Part II

Why and how we measure trade in value-added terms

3 Estimating trade in value-added: why and how?

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3.1. Introduction

Global value chains (GVCs) have become a dominant feature of today's global economy. This growing process of international fragmentation of production, driven by technological progress, cost, access to resources and markets and trade policy reforms has challenged our conventional wisdom on how we look at and interpret trade and, in particular, the policies that we develop around it. Indeed, traditional measures of trade that record gross flows of goods and services each and every time they cross borders, alone, may lead to misguided decisions being taken.

In practice, two main approaches (micro and macro) have been used to shed light on this issue. The former is perhaps best characterized by the well known Apple iPod example (Dedrick et al., 2010), which showed that of the US$ 144 (Chinese) factory-gate price of an iPod, less than ten per cent contributed to Chinese value-added, with the bulk of the components (about US$ 100) being imported from Japan and much of the rest coming from the United States and the Republic of Korea.

This stylized approach, however, can generally only be conducted for specific products and, even then, only reveals part of the story related to who benefits from trade and how global value chains work as it is typically unable to reveal how the intermediate parts are created. For example, the message would be significantly different if, for sake of argument, the imported parts from Japan used to make the iPod required significant Chinese content. To deal with the bigger picture and also to capture all of the upstream effects, a number of studies have adopted a macro approach based on the construction of inter-country or world input-output (I-O) tables (Hummels et al., 2001; Daudin et al., 2006; 2009), Johnson and Noguera, 2011 and Koopman et al., 2011). A number of pioneering initiatives, such as those of GTAP, the WTO with IDE-JETRO and the WIOD (World Input-Output Database), have helped accelerate improvements in the underlying statistics used to construct the results.

These studies and initiatives have generally been one-off in nature and often require the use of non-official statistical data. What has been lacking thus far has been a systematic attempt to mainstream the development of statistics in this area. In response to this need, on 15 March 2012, the OECD and WTO joined forces to develop a database of Trade in Value-Added (TiVA) indicators and to mainstream their production within the international statistics system. The first preliminary results from this initiative were released on 16 January 2013.

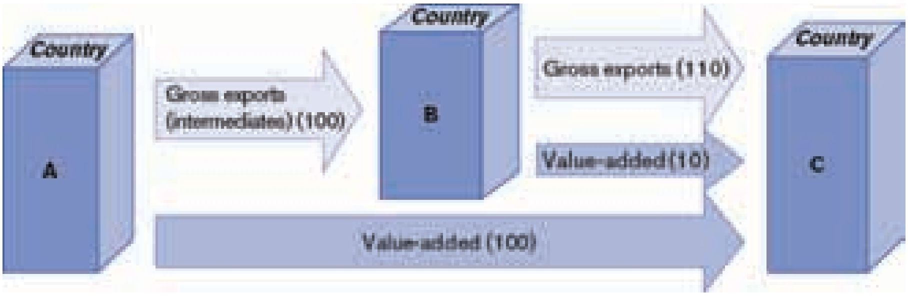
While the literature on trade in value-added is quite technical, it has attracted a lot of attention from policymakers. What initially seemed a concern for trade statisticians is now understood as a key issue for the policy debate. For example, WTO Director-General Pascal Lamy noted, "the statistical bias created by attributing commercial value to the last country of origin perverts the true economic dimension of the bilateral trade imbalances. This affects the political debate, and leads to misguided perceptions".[1] Recently, the French Senate devoted a special seminar to the related statistical and policy issues.[2]

The remainder of this section describes the motivation for this initiative and the underlying methodology and assumptions used to estimate trade in value-added, as well as future avenues of research.

3.2. What is trade in value-added?

The Trade in Value-Added initiative addresses the double counting implicit in current gross flows of trade, and instead measures flows related to the **value** that is **added**

Figure 3.1: Trade in value-added



Source: Author.

(labour compensation, other taxes on production and operating surplus or profits) by a country in the production of any good or service that is exported.

A simple example illustrates this. Country A exports US$ 100 of goods, produced entirely within A, to country B that further processes them before exporting them to C where they are consumed. Country B adds value of US$ 10 to the goods and so exports US$ 110 to C. Conventional measures of trade show total global exports and imports of US$ 210 but only US$ 110 of value-added has been generated in their production. Conventional measures also show that country C has a trade deficit of US$ 110 with B and no trade at all with A, despite the fact that A is the chief beneficiary of C's consumption.

If instead we track flows in value-added, one can recalculate country C's trade deficit with country B on the basis of the value-added it "purchases" from B as final demand, which reduces its deficit on this basis, to US$ 10, and then apply the same approach to A's value-added to show C running a deficit of US$ 100 with A. Note that country C's overall trade deficit with the world remains at US$ 110. All that has changed are its bilateral positions. This simple illustration reveals how output in one country can be affected by consumers in another and by how much (for example country C's consumers driving A's output) but it can also reveal many other important insights into global value chains. For example, it shows that country B's exports depend significantly on intermediate imports from A and so reveals that protectionist measures on imports from A could harm its own exporters and hence competitiveness. Indeed, by providing information at the level of specific industries, it is possible to provide insights in other areas too, such as the contribution of the service sector to international trade.

3.3. Motivation – why?

There are a number of areas where measuring trade in value-added terms brings a new perspective and is likely to impact on policies:

- Trade, growth and competitiveness: better understanding how much domestic value-added is generated by the export of a good or service in a country is crucial for development strategies and industrial policies. Some countries have capitalized on global value chains by developing comparative advantages in specific parts of the value chain. For example in China, much of its exports reflect assembly work where the foreign content is high. Access to efficient imports therefore matters as much in a world of international fragmentation as does access to markets. Conventional gross trade statistics, however, are not able to reveal the foreign content of exports and so there is a risk that policies to protect industries where gross statistics reveal a comparative advantage may decrease the competitiveness of those very same domestic industries, and so mercantilist-styled “beggar-thy-neighbour” strategies can turn out to be “beggar thyself” miscalculations.

- In addition, domestic value-added is not only found in exports but also in imports: goods and services produced in one domestic industry are intermediates shipped abroad whose value comes back to the domestic economy embodied in the imports of other, and often the same, industries. As a consequence tariffs, non-tariff barriers and trade measures – such as anti-dumping rights – can also impact on the competitiveness of domestic upstream producers (as well as the competitiveness of downstream producers as mentioned above) in addition to foreign producers. For example, a study of the Swedish National Board of Trade on the European shoe industry highlights that shoes “manufactured in Asia” incorporate between 50 per cent and 80 per cent of European Union value-added. In 2006, the European Commission introduced anti-dumping rights on shoes imported from China and Viet Nam. An analysis in value-added terms would have revealed that EU value-added was in fact subject to the anti-dumping rights.[3]

- Looking at trade from a value-added perspective is also able to better reveal how upstream domestic industries contribute to exports, even if those same industries have little direct international exposure. Gross trade statistics, for example, reveal that less than one-quarter of total global trade is in services, but in value-added terms the share is significantly higher. Goods industries require significant intermediate inputs of services (both from foreign and domestic suppliers). Looking at trade in value-added terms therefore can reveal that policies to encourage services trade liberalization and more foreign direct investment, and so policies designed to improve access to more efficient services, can improve the export competitiveness of goods industries.

- Global imbalances: accounting for trade in value-added (specifically accounting for trade in intermediate parts and components) and taking into account “trade in tasks” does not change the overall trade balance of a country with the rest of the world – it redistributes the surpluses and deficits across partner countries. When bilateral trade balances are measured in gross terms, the deficit with final goods producers (or the surplus of exporters of final products) is exaggerated because it incorporates the value of foreign inputs. The underlying imbalance is in fact with the countries that supplied inputs to the final producer. As pressure for rebalancing increases in the context of persistent deficits, there is a risk of protectionist responses that target countries at the end of global value chains on the basis of an inaccurate perception of the origin of trade imbalances. As shown below, the preliminary results from the OECD-WTO database point to significant changes.

- The impact of macro-economic shocks: the 2008–09 financial crisis was characterized by a synchronized trade collapse in all economies. Authors have discussed the role of global supply chains in the transmission of what was initially a shock on demand in markets affected by a credit shortage. In particular, the literature has emphasized the "bullwhip effect" of global value chains.[4] When there is a sudden drop in demand, firms delay orders and run down inventories with the consequence that the fall in demand is amplified along the supply chain and can translate into a standstill for companies located upstream. A better understanding of value-added trade flows would provide tools for policymakers to anticipate the impact of macroeconomic shocks and adopt the right policy responses. Any analysis of the impact of trade on short-term demand is likely to be biased when looking only at gross trade flows. This was again more recently demonstrated in the aftermath of the natural disaster that hit Japan in March, 2011.[5]

- Trade and employment: several studies on the impact of trade liberalization on labour markets try to estimate the "job content" of trade. Such analysis is only relevant if one looks at the value-added of trade. What the value-added figures can tell us is where exactly jobs are created. Decomposing the value of imports into the contribution of each economy (including the domestic one) can give an idea of who benefits from trade. The EU shoe industry example given above can be interpreted in terms of jobs. Traditional thinking in gross terms would regard imports of shoes manufactured in China and Viet Nam by EU shoe retailers as EU jobs lost and transferred to these countries. But in value-added terms, one would have to account for the EU value-added and while workers may have indeed lost their jobs in the EU at the assembly stage, value-added-based measures would have highlighted the important contribution made by those working in the research, development, design and marketing activities that exist because of trade (and the fact that this fragmented production process keeps costs low and EU companies competitive). When comparative advantages apply to "tasks" rather than to "final products", the skill composition of labour imbedded in the domestic content of exports reflects the relative development level of participating countries. Industrialized countries tend to specialize in high-skill tasks, which are better paid and capture a larger share of the total value-added. A WTO and IDE-JETRO study on global value chains in East Asia shows that China specializes in low-skill types of jobs. Japan, on the contrary, has been focusing on export activities intensive in medium and high-skill labour, while importing goods produced by low-skilled workers. The study also shows that the Republic of Korea was adopting a middle-of-the-ground position (in 2006), but was also moving closer to the pattern found in Japan.[6]

- Trade and the environment: another area where the measurement of trade flows in value-added terms would support policymaking is in the assessment of the environmental impact of trade. For example, concerns over greenhouse gas emissions and their potential role in climate change have triggered research on how trade openness affects CO_2 emissions. The unbundling of production and consumption and the international fragmentation of production require a value-added view of trade to understand where imported goods are produced, and hence where CO_2 is produced as a consequence of trade. Various OECD studies note that the relocation of industrial activities can have a significant impact on differences in consumption-based and production-based measures of CO_2 emissions (Ahmad et al., 2003 and Nakano et al., 2009).

3.4. Early evidence from the OECD-WTO database[7]

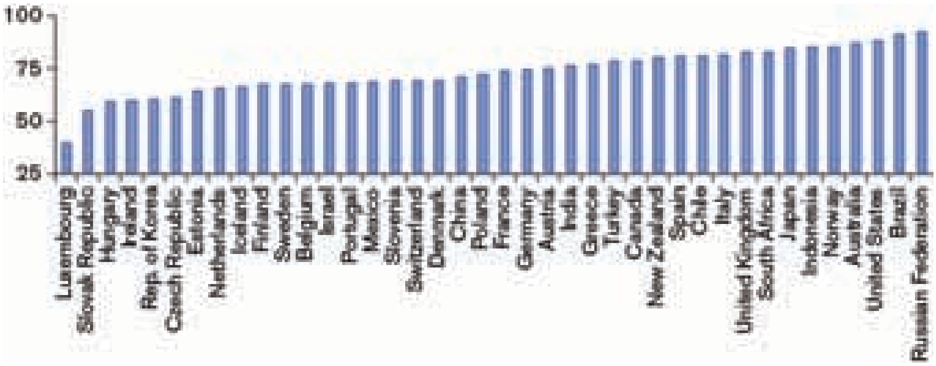
At the time of writing the database is based on a global input-output table that brings together national input-output tables for 57 economies, combined with bilateral trade data on goods and services, with a breakdown into 37 industries (see below). The following provides an overview of the key messages provided by the data.

Exports require imports

The data reveal that the import content of exports, or the share of value-added by the export of a given product that originates abroad is significant in all countries for which data is presented (40 at the time of writing including all 34 OECD countries, Brazil, China, India, Indonesia, the Russian Federation and South Africa). See Figure 3.2.

Typically, the larger a country the lower the overall foreign content, reflecting in part scale and cost. A number of smaller economies also have relatively low foreign

FIGURE 3.2: Domestic content of exports (domestic value-added exports, per cent of total gross exports), 2009



Source: OECD-WTO Trade in Value-Added (TiVA) indicators, Preliminary Results, OECD January 2013.

