korea, and Thailand. Singapore and Hong Kong, China were not in the ranking, but would probably be among the top performers.[11] Similarly, the WTO and IDE-JETRO (2011) highlight the role of transport and logistics in fostering the development of global value chains in East Asia by stating that, in 2009, of the top 10 leading world ports in terms of container traffic, five were located in the PRC and one each in Hong Kong, China; the Republic of Korea; and Singapore. These four economies account for 38 % of the world's container port traffic.

Figure 6.10 shows that, despite the high efficiency of the Asian hubs (Singapore ranks second after Germany on the World Bank's logistics index, while Japan ranks seventh and Hong Kong, China 13th, all ahead of the US and Canada), there is still room for improvement in most of the region's countries. In particular, the region is still far removed from best practices in customs procedures found in high-income countries. Improving efficiency in customs procedures is a matter of introducing relatively low-cost administrative reforms, unlike improving trade- and transport-related infrastructure, which requires costly investments in ports, railroads, roads, and information technology.

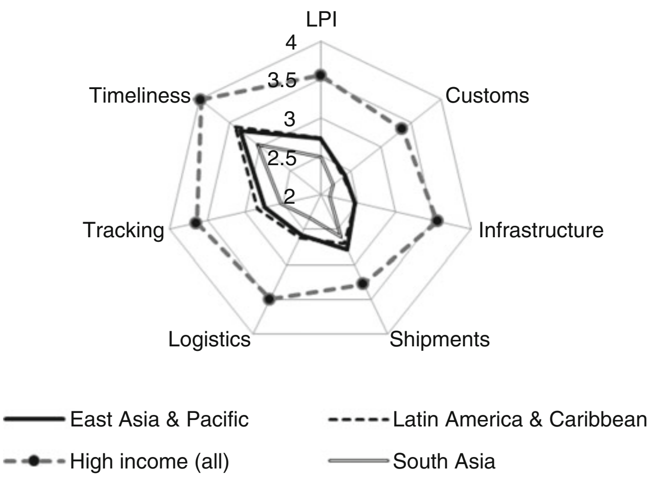


Fig. 6.10 Trade, logistics, and transportation: East Asia in perspective. Note: Logistics performance index (LPI), weighted average of the six key dimensions (*Source*: Elaborated on the basis of the World Bank LPI for 2012)

[11] Bilateral "natural" trade costs between trade partners were found to account for nearly a third of non-tariff trade costs. While significant, this incompressible share leaves a lot of room for transport and trade facilitation policies.

6.3.4 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, if it is disruptive, stop production chains. 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 I–O setting, a rough measure of the depth and length of supply shocks along production chains is given by the APL of this shock.

Table 6.3 presents a modified version of the APL (Diakantoni and Escaith 2012) calculated for 2005 using IDE-JETRO's aggregated 26-sector Asian input–output matrix. From a country perspective, the PRC is the main hub for inter-industrial

Table 6.3 Sectoral average propagation length in East Asia, 2005 (selected cases)

	PRC	Japan	US	Rep. of Korea	Taipei,China	Malaysia	***Average***[a]
Paddy	1.2	0.4	0.0	0.3	0.0	0.1	*0.4*
Crude petroleum and natural gas	11.5	0.3	17.5	1.3	0.1	16.3	*6.8*
Food, beverage, and tobacco	9.6	4.6	6.9	1.7	0.6	7.0	*4.1*
Textile, leather, and other	18.5	4.2	2.3	3.7	3.7	1.3	*3.9*
Chemical products	40.7	66.8	45.0	27.3	23.5	8.8	***24.1***
Petroleum and petrol products	22.5	11.3	9.7	12.9	10.7	12.5	*11.7*
Metals and metal products	75.8	100.0	27.3	31.6	17.8	6.9	***27.5***
Industrial machinery	20.7	23.1	9.5	3.8	2.6	2.5	*6.8*
Computers and electronic equipment	25.2	43.1	19.3	18.1	20.3	9.9	***16.5***
Other electrical equipment	25.2	25.7	23.2	8.4	8.5	5.5	*10.7*
Transport equipment	10.5	29.0	10.4	3.8	0.6	1.3	*6.4*
Other manufacturing products	18.1	17.6	8.4	3.8	3.0	2.8	*5.9*
Average[a]	*16.9*	*17.0*	*10.0*	*6.0*	*4.7*	*4.5*	*7.0*
Median[a]	*11.5*	*4.6*	*6.9*	*2.1*	*0.7*	*2.8*	*4.3*

Source: Based on Diakantoni and Escaith (2012)
Note: Results exclude domestic impacts and were rescaled to 100 for maximum value
PRC People's Republic of China; *US* United States
[a]Average and median values are calculated on the full sample of 10 economies and 21 industrial sectors included in the IDE-JETRO Asian International Input–Output Table

connections, when both intensity and length are considered. Japan follows closely in second place in terms of average APL indexes due to the high value of some sectors (metals, chemical products, and computers), and the US is the third most important hub. From a sectoral perspective, chemical products and metals and metal products are the sectors generating most of the depth in inter-industrial connections by far; industries producing computers and electronic equipment are also highly interconnected.

6.4 Conclusions

Thanks to a close relationship between I–O analysis and graph theory, diachronic IIOs are useful tools for mapping and visualizing the evolution of productive networks, enabling us to identify the main industrial clusters and their B2B trade relationships. Applying these geometric properties to the Asia–US context, it is shown that the inter-industry network moved from a simple hub-and-spokes cluster, centered on Japan in 1985, to a much more complex structure in 2005 with the emergence of the PRC, forming a vertically specialized production system with a highly asymmetric flow of value-added among the constituent countries.

The rise of "Factory Asia" and the present topology of its regional supply chains were determined by specific policies. The densification of productive networks in East Asia resulted from the coincidence of common business strategies (linked to the widespread adoption of international supply chain management by lead firms in Japan and the US) and the promotion of export-led growth strategies from developing East Asian countries. These countries applied a series of trade facilitation policies that not only lowered tariff duties, but also reduced other transaction costs.

We show that between 1995 and 2005 tariff escalation was greatly reduced in developing East Asia, lowering the dissuasive 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 East Asia is well ahead of the rest of developing Asia in terms of trade and transport facilitation, substantial progress needs to be made to close the gap with best international practices, particularly in terms of customs administration. The outcome of the WTO's Ministerial Conference in Bali in December 2013 opened the way for a renewed global effort toward greater trade facilitation, which will provide new regional and extra-regional trade opportunities. The potential is particularly important for extending inter-industrial networks, offering lesser developed economies new opportunities for industrialization.

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