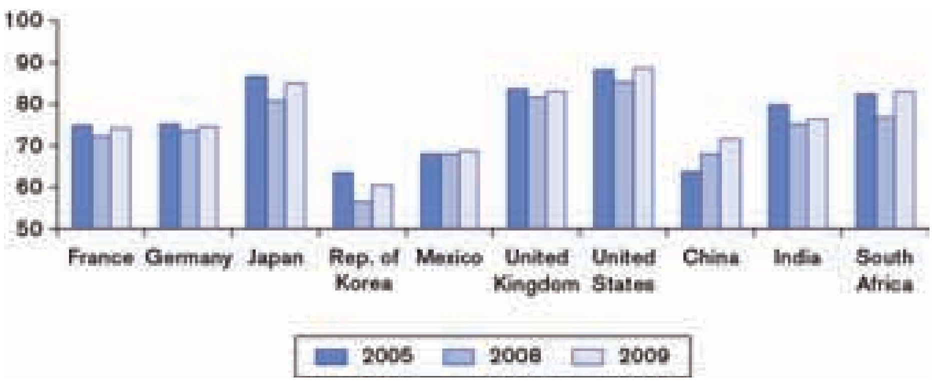
content in their exports such as Australia, Chile, and Norway, reflecting their high share of exports of natural resource goods (including ores, oil and copper which have not surprisingly a low foreign content). Geography also plays a role, which helps to explain New Zealand's relatively low ratio as well as its relatively high dependency on agricultural exports, which also have a relatively low foreign content. For mid-sized economies however, particularly those in Eastern Europe, the norm is for around one-third of the value of exports to reflect foreign content.

Notwithstanding some of the interpretative caveats above, the ratio is perhaps the single most digestible indicator of the propensity of a country to engage in GVCs. It reveals the existence of European, Asian and North American production hubs and also the significant dependency many countries have on imports to generate exports. Mexico, with its *maquilladores*, and China with its processors and assemblers, about one-third of overall exports reflect foreign content (as described below, these are considered to be conservative estimates).

Some care is needed in interpreting the results however: 2009 was an exceptional year, the year that signified perhaps the nadir of the recent financial crisis, which was partly characterized by an unprecedented slowdown in global trade. Although the database only provides data as far back as 2005, illustrative data going back to 1995 suggest that international fragmentation of production, (the import content of exports) had been steadily rising in most countries over recent decades, which continued over the period 2005–08 (Figure 3.3), despite the slowdown that began to occur in many countries in 2008. But 2009 saw falls in the import content of exports, suggesting that the greater the fragmentation of a good or service, the more likely it was to be affected by the synchronized slowdown in trade. In most countries, therefore, the import content of overall exports in 2009 returned to around the ratios seen in 2005, but in China the data point to a steady rise over the period, suggesting developments that saw China begin to move up the value-added chain.

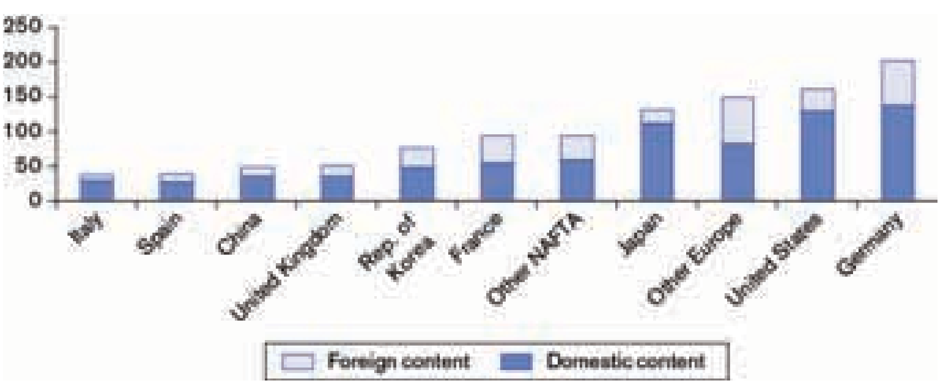
Tangible evidence of the scale of global value chains emerges more clearly when considering specific sectors. For example, between one-third to half of the total value

FIGURE 3.3: Domestic content of exports (domestic value-added exports, per cent of total gross exports), 2005–09



Source: OECD-WTO Trade in Value-Added (TiVA) indicators, Preliminary Results, OECD January 2013.

FIGURE 3.4: Transport equipment, gross exports decomposed by source, US$ billion, 2009

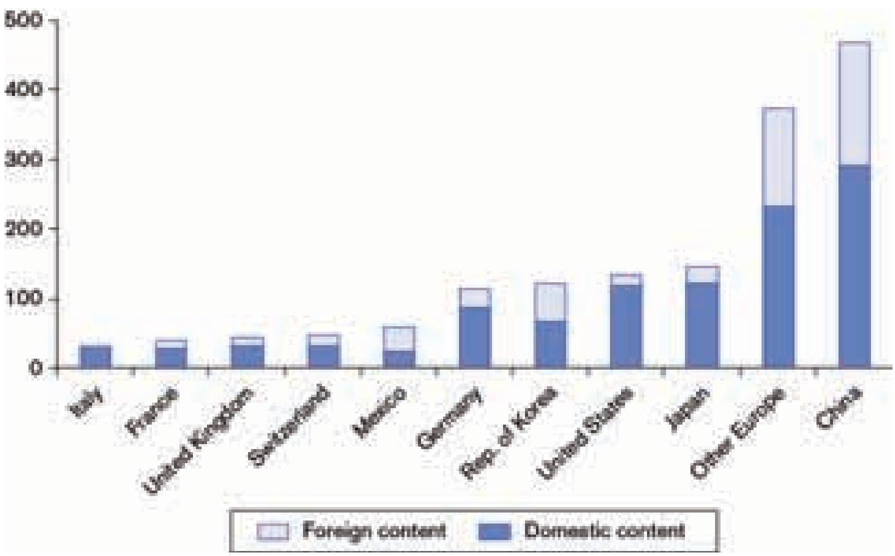


Source: OECD-WTO Trade in Value-Added (TiVA) indicators, Preliminary Results, OECD January 2013.

of exports of transport parts and equipment by most major producers originated abroad in 2009 (Figure 3.4), driven by regional production hubs. In the United States and Japan, the shares were only about one-fifth, reflecting their larger scope to source inputs from domestic providers, but this was also the case for Italy, possibly reflecting efficient upstream domestic networks of small and medium enterprises. Interestingly, in 2009, Germany exported 25 per cent more than the United States in gross terms but only five per cent more in value-added terms.

Similar patterns emerge in other sectors with a high degree of international fragmentation. For example, in China and the Republic of Korea in 2009, the foreign content of exports of electronic products was about 40 per cent (Figure 3.5) and in Mexico the share was over 60 per cent.

FIGURE 3.5: Electronic equipment, gross exports decomposed by source, US$ billion, 2009



Source: OECD-WTO Trade in Value-Added (TiVA) indicators, Preliminary Results, OECD January 2013.

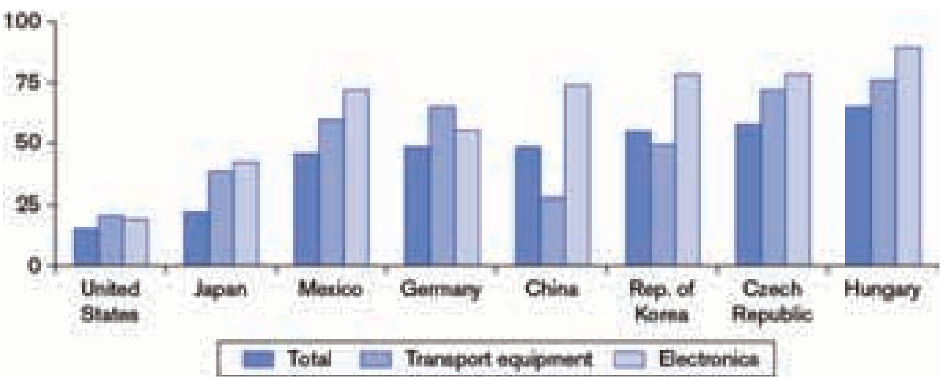
High shares of intermediate imports are used to serve export markets

The figures above reveal that exporting firms require access to efficient imports in order to be competitive and so highlight the potential counter-productive effects of protectionist measures. An alternative way of indicating the adverse effects of such policies can be seen when looking at the overall share of intermediate imports that are used to serve export markets.

In most economies, around one-third of intermediate imports are destined for the export market. Typically, the smaller the economy the higher the share, but even in the United States and Japan these shares are 15 per cent and 20 per cent respectively, at the total economy level with a higher incidence of intermediate imports in some highly integrated industries (Figure 3.6). In Japan, for example, nearly 40 per cent of all intermediate imports of transport equipment end up in exports.

In many other countries, the share of intermediate imports embodied in exports is significantly higher. In Hungary, two-thirds of all intermediate imports are destined for the export market after further processing, with the share reaching 90 per cent for electronic intermediate imports. In China, the Republic of Korea and Mexico around three-quarters of all intermediate imports of electronics are embodied in exports. The database also shows that close to 85 per cent of China's intermediate imports of textile products end up in exports.

FIGURE 3.6: Intermediate imports embodied in exports, per cent of total intermediate imports, 2009



Source: OECD-WTO Trade in Value-Added (TiVA) indicators, Preliminary Results, OECD January 2013.

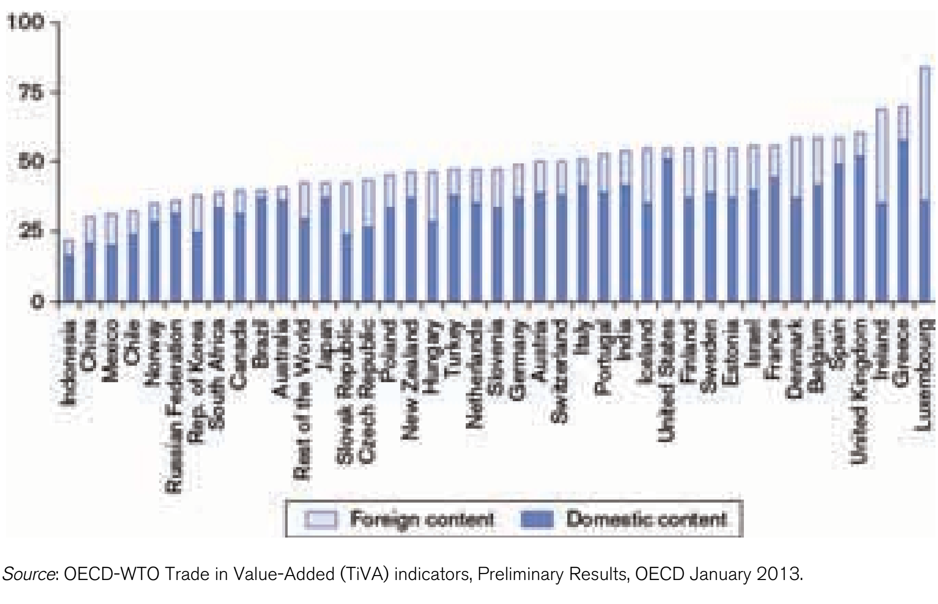
3.5. Open and efficient services markets matter

Services comprise about two-thirds of GDP in most developed economies. However, based on gross terms, trade in services typically account for less than one-quarter of total trade in most countries. This partly reflects the fact that significant shares of services output are generally not tradable, as with government services, many personal services and imputations such as those made in GDP calculations to reflect the rent homeowners are assumed to pay themselves (between six and ten per cent of GDP in most developed economies). It also reflects the fact that the services sector provides significant intermediate inputs to domestic goods manufacturers.

Accounting for the value-added produced by the services sector in the production of goods shows that the service content of total gross exports is over 50 per cent in most OECD economies, approaching two-thirds of the total in the United Kingdom (Figure 3.7). Canada, with significant exports of natural resources, which have typically low services content, has the lowest services content of its exports in the G7 but even here the share is close to 40 per cent.

Typically, emerging economies and other large exporters of natural assets, such as Australia, Chile and Norway, have the lowest shares of services. In India, however, over half of the value of its gross exports originates in the services sector. Indonesia has the lowest share of the 40 countries in the database at around 20 per cent.

FIGURE 3.7: Services value-added – per cent of total exports, 2009

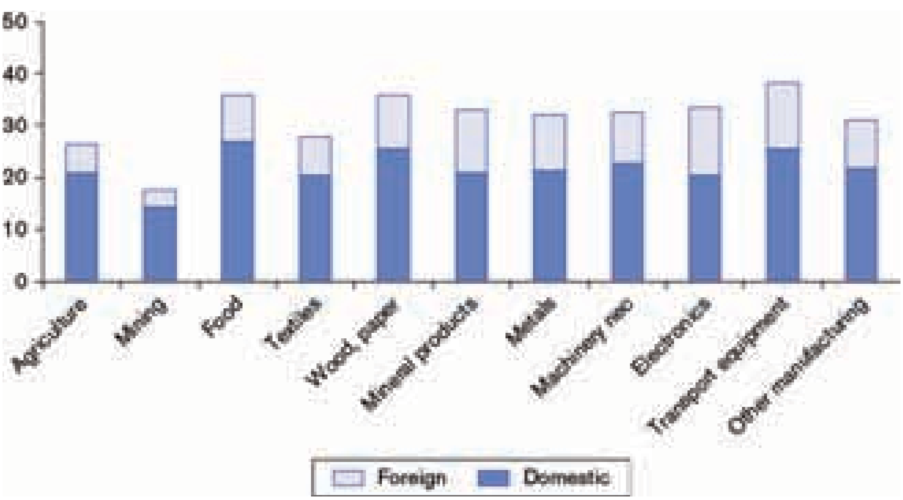


Source: OECD-WTO Trade in Value-Added (TiVA) indicators, Preliminary Results, OECD January 2013.

Part of the explanation for the difference between OECD countries and emerging economies lies in the relatively higher degree of largely domestic outsourcing of services by manufacturers in OECD countries in recent decades, suggesting that a similar process could lead to improvements in the competitiveness of emerging economy manufacturers. Figure 3.7 also reveals a not insignificant contribution to exports coming from foreign service providers.

Perhaps a clearer way of illustrating the importance of services to exports is to consider the services content of specific exports in goods-producing sectors. Figure 3.8, which takes an average of all 40 countries in the database, shows that services make a significant contribution (typically one-third) across all manufacturing sectors, with significant shares provided by both foreign and domestic services providers. For individual sectors in specific countries the importance of the services sector is often starker. In France, for example, the data reveal that over half of the domestic value-added generated in producing transport equipment originates in the French services sector.

FIGURE 3.8: Services value-added – per cent of total exports of goods, 2009

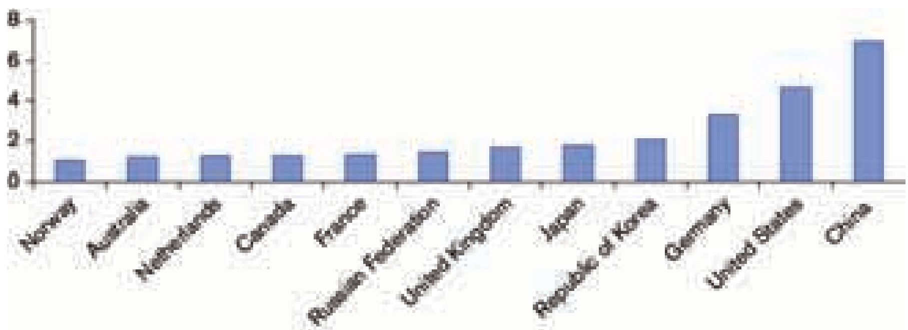


Source: OECD-WTO Trade in Value-Added (TiVA) indicators, Preliminary Results, OECD January 2013.

Intermediate imports often embody a country's own returned domestic value-added

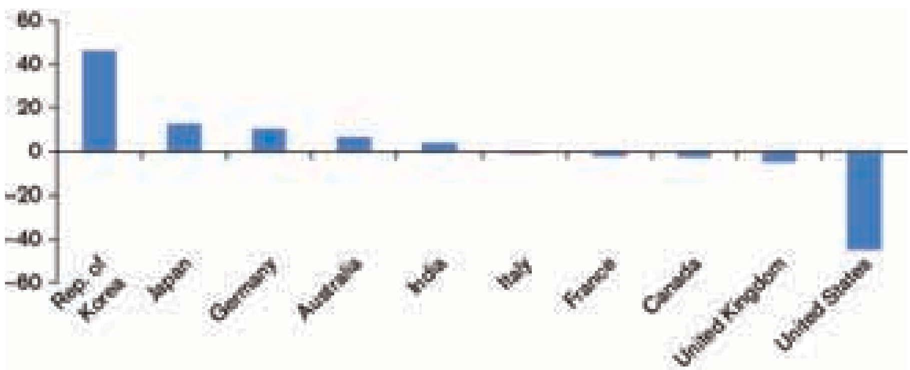
Imports can also contain "returned" value-added that originated in the importing country. Preliminary and conservative estimates show that in the United States nearly five per cent of the total value of imported intermediate goods reflects US value-added (Figure 3.9) and in China the equivalent share is close to seven per cent. For electronic goods, Chinese intermediate imports contain over 12 per cent of "returned" Chinese domestic value-added, and the Republic of Korea's intermediate imports contain close to five percent of "returned" the Republic of Korea's domestic value-added.

FIGURE 3.9: Domestic content of imports – per cent of total intermediate imports, 2009



Source: OECD-WTO Trade in Value-Added (TiVA) indicators, Preliminary Results, OECD January 2013.

FIGURE 3.10: Difference between China's value-added and gross trade balances, US$ billion, 2009



Source: OECD-WTO Trade in Value-Added (TiVA) indicators, Preliminary Results, OECD January 2013.

3.6. What you see is not what you get: trade patterns change

Bilateral trade balance positions can change significantly when measured in value-added terms, although the total trade balance is unaffected. China's bilateral trade surplus with the United States was over US$ 40 billion, or 25 per cent smaller in value-added terms in 2009 and 30 per cent smaller in 2005. This partly reflects the higher share of US value-added imports in Chinese final demand but also the fact that a significant share (one-third) of China's exports reflect foreign content – the "factory asia" phenomenon. The data illustrate that significant exports of value-added from the Republic of Korea and Japan pass through China on their way to final consumers, resulting in significantly smaller Chinese trade deficits with these countries but also typically higher Japanese and the Republic of Korea's trade surpluses with other countries. Similarly, the database shows that the Republic of Korea's significant trade deficit with Japan in gross terms almost disappears when measured in value-added terms

3.7. Estimating trade in value-added – how?

As mentioned above, several initiatives and efforts have tried to address the issue of the measurement of trade flows in the context of the fragmentation of world production.[8] The most commonly used approach to develop a macro picture is based on global input-output tables, using simple standard Leontief inverses, and more detail can be found in OECD-WTO (2012).[9]

Constructing the global table is the hardest task. Constructing such a table is a data-intensive process and presents numerous challenges. This section describes in simple terms the work undertaken at the OECD to harmonize single-country input-output tables that form the basis of the construction of an international input-output database that can be used to estimate trade in value-added terms.

The key challenge is to identify and create links between exports in one country and the purchasing industries (as intermediate consumption) or final demand consumers in the importing country. In this respect it is important to note that the data issues faced by the OECD are similar to those confronted by other initiatives such as IDE-JETRO (Asian Input-Output Tables) or the World Input Output Database project, with whom (as well as the US-ITC) the OECD and WTO have been coordinating actively in order to share experiences and derive a set of best practices.

The data sources at OECD are harmonized input-output tables and bilateral trade coefficients in goods and services, derived from official sources.[10] The model specification and estimation procedures can be summarized as follows:

- Preparation of I-O tables for reference years using the latest published data sources such as supply and use tables (SUTs), national accounts and trade statistics

- Preparation of bilateral merchandise data by end-use categories for reference years. The published trade statistics are adjusted for analytical purposes, such as confidential flows, re-exports, waste and scrap products and valuables. Trade coefficients of utility services are estimated based on cross-border energy transfers. Other trade coefficients of services sectors are based on OECD trade in services and UN service trade statistics. However, many missing flows are currently estimated using econometric model estimates

- Conversion of c.i.f. price-based import figures to f.o.b. price-based imports to reduce the inconsistency issues of mirror trade (because of asymmetry in reporting exports and imports in national trade statistics, imports of country A from B often differ significantly from the exports reported from B to A). In an international I-O system, trade flows need to be perfectly symmetric (the bilateral trade flows should be consistent at the highest relevant level of disaggregation) and consistent with the supply-utilization tables trade data

- Creation of import matrices

- Total adjustment (as per missing sectors and trade with rest of the world) and minimization of discrepancy columns using bi-proportional methods

The OECD has been updating and maintaining harmonized I-O tables, splitting intermediate flows into tables of domestic origin and imports, since the mid-1990s – usually following the rhythm of national releases of benchmark I-O tables. The first edition of the OECD I-O database dates back to 1995 and covered ten OECD countries with I-O tables spanning the period from the early 1970s to the early 1990s. The first updated edition of this database, released in 2002, increased the country coverage to 18 OECD countries, China and Brazil and introduced harmonized tables for the mid-1990s. The database now includes national I-O tables for 57 economies:[11] Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Republic of Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States, Argentina, Brazil, China, Chinese Taipei, Cyprus, India, Indonesia, Latvia, Lithuania, Malaysia, Malta, Romania, Russian Federation, Singapore, South Africa, Thailand and Viet Nam.

The I-O tables show transactions between domestic industries, but supplementary tables, which break down total imports by user (industry and category of final demand), are included. Some countries provide these import tables in conjunction with their I-O tables, but in some cases they are derived by the OECD.

The main assumption used in creating these import matrices is the "proportionality" assumption, which assumes that the share of imports in any product consumed directly as intermediate consumption or final demand (except exports) is the same for all users. Indeed, this is also an assumption that is widely used by national statistics offices in constructing tables. This hypothesis is acceptable for industrialized countries, where there is little product differentiation between what is produced for export and what is produced for the domestic market.[12] It is less convincing, however, for developing countries as the import content of exports is usually higher (and much higher for processing) than the import content of products destined for domestic consumption. Improving the way that imports are allocated to users will form a central part of the future work of the OECD and WTO as well as the international statistical system, as stated in the Global Forum on Trade Statistics, in Geneva in February 2011.[13] Indeed, the tables included for China capture this heterogeneity by breaking each industry into three categories: firms that provide goods and services for domestic markets only, processing firms and other exporters.

Measuring trade in value-added relates to industries' activity rather than to products, as in conventional trade statistics. The OECD's input-output tables are based on an industry-by-industry basis reflecting the fact that the underlying source data measures the activities and production of industries, which means that the relationships between value-added and industrial output are unaffected by statistical manipulations that will be required to build product-by-product-based input-output tables. The industry classification used in the current version of the OECD's I-O database is based on ISIC Rev.3 (Table 3.1), meaning that it is compatible with other industry-based analytical data sets and in particular with the OECD bilateral trade in goods by industry dataset which is derived from merchandise trade statistics via standard harmonized system to ISIC conversion keys. The system, by necessity (to maximize cross country comparability), is relatively aggregated. Differentiating between types of companies within a given sector is essential, however, to improve the quality of trade in value-added results (particularly in the context of exporting and non-exporting companies). Thus, part of future work will be to explore ways, using microdata, which could improve the quality of results. See Ahmad and Araujo (2011) and below.

TABLE 3.1: OECD input-output industry classification

ISIC Rev.3 code	Description	
1+2+5	1	Agriculture, hunting, forestry and fishing
10+11+12	2	Mining and quarrying (energy)
13+14	3	Mining and quarrying (non-energy)
15+16	4	Food products, beverages and tobacco
17+18+19	5	Textiles, textile products, leather and footwear
20	6	Wood and products of wood and cork
21+22	7	Pulp, paper, paper products, printing and publishing
23	8	Coke, refined petroleum products and nuclear fuel
24ex2423	9	Chemicals excluding pharmaceuticals
2423	10	Pharmaceuticals
25	11	Rubber and plastics products
26	12	Other non-metallic mineral products
271+2731	13	Iron and steel
272+2732	14	Non-ferrous metals
28	15	Fabricated metal products, except machinery and equipment
29	16	Machinery and equipment, nec
30	17	Office, accounting and computing machinery
31	18	Electrical machinery and apparatus, nec
32	19	Radio, television and communication equipment
33	20	Medical, precision and optical instruments
34	21	Motor vehicles, trailers and semi-trailers
351	22	Building and repairing of ships and boats
353	23	Aircraft and spacecraft
352+359	24	Railroad equipment and transport equipment n.e.c.
36+37	25	Manufacturing nec; recycling (include furniture)
401	26	Production, collection and distribution of electricity
402	27	Manufacture of gas; distribution of gaseous fuels through mains
403	28	Steam and hot water supply
41	29	Collection, purification and distribution of water
45	30	Construction
50+51+52	31	Wholesale and retail trade; repairs

(Continued)

TABLE 3.1: (Continued)

ISIC Rev.3 code	Description	
55	32	Hotels and restaurants
60	33	Land transport; transport via pipelines
61	34	Water transport
62	35	Air transport
63	36	Supporting and auxiliary transport activities; activities of travel agencies
64	37	Post and telecommunications
65+66+67	38	Finance and insurance
70	39	Real estate activities
71	40	Renting of machinery and equipment
72	41	Computer and related activities
73	42	Research and development
74	43	Other business activities
75	44	Public administration and defence; compulsory social security
80	45	Education
85	46	Health and social work
90-93	47	Other community, social and personal services
95+99	48	Private households and extra-territorial organisations

Source: OECD.

Central to the construction of an international input-output database is the estimation of trade flows between countries. Indeed, these trade flows in intermediate goods and services are the glue which tie together the individual input-output matrices derived from national accounts. National sources on disaggregated bilateral trade flows show a high level of asymmetry, and are not always compatible with national account data. The OECD has developed the Bilateral Trade Database by Industry and End-Use Category (BTDIxE),[14] derived from OECD's International Trade by Commodities Statistics (ITCS) database and the United Nations Statistics Division (UNSD) UN Comtrade database, where values and quantities of imports and exports are compiled according to product classifications and by partner country. The database has provided the basis for a finer allocation of imports by exporting country to users (intermediate consumption, household final demand and investment) and has greatly improved the quality of inter-industry trade flows in the global input-output matrix and, therefore, the trade in value-added results.

It is important to stress that the indicators shown in the database are estimates. Official gross statistics on international trade produced by national statistics institutions result in inconsistent figures for total global exports and total global imports – inconsistencies which are magnified when bilateral partner country positions are considered. The global input-output tables from which trade in value-added indicators are derived, necessarily eliminate these inconsistencies such as those that reflect different national treatments of re-exports and transit trade (as through hubs such as the Netherlands and Hong Kong, China) to achieve a coherent picture of global trade. For the countries for which data is presented, total exports and imports are consistent with official national accounts estimates. But bilateral trade positions presented in the database (based on gross flows) and those published by national statistics institutions may differ. Work is ongoing within the international statistics community to achieve coherence in international trade flows, particularly in the area of trade in services, where significant differences exist when comparing national statistics. In addition, it is useful to put the two key underlying assumptions used to derive indicators into a broader content:

- Production assumption – indicators created via input-output techniques are limited by the degree of industry disaggregation provided by the tables. As shown above, the national input-output tables used by the OECD are based on a harmonized set of 37 industries. Any given indicator, therefore, assumes that all consumers of a given industry's output purchase exactly the same shares of products produced by all of the firms allocated to that industry. This boils down in practice (but is not the same thing) to assuming that there exists only one single production technique for all of the firms and all of the products in the industry grouping. We know that this is not true and that different firms, even those producing the same products, will have different production techniques and technical coefficients, and we also know that different firms produce different products and that these products will be destined for different types of consumers and markets. A chief concern in this respect is the evidence that points to exports having very different coefficients to goods and services produced for domestic markets, particularly when the exports (typically intermediate) are produced by foreign-owned affiliates in a global value chain. Because exporting firms are generally more integrated into value-added chains, they will typically have higher foreign content ratios, particularly when they are foreign owned. As such, the estimates provided in this version should be considered as prudent. Generally, they will point to lower shares of foreign content than might be recorded if more detailed input-output tables were available with consequences for all other indicators presented. One important innovation in the indicators presented here is to use specially constructed input-output tables for China that differentiate between processing firms, other exporting firms and those that produce goods and services only for domestic consumption. Because of China's importance to trade this significantly improves the quality of the results.

- Proportionality assumption: on its own, this assumption is not expected to have a significant impact on total economy estimates but it will affect the import content of various industries and, by extension, bilateral trade estimates of trade in value-added. The results, however, are not expected to be biased in any particular direction.

3.8. Concluding remarks: challenges ahead

The OECD and the WTO have been closely cooperating with other stakeholders involved or interested in the issue of producing estimates of trade in value-added. However, as shown above, many statistical issues remain to be resolved. More generally, best practices need to be established when trade and national accounts divergences cannot be resolved simply and diverging sources need to be arbitraged. Given the importance of the subject, the OECD and the WTO will be looking to engage more closely with their networks of official statistics institutes and other international organizations in the coming years in order to attempt to mainstream the production of trade in value-added statistics, such that their quality can be considered in the same light as other official statistics.

Clearly, the key technical challenges in the immediate future concern the quality of trade statistics and the assumptions made to allocate imports to users, be they industries or consumers. In addition, there are a number of issues that arise from the recent revision to the System of National Accounts (2008 SNA) and Balance of Payments Manual (BPM6) which provide the underlying basis for international trade transactions and indeed those recorded in input-output tables. Chief among these concerns are changes made to the recording of "goods sent abroad for processing" and "merchanting". Other important changes have been made, such as the recognition that research and development expenditures should be recorded as investment, which directly changes value-added. Indeed, the recognition of R&D as investment shines a spotlight on other intellectual property products and on the importance of flows of income as opposed to only value-added.

Additionally, work will begin on looking at a corollary to trade in value-added, namely trade in jobs. Other areas include the contribution made by capital more generally. Because of the way capital (gross fixed capital formation) is recorded in the accounting system, the goods content of services is generally low but in theory this value is captured in the services sector's operating surplus. Capturing these flows is also important, particularly for those countries with high exports of capital goods. Work will also begin to look at the benefits to the wholesale and retail sector of selling imported goods to final consumers. Again, the institutional networks of the OECD and its partner organizations in the international statistics community are well placed to provide an umbrella for these issues to be further developed.

Endnotes

1 *Financial Times*, 24 January 2011.

2 WTO and Commission des Finances du Sénat, (2011).

3 "Adding value to the European Economy. How anti-dumping can damage the supply of globalised European companies. Five case studies from the shoe industry", Kommerskollegium, National Board of Trade, Stockholm, 2007.

4 See Escaith et al., (2010) and Lee et al., (1997).

5 See an application of international IO on "Japan's earthquake and tsunami: International trade and global supply chain impacts", VoxEU, April 2011. Available at: http://www.voxeu.org/index.php?q=node/6430

6 See WTO and IDE-JETRO (2011).

7 For more information on the database see www.oecd.org/trade/valueadded.

8 An OECD-World Bank workshop, "new metrics for global value chains", was organized on 21 September 2010. WTO hosted a Global Forum on Trade Statistics on 2–4 February 2011, in collaboration with Eurostat, UNSD and UNCTAD.

9 OECD-WTO, 2012.

10 Some research-oriented initiatives have been using the GTAP data base for international input-output data. This is not however based on official sources of statistics.

11 For more details, see also www.oecd.org/sti/inputoutput.

12 The results of parallel projects at the OECD and EUROSTAT on micro-data bases linking trade statistics and business registers will help characterizing better the profile of export-oriented firms.

13 Global Forum "Measuring Global Trade – Do we have the right numbers?" 2–4 February 2011, jointly organized by the United Nations Statistics Division (UNSD), the Statistical Office of the European Communities (Eurostat) with the World Trade Organization (WTO) and the United Nations Conference on Trade and Development (UNCTAD).

14 For more details, see www.oecd.org/sti/btd.

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4 The implications of using value-added trade data for applied trade policy analysis[1]

Robert B. Koopman, Marinos Tsigas, David Riker and William Powers

4.1. Introduction

Recent efforts to examine trade data from a value-added perspective, and linking that work to global value and supply chains, has largely been driven by the recognition that traditional data on imports and exports may be masking the increasingly cross-border nature of global production networks. In this paper we examine how using new data sets on value-added trade in two traditional empirical models, a trade-based computable general equilibrium model and an econometric estimation of exchange rate pass through, generate new and useful insights. Our results suggest that the new data sets could improve empirical information used to support policy making.

The two empirical exercises we undertake aim to capture features of the increasing fragmentation of production in international trade. Early efforts to explain and measure this fragmentation include papers such as Feenstra (1998; 2000) and Hummels et al., (1999), which focused largely on factor content and/or vertical specialization measures. Later papers by Koopman et al., (2010), Koopman et al., (2012b) and Johnson and Noguera (2012) extended this work in country specific and global settings by explicitly focusing on value-added in trade and aimed to explain and measure the links between standard trade data measured in gross terms and trade measured in value-added terms. Papers by Grossman and Rossi-Hansberg (2008) and Baldwin (2011) are among those that develop conceptual explanations as to why fragmentation in trade occurs.

The growing body of work on measuring trade in value-added is largely aimed at providing empirical estimates of trade data that are consistent with measures of gross domestic product (GDP), purging double counting of intermediates and tracing the global value chain more precisely through countries' domestic production, exports and imports (see, for example, Timmer, 2012 regarding the World Input Output Database (WIOD), OECD/WTO, 2013, USITC, 2011).[2] These new databases tell a rich and consistent story of how production in many countries is dependent on imports, and that imports are often further transformed and exported. Thus we now have global databases of value-added trade at the broad sectoral level, consistent with global macro variables for GDP that also clearly capture empirically the stories widely circulated about value chains in specific products such as the iPod, iPad, iPhone, notebook computers and Barbie Dolls.[3] One of the iPhone calculations illustrates that a US$ 179 import from China contains approximately US$ 7 of Chinese value-added, and that the iPhone imported from China probably contains more US value-added than Chinese value-added.[4]

These databases are important because they provide a more accurate and nuanced understanding of trade flows that are often masked by the traditional trade data. For instance, policy debates around the US–China bilateral trade imbalance often propose policies to offset what are described as the artificially low renminbi–dollar exchange rate, unfair subsidies and trading practices of the Chinese Government and the inability to compete with exceptionally low Chinese wages. Policy prescriptions typically call for the Chinese to substantially appreciate the renminbi or for the US to place a tariff on imports from China to offset the perceived undervaluation. The value-added trade databases illustrate clearly at a more macro level the iPhone story. The WTO/OECD value-added estimates of the US-China merchandise trade balance for 2010 is US$ 131 billion, compared to the traditional trade data's balance of US$ 176 billion, while US deficits with Japan, the Republic of Korea and other Asian countries grow.[5] Koopman et al., (2010) show that Chinese value-added by sector varies widely, with electronic products and many other products produced in Chinese export processing zones containing relatively low levels of Chinese value-added, while products such as steel, textiles and clothing contain relatively high levels of Chinese value-added. Thus policy responses to concerns over gross trade imbalances are likely to have unexpected and unintended consequences that are specific to the policy response. A unilateral appreciation of the renminbi will have a bigger impact on the importing country prices of goods produced by Chinese sectors containing substantial Chinese value-added, such as steel and textiles. However, unilateral renminbi appreciation is likely to have smaller impacts on the importing country prices for those products exported from China using substantial amounts of imported components, such as those produced in export processing zones, for example electronic goods.[6] These effects suggest that standard, bilateral macro level comparisons of exchange rate effects on a country's exports could be very misleading.

Obviously China is not the only country affected by such factors. De La Cruz et al., (2010) illustrate that Mexican exports to the US have less domestic value-added than Chinese exports to the US. The efforts to create global databases such as (1) WIOD, (2) Global Trade Analysis Project (GTAP) based databases (used by Koopman et al., and Johnson and Noguera, among others), and (3) the WTO-OECD database demonstrate clearly that all countries participate in global value chains and the extent and depth to which they participate can be masked when using databases based on traditional gross trade statistics. These new databases suggest that traditional economic models that use databases built using simplifying assumptions about import uses in consumption, investment and export production in the domestic economy may not accurately capture the value chain impacts across countries.[7]

In the remainder of this paper we examine the effect of using the new value-added trade databases on two important empirical applications. First, we build a version of the now standard computable general equilibrium (CGE) trade model, using a GTAP based database and a model that uses information derived from the USITC global value chains work instead of traditional trade data and examine the impact of two scenarios – a US tariff placed on Chinese imports aimed at offsetting a low exchange rate and a second scenario approximating an appreciation of the renminbi by a similar amount as the US tariff. We then compare the results of this global value chains (GVC) based model with results from a model based on traditional data and find that the GVC trade model has quite important differences that more clearly illustrate how global value and supply chains work through the global economy, and how they can cause some unexpected and unintended effects within and across economies.

The second application is to use the WIOD value-added trade database to empirically estimate exchange rate and other price change pass-through, and compare the results of those estimations from the same data but using gross trade data instead of value-added trade. There is a broad literature, which we describe later in this paper, that examines a long-running question on why exchange rates and other global price changes have less than perfect pass through to domestic prices. Again we find substantial differences between the estimates, with the value-added-based estimates providing a statistically superior fit and intuitively more appealing results than those based on the literature.

4.2. Value-added trade data and CGE experiments of two hypothetical US-Asia rebalancing scenarios[8]

In this section we examine the potential effects of two US-Asia rebalancing scenarios using two different CGE models and databases. We compare selected results from the GTAP global trade CGE model (Hertel, 1997; Narayanan et al., 2012) with results from a CGE global trade model based on the global value chain (GVC) data discussed thus far (this model is discussed in detail in Koopman et al., 2013). The economic theory of the GVC model is similar to the theory of the GTAP model except for two differences that are discussed below.

We run two hypothetical comparative-static experiments to illustrate two alternative mechanisms that could result in a rebalancing in US-Asia trade flows using the GTAP model and the GVC model. The first hypothetical scenario is a decline in real savings in China by about 17 per cent. The second hypothetical scenario is the US applies additional duties on imports from China at the rate of 27.5 per cent. These two experiments are not calibrated to produce the same effect for any particular variable; thus differences in a particular effect across the two experiments do not imply that one change is more effective than the other change.

4.3. CGE models and data

The data sets for both the GTAP model and the GVC model have essentially the same regions and sectors. Both data sets focus on the United States and China as well as their top trade partners. Table 4.1 shows the 26 regions and 41 production sectors in each region that are specified to represent the world economy. The first difference between the GTAP and the GVC model is that in the GVC model China and Mexico have export processing zones and these zones are modelled as separate economies. Thus the total number of economies in the GVC model is 28. Figure 4.1 illustrates the GVC model linkages between the processing trade economy in China, the rest of China and a third economy, Japan. Figure 4.1 shows that there is two-way trade between Japan and the two Chinese economies; Japanese products enter the Chinese processing zone duty free; the rest of the Chinese economy exports products to its processing zone but does not import any products from it; finally, it is assumed that labour and capital can move freely between the Chinese export processing zone and the rest of the economy in China. The same linkages apply to Mexico and its processing zone in the GVC model. In the standard GTAP model trade is only specified

TABLE 4.1: Regions and sectors in the GVC CGE model

Regions		Sectors	
1	China	1	Crops
2	China – export processing zones	2	Livestock
3	Hong Kong, China	3	Forestry
4	Chinese Taipei	4	Fishing
5	Japan	5	Coal
6	Korea, Republic of	6	Oil and gas
7	Indonesia	7	Minerals nec
8	Philippines	8	Meat and dairy products
9	Malaysia	9	Other foods
10	Singapore	10	Beverages and tobacco products
11	Thailand	11	Textiles
12	Viet Nam	12	Wearing apparel
13	India	13	Leather products
14	Australia, New Zealand	14	Wood products
15	Canada	15	Paper products, publishing
16	United States	16	Petroleum, coal products
17	Mexico	17	Chemical, rubber, plastic products
18	Mexico – export processing zones	18	Mineral products nec
19	Brazil	19	Ferrous metals
20	European Union – 12	20	Metals nec
21	European Union – 15	21	Metal products
22	Russian Federation	22	Motor vehicles and parts
23	South Africa	23	Transport equipment nec
24	Rest of high income countries	24	Electronic equipment
25	Rest of South America	25	Machinery and equipment nec
26	Rest of Asia	26	Manufactures nec
27	Rest of East Asia	27	Electricity
28	Rest of the world	28	Gas manufacture, distribution
		29	Water
		30	Construction
		31	Trade
		32	Transport nec

(Continued)

TABLE 4.1: (Continued)

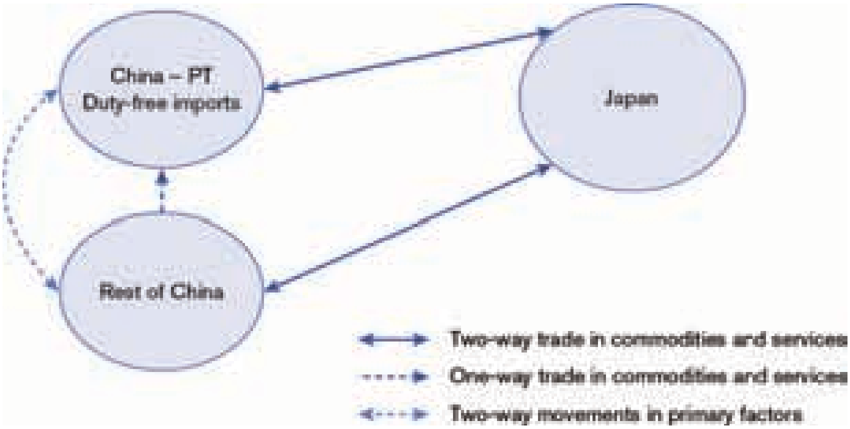
Regions	Sectors	
	33	Water transport
	34	Air transport
	35	Communication
	36	Financial services nec
	37	Insurance
	38	Business services nec
	39	Recreational and other services
	40	Public Admin., Defense, Educ., Health
	41	Dwellings

Source: Authors.

bilaterally between Japan and China, as China processing is subsumed in China, and similarly with respect to the Mexico component.

Trade flows in both models are represented by gross trade figures. The global value chain aspect of current international trade is reflected in the GVC model via the Armington specification. In both the GTAP and the GVC model, commodities (and

FIGURE 4.1: Linkages between processing trade in China, the rest of China, and Japan in the GVC Model

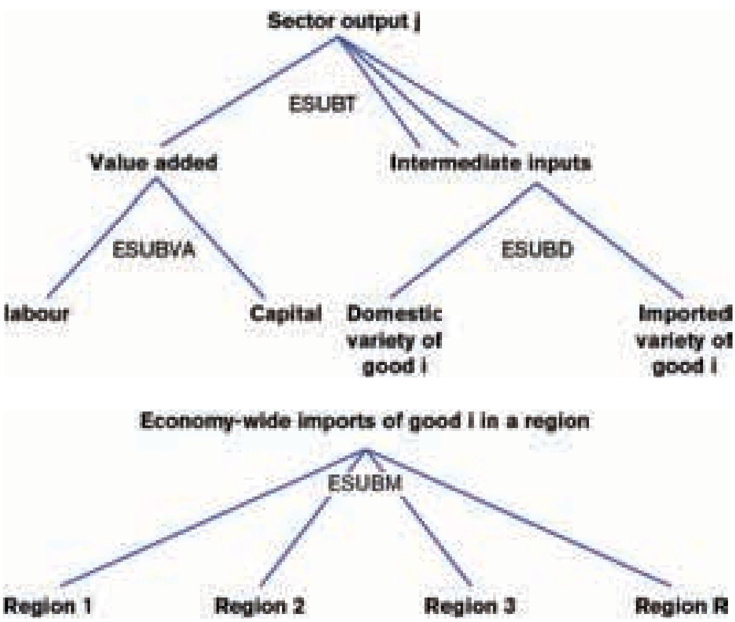


Source: Authors.

services) are assumed to be differentiated by their region of origin, i.e., the Armington specification is applied (Armington 1969a; 1969b). The two models, however, implement the Armington assumption in different ways.

Because of the lack of necessary data, the Armington assumption is implemented in two levels in the GTAP model: producers and consumers distinguish the domestic variety of a good from its imported variety without regard to the country of origin of the imported input; the sourcing of imported goods is placed at the border of an economy. Figure 4.2 illustrates the implementation of the Armington specification in the GTAP model. The left-hand side of Figure 4.2 sketches substitution possibilities in the production process of a particular sector. At the top level, valued-added, a composite of labour and capital, can be substituted with intermediate inputs. At the second level, the domestic variety of a particular intermediate input can be substituted with its imported variety; this is the first component of the Armington assumption. The GTAP model incorporates similar substitution possibilities for household demands. The left-hand side of Figure 4.2 shows that the sourcing of imported goods, for instance how much to import from particular countries, is modelled for the economy as a whole;

FIGURE 4.2: Sourcing of imported goods in the GTAP model



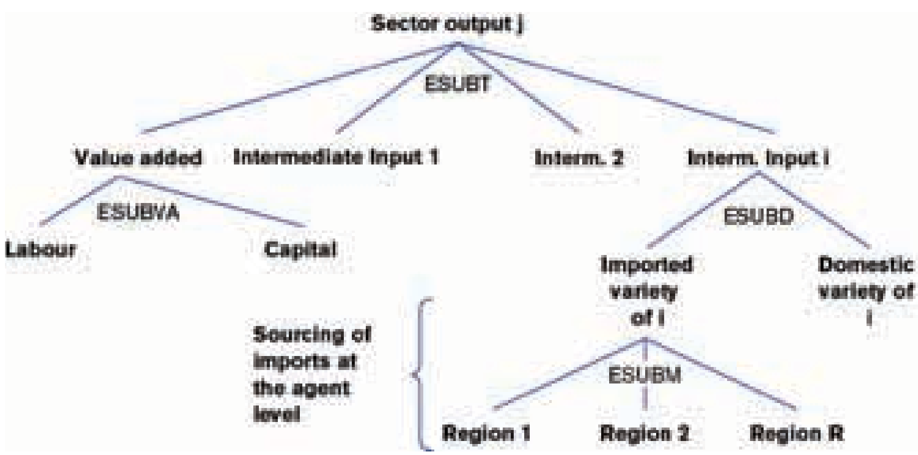
Source: Authors.

this is the second component of the Armington assumption. We can visualize the economic mechanisms incorporated in Figure 4.2 as follows: for each economy and for each good, there is an importing firm which imports the good from other countries; the sourcing of imports changes as the relative prices change. This importing firm blends the country varieties of the particular good and supplies the blended imported good to producers and consumers.

Because of additional data work done for the development of the GVC data, it is possible to place the sourcing of imports in the GVC model at the agent level as shown in Figure 4.3. This is the second difference between the GTAP model and the GVC model. Figure 4.3 shows that in the GVC model, a particular producer decides not only how much to import of a particular good, but also from where to source these imports from. Thus in the GVC model we have potentially established tighter linkages between sectors located in different economies than the linkages contained in the GTAP model. We have also substituted an aggregate mechanism that determines bilateral trade, i.e., sourcing of imports for the economy as a whole in the GTAP model, with a micro-based mechanism of bilateral trade, such as the sourcing of imports at the agent level.

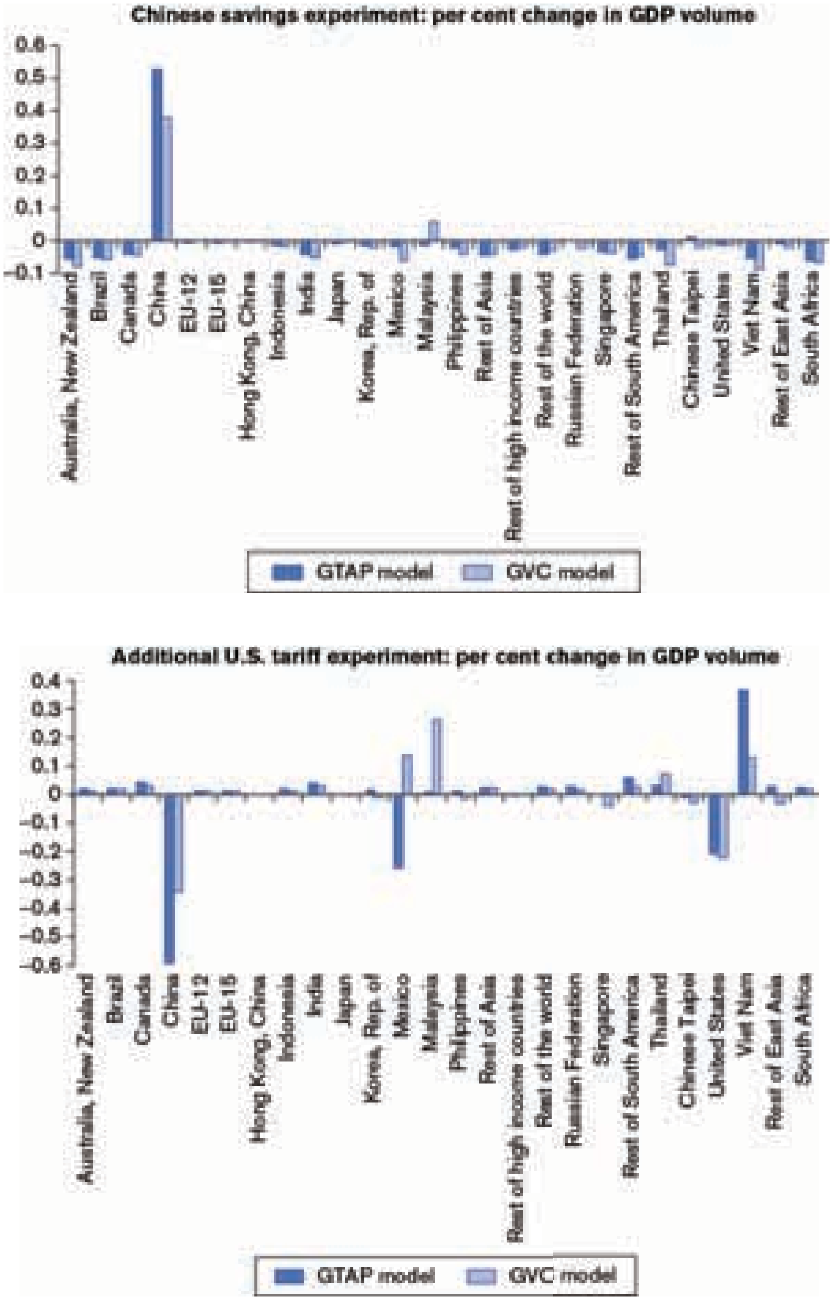
In Figure 4.4 we present GDP results from the two rebalancing scenarios in the GTAP and GVC models. We can see that country level GDP effects

FIGURE 4.3: Sourcing of imported goods in the GVC model



Source: Authors.

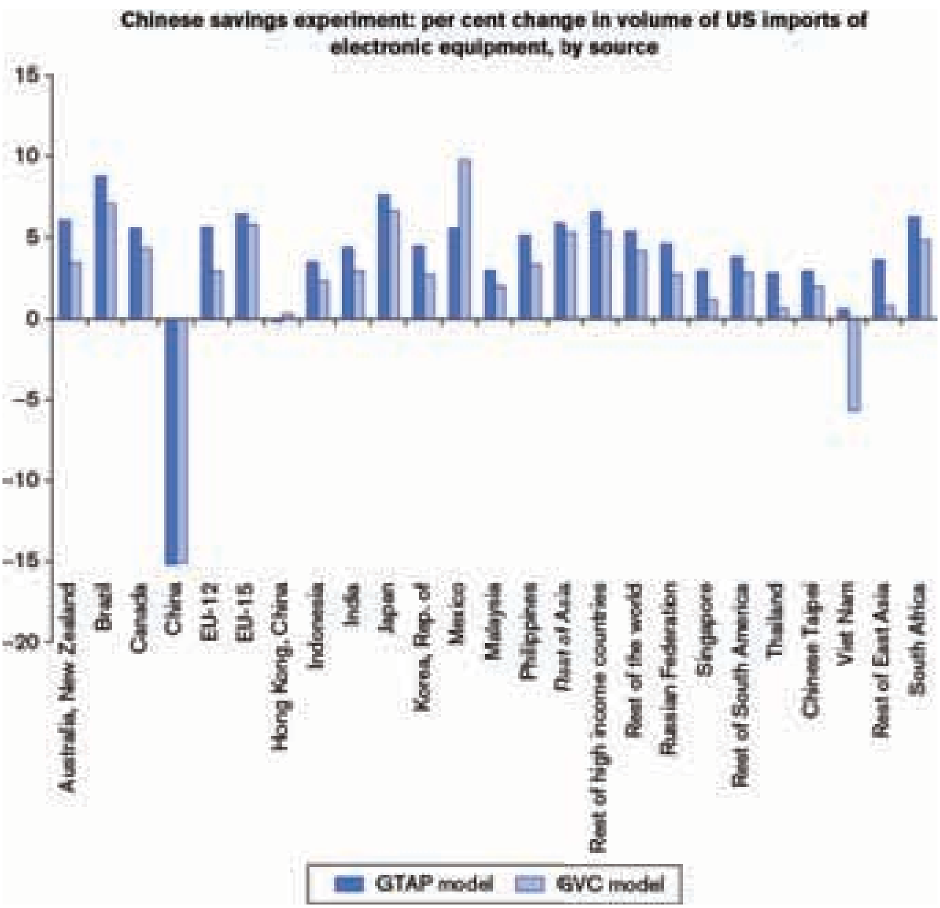
FIGURE 4.4: Per cent change in GDP volume



Source: Authors' calculations.

are sensitive to the model chosen, despite identical parameterization and experimental shocks. In the savings experiment, the GVC model produces a smaller impact on China's GDP than in the traditional model, while many other countries experience larger GDP effects. In the tariff experiment, the GDP effects on China are muted in the GVC model compared to the GTAP model, and the other countries experience large differences in impacts with particularly big differences for Mexico, Malaysia, Singapore, Thailand, Chinese Taipei and Viet Nam. Clearly, at the GDP level in the models, the GVC model produces quite

FIGURE 4.5: United States' imports of electronics



Source: Authors' calculations.

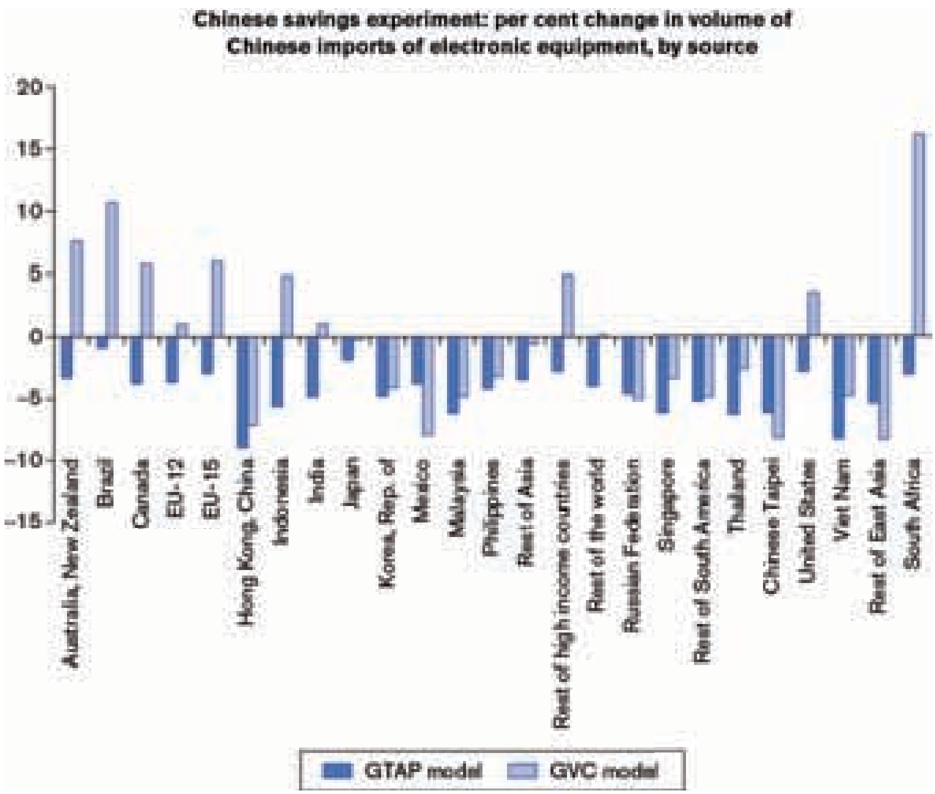
different results from the traditional GTAP model. GDP is a much-aggregated measure of model impacts and can be complicated to explain the various factors driving its change. Thus we now turn to some sectoral examples that highlight more clearly the impact of a GVC based model compared to a traditional GTAP model.

Figure 4.5 presents the change in US imports of electronic equipment in the two savings-rate experiments. The two experiments show almost exactly the same decline in imports from China (–15 per cent), but results for other suppliers differ widely depending on their roles in the electronics value chain. For example, Mexico experiences the largest export gain because its exports of electronics to the United States contain very little Chinese content. In fact, China had a lower market penetration in Mexico for imported intermediate inputs in 2007 than it did in any other country in our data set. Hence, when Chinese exchange rates rise, driving up the cost of Chinese intermediate inputs, prices of electronics from Mexico rise less than electronics from its competitors. Viet Nam has a very different role in the electronics supply chain. In 2007, Viet Nam was largely an assembler of Chinese intermediates, with little production of its own intermediates. Hence, it is quite negatively affected by the rise in price of Chinese intermediates. For other countries, the two models showed much smaller differences. Particularly for East Asia, results are similar because these countries are both upstream and downstream, exporting intermediates to China and receiving intermediates from it.

Figure 4.6 presents Chinese imports of electronic equipment in the two experiments. The GVC model shows substantial deviations from the standard GTAP model, particularly for countries outside of East Asia. In many cases, countries have higher exports in the GVC experiment. In both models, the resulting rise in China's real exchange rate causes substitution away from Chinese sourcing of electronics inputs. Only the GVC model, however, captures the important differences between Chinese processing and non-processing imports. In this model, Chinese non-processing imports rise, but Chinese processing imports fall. Even though these imports fall by 10–20 per cent for many countries, processing zones become relatively less reliant on domestic sourcing because of the even greater (42 per cent) decline in domestic inputs. Hence, the overall change in Chinese imports from a particular source depends on how involved that source is in Chinese processing trade. For many countries in East Asia, the declines in processing imports dominate the rise in non-processing imports, and so overall Chinese imports from these sources decline.

Figure 4.7 presents Chinese imports of iron and steel in the two experiments. As with Chinese imports of electronics, the two experiments present different pictures of the results of a rise in the real Chinese exchange rate. In Figure 4.7, however, the deviation is more consistent across countries, with higher imports in the GVC experiment for 19 of 26 countries. As with electronics, the exchange rate rise causes substitution away from Chinese sourcing, with a rise in processing imports and a fall in non-process imports. Results are more uniformly positive for the GVC experiment because export suppliers are much less involved in processing trade

FIGURE 4.6: Chinese imports of electronics

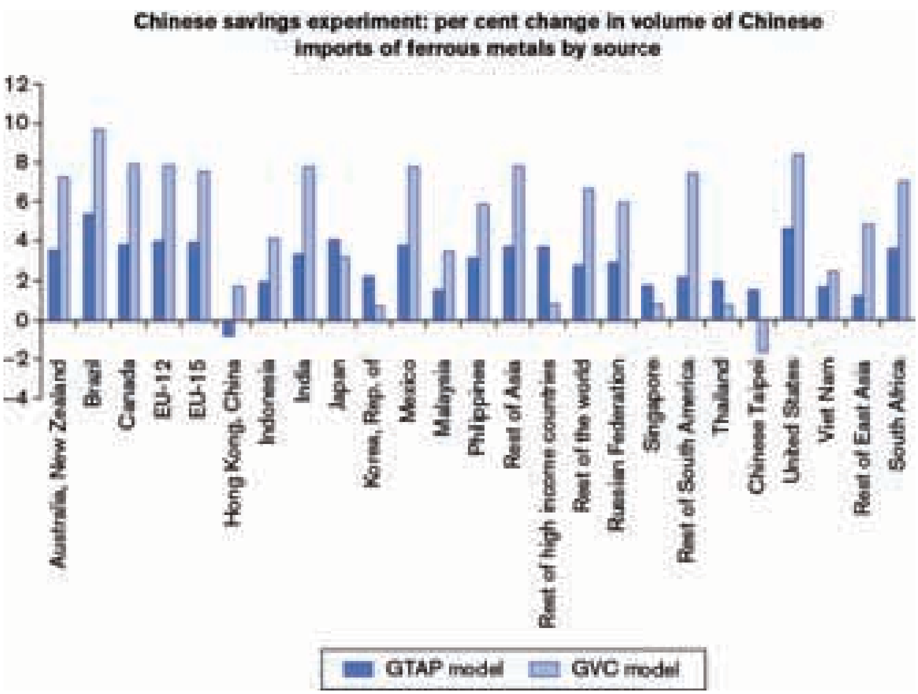


Source: Authors' calculations.

for steel. In 2007, processing trade constituted 90 per cent of overall electronics imports but only 17 per cent of iron and steel imports. Processing trade for iron and steel come mostly from specific East Asian suppliers (for example, Chinese Taipei, Japan, the Republic of Korea) which were the most negatively affected suppliers in Figure 4.7.

These experimental results illustrate that a CGE model specified in such a way as to better reflect the trade linkages found in modern global supply and value chains can produce substantial differences in macro-level impacts and also reflect the realities of specific product chain relationships. Focusing on development of better model specification and database development may result in more realistic and accurate experiment results that could improve advice provided to policy makers.

FIGURE 4.7: Chinese imports of steel



Source: Authors' calculations.

4.4. Value-added trade data and estimation of exchange rate and price pass through effects[9]

We now examine the impact of using value-added trade data compared to traditional gross trade data to examine exchange rate pass-through. Fluctuations in exchange rates can have significant effects on the competitiveness of foreign producers who export to the US market. As long as there are rigidities in nominal wages and prices, reductions in the nominal value of an exporter's currency will lower its relative costs of production and the relative price of its exports. The magnitude of the resulting change in the demand for US imports will depend on the substitutability of imports from other countries and on the currency denomination of the costs of these international competitors.

There is a sizeable empirical and theoretical literature that investigates the pass-through of nominal exchange rate fluctuations into import prices and the resulting change in international trade flows. Goldberg and Knetter (1997) provide a broad review of the literature on exchange rate pass-through. Marazzi et al., (2005) and Brun-Aguerre et al., (2012) are important recent contributions. A common assumption in empirical studies of exchange rate pass through is that each exporter's entire marginal cost of product is denominated in the exporter's domestic currency. However, if some of the exporter's intermediate inputs are imported, and these costs are not denominated in the exporter's domestic currency, then the exporter's marginal costs of production will only be partly exposed to fluctuations in the value of its currency. In this more realistic case, the effect of the exchange rate changes will depend on the share of domestic value-added in marginal costs.

This limitation – the unrealistic representation of the currency exposure of production costs – is often recognized in the literature as a caveat, but it is difficult to resolve because there is often only limited information on costs of production. More realistic modelling of costs requires information about value-added shares in the exporting country, but it also requires information about the currency denomination of the marginal costs of all of the other countries that compete in the same destination market. For example, an appreciation of the renminbi will affect the marginal costs (and prices) of exporters from China, according to the domestic share of the value-added in their exports, but it will also affect the marginal costs (and prices) of any exporters in Mexico or other countries whose products include value-added from China. Thus the recent developments in the estimation of value-added trade flows provide the needed information in a form that is easy to use and we can then compare empirical results using this new data with results estimated using traditional trade data.[10]

To examine the effect of the alternative data sets we estimate a set of econometric models of exchange rate pass through and the link between exchange rates and trade flows using data on the value-added content of trade. Our analysis focuses on trade in non-petroleum manufactured goods for final use over the last decade, as recorded in WIOD. We translate our parameter estimates into pass-through rates and Armington elasticities, and then ultimately into trade elasticities (defined here as the change in export value resulting from a change in the nominal exchange rate). We find evidence that value-added trade data can significantly improve estimates of exchange rate pass-through rates and trade elasticities by more fully accounting for the effects of a reduction in the value of an exporter's currency on its own costs and the costs of its international competitors.

Two important differences between our methodology and other recent studies of exchange rate pass through are the level of product aggregation and the use of trade values rather than price data. Recent contributions to the exchange rate pass through literature often use price data for narrow products and estimate a correlation between import prices and nominal exchange rates. In contrast, we use the fairly aggregated WIOD sectors and estimate a correlation between the value of trade flows and nominal exchange rates. Our method is constrained by the level of aggregation in the WIOD data and by the absence of prices in the WIOD data. Despite these limitations, our methodology makes two important contributions. First, it utilizes the value-added shares to calculate a more realistic measure of the currency denomination of the exporters' costs. Second, it generates estimates of trade elasticities in addition to pass through rates.

4.5. Econometric estimates

Our econometric analysis is derived from an import demand specification for goods. Its theoretical underpinnings are similar to those of the gravity model of international trade.[11] All variables in the model are derived and estimated as a percentage change over time. For each sector, the model examines the determinants of the percentage change over time in the value of bilateral exports from exporter i to importer j.[12] It explains the export value change in terms of an export price change measured using the information on the global sources of value-added in goods exported by country i.[13] For each country adding value to this flow, the country's value-added share is combined with information on price changes in that country and nominal exchange rate changes that the country had with the importing country *j*. Thus, rather than explaining the change in export values with only the final exporter *i*'s price and exchange rate information, the model uses the price and exchange rate changes of all countries adding value to *i*'s exports, weighted by the share of value each of these countries contributes. Appendix A specifies the estimating equation and shows how the exchange-rate pass-through (λ) and elasticity of substitution (σ) are calculated from the regression coefficients.

For our econometric estimation we use data from WIOD.[14] The estimate of value-added shares relies on a transformation from the direct input-output table provided by WIOD into the Leontief inverse matrix, which describes all inputs, direct and indirect, used in the provision of final goods.[15] For our estimates, the WIOD database provides the required data on sectoral trade, domestic expenditure, and, after transformation, the value-added shares. We estimate the model using OLS and a panel of log-first-differences from 2000 to 2009 for 13 non-petroleum manufacturing sectors in 28 of the largest countries in the WIOD dataset.

Table 4.2 presents the estimates of the exchange rate pass-through rate (λ) and the substitution elasticity (σ) for each sector. Overall, the estimated pass-through rates are sensible and precisely estimated in our preferred specification (the first three columns of the table). In eight of the 13 sectors, estimates are bounded between zero and one at the 95 per cent significance level, and only two sectors (transportation equipment and food, beverages and tobacco) have point estimates outside this range. Thus for most sectors, we can strongly reject the hypothesis that there is complete pass through of nominal exchange rate fluctuations. The median pass-through estimate is 0.44. Estimated pass-through rates of this magnitude are consistent with the finding of incomplete pass-through in the prior studies cited above. The estimates for substitution elasticity for our preferred specification in table 4.1 are also precisely estimated. The point estimates are all greater than one and significantly different from one in nine sectors at the 95 per cent significance level. The median elasticity is 1.84. For comparison, we are not aware of any estimates employing the current methodology or WIOD data, but elasticities in the GTAP model may be the closest available estimates at a similar level of aggregation. The median elasticity in the 15 non-food, non-petroleum manufacturing sectors in the GTAP model is 3.75, twice the median estimate in this study.

Table 4.2 also presents estimates employing an alternative specification that assumes that exports contain 100 per cent domestic content (a constraint on the value-added shares in equation (1)). These estimates depart from the preferred estimates employing value-added estimates in consistent ways. Although elasticities are generally higher in the alternative specification, estimates of pass-through rates are consistently lower. The alternative estimates are not preferred on statistical grounds. The table reports F-statistics of the joint hypothesis that the coefficients in the regression models are equal to zero, along with p-values in parentheses. The alternative specification has

TABLE 4.2: Estimates of exchange rate pass-through and the substitution elasticity

	Estimates based on value-added shares			Alternative assuming 100% domestic content		
	λ	σ	F-Statistic	λ	σ	F-Statistic
Food, beverages ,and tobacco products	2.649 (10.236)	1.092 (0.356)	4.17 (0.016)	1.799 (4.688)	1.136 (0.353)	4.50 (0.011)
Textiles	0.433 (0.327)	1.607 (0.400)	4.81 (0.008)	0.383 (0.255)	1.686 (0.398)	5.28 (0.005)
Leather products	0.534 (0.190)	1.764 (0.354)	5.31 (0.005)	0.458 (0.158)	1.787 (0.370)	4.62 (0.010)
Wood products	0.365 (0.047)	2.727 (0.247)	29.83 (0.000)	0.324 (0.040)	2.796 (0.260)	27.99 (0.000)
Paper	0.463 (0.356)	1.373 (0.318)	1.64 (0.194)	0.402 (0.301)	1.383 (0.329)	1.41 (0.245)
Chemicals	0.507 (0.135)	1.917 (0.274)	16.51 (0.000)	0.429 (0.104)	2.000 (0.288)	15.14 (0.000)
Rubber and plastic products	0.380 (0.050)	2.403 (0.241)	29.45 (0.000)	0.320 (0.039)	2.505 (0.256)	26.63 (0.000)
Non-metallic mineral products	0.462 (0.066)	2.438 (0.312)	13.65 (0.000)	0.422 (0.058)	2.499 (0.319)	14.11 (0.000)
Metal products	0.550 (0.502)	1.403 (0.394)	2.79 (0.062)	0.449 (0.455)	1.363 (0.406)	1.58 (0.206)
Machinery	0.225 (0.073)	1.770 (0.193)	8.05 (0.000)	0.198 (0.063)	1.796 (0.201)	7.81 (0.000)
Electrical and optical equipment	0.372 (0.074)	1.871 (0.172)	16.18 (0.000)	0.307 (0.055)	1.958 (0.183)	15.95 (0.000)
Transportation equipment	–0.083 (0.219)	1.844 (0.396)	4.93 (0.007)	0.008 (0.151)	1.954 (0.424)	4.72 (0.009)
Other manufacturing	0.436 (0.065)	2.191 (0.235)	20.58 (0.000)	0.369 (0.055)	2.212 (0.245)	17.75 (0.000)
Median	0.436	1.844	8.050	0.383	1.954	7.81

Source: Authors' calculations.

Note: robust standard errors of the parameter estimates and p-values of the F-statistics in parentheses.

a lower F-statistic in 10 of the 13 sectors than the preferred specification. Thus the model based on value-added shares performs better than the simpler model that ignores this information.

4.6. Trade elasticities

The trade elasticity TE_{ijt} is defined as the percentage change in the value of exports from country *i* to country *j* for every one percent increase in the value of the exporter's currency.[16]

The trade elasticity consists of two parts: an own-price effect and a price-index effect. For country *i*, the own-price effect is determined by the share of *i*'s value-added in its own exports, while the price-index effect depends on the share of *i*'s value-added used by all competing exporters. Appendix A gives the expression for the trade elasticity based on value-added shares, export shares and the pass-through and elasticity of substitution values given in Table 4.2.

To illustrate the model, we have calculated trade elasticity estimates for exports to the United States in 2009. We use WIOD data for all countries in 2009 to calculate the value-added shares and US expenditure shares of exports from 27 countries in 13 manufacturing sectors.[17] We also use our econometric estimates of λ and σ from Table 4.2. Table 4.3 provides specific examples for exports of electrical and optical equipment in 2009 from three different countries to the United States. The table reports the two sets of trade elasticity estimates, and it reports the value-added shares measures that underlie the differences in the estimates across the four countries. For example, the China column indicates that a 10 per cent increase in the renminbi price of a US dollar (a 10 per cent renminbi depreciation relative to the US dollar) will increase the value of China's exports to the US in this sector by 2.039 per cent (if the value-added trade data are not used in the estimate) or by 1.373 per cent (in our preferred specification using value-added trade data). The latter is almost a third lower. The trade elasticity that uses the value-added trade data is a combination of a positive 2.156 per cent own-price effect and a negative 0.783 percent price-index effect that offsets some of the own price effect.

The trade elasticity estimates for exports from Brazil are much larger than their counterparts for China, reflecting Brazil's relatively small share of US imports, its relatively large domestic value-added share in its exports and its relatively small value-added share in competing exporters like Mexico. These factors also imply that there is a small – in fact negligible – price index effect for the imports of electrical and optical equipment from Brazil. The third column reports estimates for Hungary; a large difference in the two trade elasticities reflects the country's unusually low value-added share in its exports of electrical and optical equipment to the United States. Like Brazil, the price index effect is negligible and the trade elasticity is determined almost entirely by the own price effect.

Table 4.4 reports simple averages of the sector-specific trade elasticity estimates for 27 exporting countries. The final column reports the ratio of these averages. For each country, this ratio is less than one, indicating that the inclusion of the value-added data reduces the estimate of the trade elasticity. The ratios of these average trade elasticities range from 0.5974 to 0.9630. The lowest are for Ireland, Hungary, the Czech Republic and Chinese Taipei. The highest are for the Russian Federation, Brazil, Japan and Australia.

TABLE 4.3: Numerical examples from the electrical and optical equipment sector in 2009

	Brazil	China	Hungary
Trade elasticity without value-added trade data	0.2936 (0.0610)	0.2039 (0.0424)	0.2934 (0.0610)
Trade elasticity with value-added trade data	0.2648 (0.0548)	0.1373 (0.0284)	0.1273 (0.0264)
Own price effect	0.2662 (0.0551)	0.2156 (0.0446)	0.1278 (0.0265)
Price index effect	–0.0014 (0.0003	–0.0783 (0.0162)	–0.0005 (0.0001)
Ratio of the two trade elasticities	0.9019	0.6734	0.4339
Ratio of the price index effect to the own price effects	–0.0053	–0.3632	–0.0039
Components of the value-added elasticity estimate	–	–	–
Domestic share of the value-added in the country's exports	0.821	0.665	0.394
The country's value-added share in the U.S. import price index	0.006	0.395	0.002

Source: Authors' calculations.

Note: robust standard errors in parentheses.

TABLE 4.4: Average trade elasticity for each exporting country

Exporting country	Trade elasticity with value-added data	Trade elasticity without value-added data	Ratio of trade elasticity estimates
Australia	0.2925	0.3236	0.9038
Austria	0.2495	0.3239	0.7704
Belgium	0.2109	0.3234	0.6522
Brazil	0.3109	0.3235	0.9613
Canada	0.2602	0.3147	0.8269
China	0.2176	0.2637	0.8253
Czech Republic	0.2235	0.3242	0.6894
Denmark	0.2531	0.3239	0.7815
Finland	0.2606	0.3242	0.8039
France	0.2890	0.3392	0.8522
Germany	0.2607	0.3201	0.8144
United Kingdom	0.2741	0.3217	0.8519
Hungary	0.2064	0.3242	0.6366
India	0.2708	0.3112	0.8704
Ireland	0.1932	0.3234	0.5974
Italy	0.2739	0.3198	0.8565
Japan	0.2992	0.3212	0.9315
Korea, Republic of	0.2348	0.3231	0.7267
Mexico	0.2663	0.3177	0.8384
Netherlands	0.2317	0.3238	0.7154
Poland	0.2513	0.3239	0.7758
Portugal	0.2566	0.3240	0.7920
Russian Federation	0.3123	0.3243	0.9630
Spain	0.2733	0.3235	0.8449
Sweden	0.2415	0.3209	0.7526
Chinese Taipei	0.2252	0.3224	0.6984
Turkey	0.2691	0.3239	0.8308

Source: Authors' calculations.

Table 4.5 reports sector-specific estimates for US imports from China. For each of the sectors, the trade elasticity estimate based on the value-added data is less than the alternative estimate that assumes 100 per cent domestic content. The largest reduction (in percentage terms) is for the electrical and optical equipment sector. The smallest reduction is for the food products sector. The final column reports the ratio of the price index effect to the own price effect for the trade elasticity based on the value-added data. For some of the sectors, there is a large price index effect that offsets much of the own price effect. This is the case for the textiles, electrical and

TABLE 4.5: Estimated trade elasticity for United States imports from China

Sector	Trade elasticity without value-added data	Trade elasticity with value-added data	Ratio of price index effect to own price effect
Food, beverages and tobacco products	0.2421 (0.0812)	0.2103 (0.0731)	–0.0273
Textiles	0.1817 (0.0644)	0.1358 (0.0502)	–0.3836
Leather	0.1313 (0.0432)	0.1203 (0.0369)	–0.6494
Wood products	0.5157 (0.0773)	0.4546 (0.0664)	–0.1318
Paper	0.1533 (0.0936)	0.1348 (0.0760)	–0.0239
Chemicals	0.4197 (0.0767)	0.3327 (0.0584)	–0.0484
Rubber and chemical products	0.3969 (0.0550)	0.3196 (0.0421)	–0.2038
Non-metallic mineral products	0.5435 (0.1044)	0.4616 (0.0904)	–0.1577
Metal products	0.1094 (0.0617)	0.1047 (0.0444)	–0.3491
Machinery	0.1376 (0.0552)	0.1090 (0.0425)	–0.1596
Electrical and optical equipment	0.2039 (0.0424)	0.1373 (0.0284)	–0.3632
Transportation equipment	0.0071 (0.1448)	–0.0496 (0.1155)	–0.0552
Other manufacturing	0.3855 (0.0661)	0.3577 (0.0567)	–0.1846

Sources: Authors calculations.

Note: robust standard errors in parentheses.

optical equipment, and metal products sectors. For other sectors like transportation equipment and paper, there is almost no price index effect.

4.7. Conclusions

We have presented two empirical examples that illustrate the relevance for policy makers of using value-added trade data compared to traditional trade data. We specified a new CGE model based on additional information derived from the USITC work on value-added trade data and the implied global linkages between countries. Using this new model we find substantial and important quantitative differences for the size of macro, sectoral and geographic impacts along supply chains compared with a more traditional gross trade based model. We also developed a practical tool for estimating the effect of fluctuations in nominal exchange rates on the value of US imports of manufactured goods using a structural model of trade and a value-added decomposition of gross trade flows. We find that estimates of pass through rates that do not incorporate value-added trade data can be systematically understated, while estimates of trade elasticities that do not incorporate value-added trade data can be systematically overstated.

Appendix A: Econometric specifications

Equation (1) gives the estimating equation used to determine the exchange rate pass-through and elasticity of substitution.

$$\hat{V}_{ijt} - \hat{V}_{jjt} = \beta_0 + \beta_1 \hat{P}_{jjt} + \beta_2 \Sigma_k \theta_{kit} (\hat{P}_{kkt} - \hat{E}_{kjt}) + \eta_{ijt}. \tag{1}$$

The variable $\hat{V}_{jjt}$ is the first difference of the log of the value of domestic shipments in country j in year t, $\hat{V}_{ijt}$ is the first difference of the log of the value of exports from country i to country j in the currency of country j, $\hat{P}_{jjt}$ is the first difference of the log of the price of domestic goods in country j in the currency of country j, and $\hat{E}_{kjt}$ is the first difference of the log of the country k currency price of the currency of country j. The variable θ_{kit} represents the cost share of country k in the sector's exports from country i in year t. Finally, the variable η_{ijt} is an error term with conventional distributional assumptions. We do not include a subscript for sector, since we estimate a separate set of econometric models for each sector. We can recover the underlying parameters of the model from the regression coefficients in (1). The elasticity of substitution, σ, is equal to $1+\beta_1$. The exchange rate pass through rate, λ, is equal to $-\beta_2/\beta_1$.

The trade elasticity TE_{ijt} is defined as the percentage change in the value of exports from country *i* to country *j* for every one percent increase in the value of the exporter's currency.

$$TE_{ijt} = \underbrace{(1-\sigma)\ \lambda\ (-\theta_{iit})}_{\text{own price effect}} + \underbrace{(1-\sigma)\ \lambda\ \Sigma_k \theta_{ikt} \gamma_{kjt}}_{\text{price index effect}} \tag{2}$$

The variable γ_{kjt} denotes the share of exports from country *k* to country *j* in the total expenditures (in the sector) of country *k* in year *t*.

Endnotes

1 The authors are economists at the International Trade Commission. This paper reflects solely the views of the authors and is not meant to represent the views of the US International Trade Commission or any of its Commissioners. We thank Zhi Wang for his valuable contributions and discussions, but all remaining errors are ours.

2 For an excellent overview of the OECD-WTO database see OECD – WTO (2013), which can be found at http://www.oecd.org/sti/industryandglobalisation/49894138.pdf. For the WIOD database overview see Timmer (2012) which can be found at http://www.wiod.org/publications/papers/wiod10.pdf. For the GTAP based database see Koopman et al., (2012) which can be found at http://www.nber.org/papers/w18579.

3 For example Kraemer and Dedrick (2002); Linden et al., (2009); Xing and Detert (2010), Tempest (1996).

4 Xing and Detart (2010).

5 OECD-WTO Database on Trade in Value-Added: First Estimates: 16 January 2013, found at http://www.oecd.org/sti/industryandglobalisation/TIVA_stats_2013OECD_WTO_final_11_01_2013.pdf.

6 See Amold (2008).

7 See for example Escaith et al., (2011).

8 This section draws from Koopman et al., (2013).

9 This section draws on Riker and Powers (2013).

10 There is a burgeoning literature examining the sources of value-added in final goods traded and consumed internationally. Examples include Johnson and Noguera (2012); Koopman et al., (2012b); Powers (2012); Stehrer (2012); and Timmer et al., (2012).

11 Powers and Riker (2013) derive this econometric specification from a CES model of international trade.

12 The change in export value is measured relative to the change in the importing country's domestic shipments in this sector.

13 As with export value, the exporter's price change is measured relative to the importer's price change in this sector.

14 The database contains data on the international sourcing of intermediate inputs and final goods in 35 sectors among 40 countries (27 EU plus 13 other major countries) for 1995–2009. We also use local-currency deflators from the IMF to measure local prices.

15 See Timmer et al., (2012) for a discussion of the Leontief inverse. We thank Zhi Wang for the provision of these inverses.

16 Powers and Riker (2013) derives this formula and discusses these two effects in more detail.

17 The exporters include all countries in the estimation sample except for the United States.

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5 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.

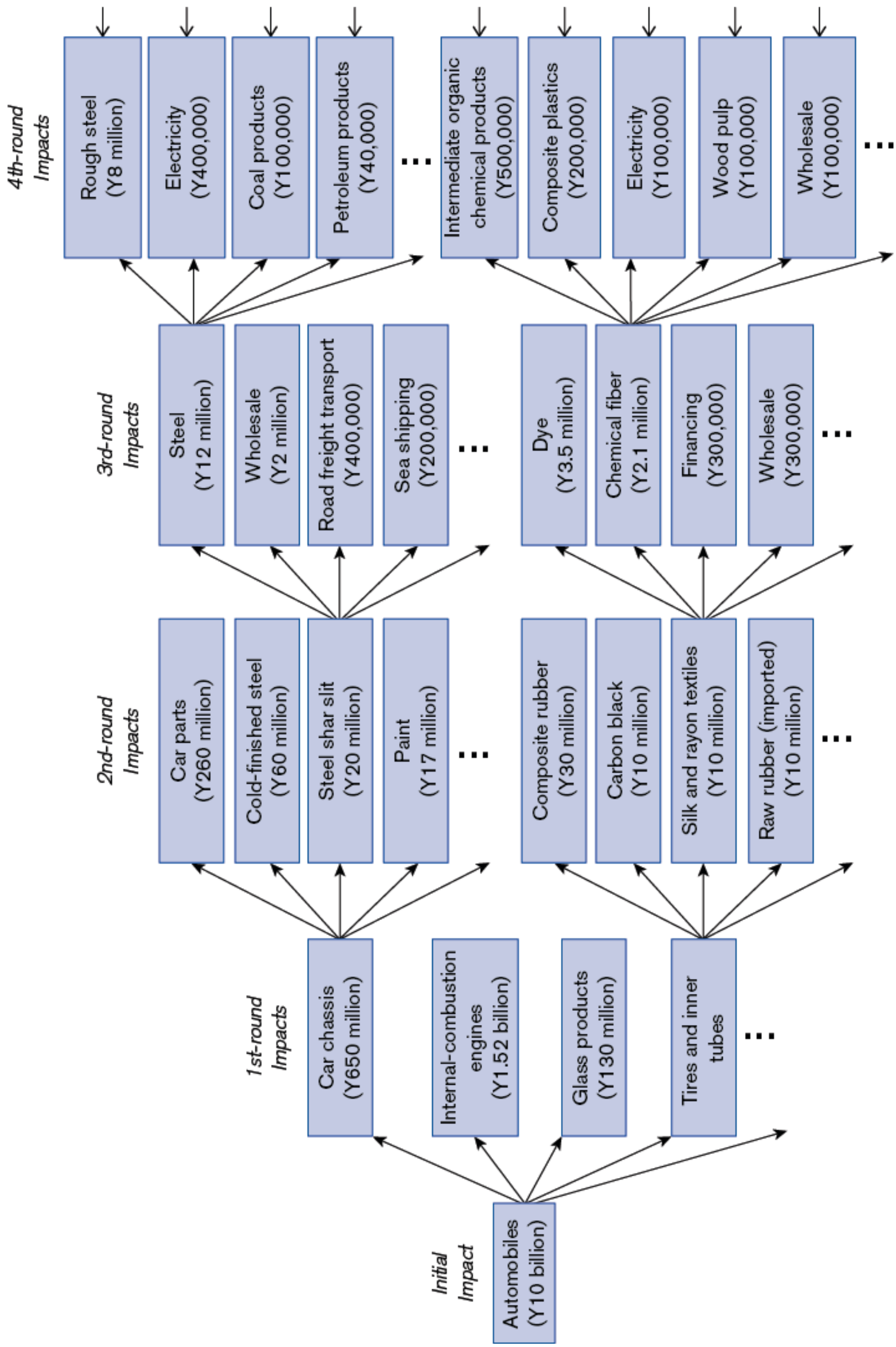
Input-output models and supply chains analyses

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)



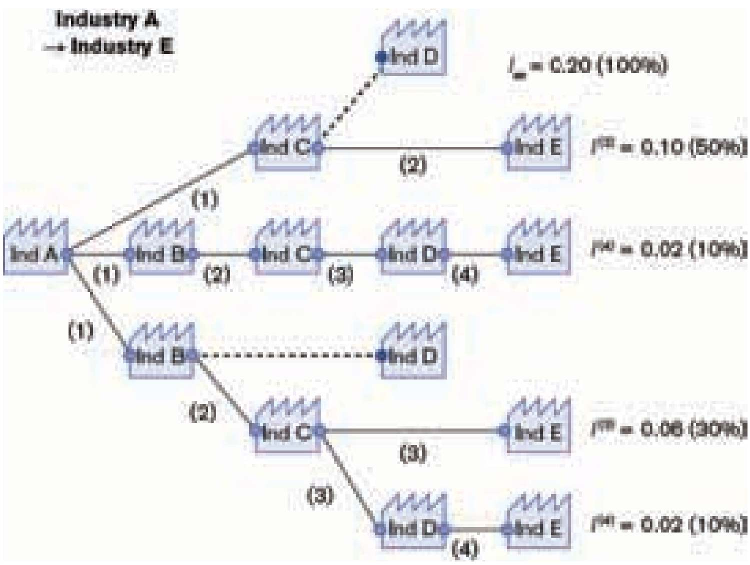
Source: Calculated and drawn by the authors.

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:

$$APL_{(A-E)} = 1 \times 0\% + 2 \times 50\% + 3 \times 30\% + 4 \times (10 + 10)\% + 5 \times 0\% + \ldots = 2.7.$$

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

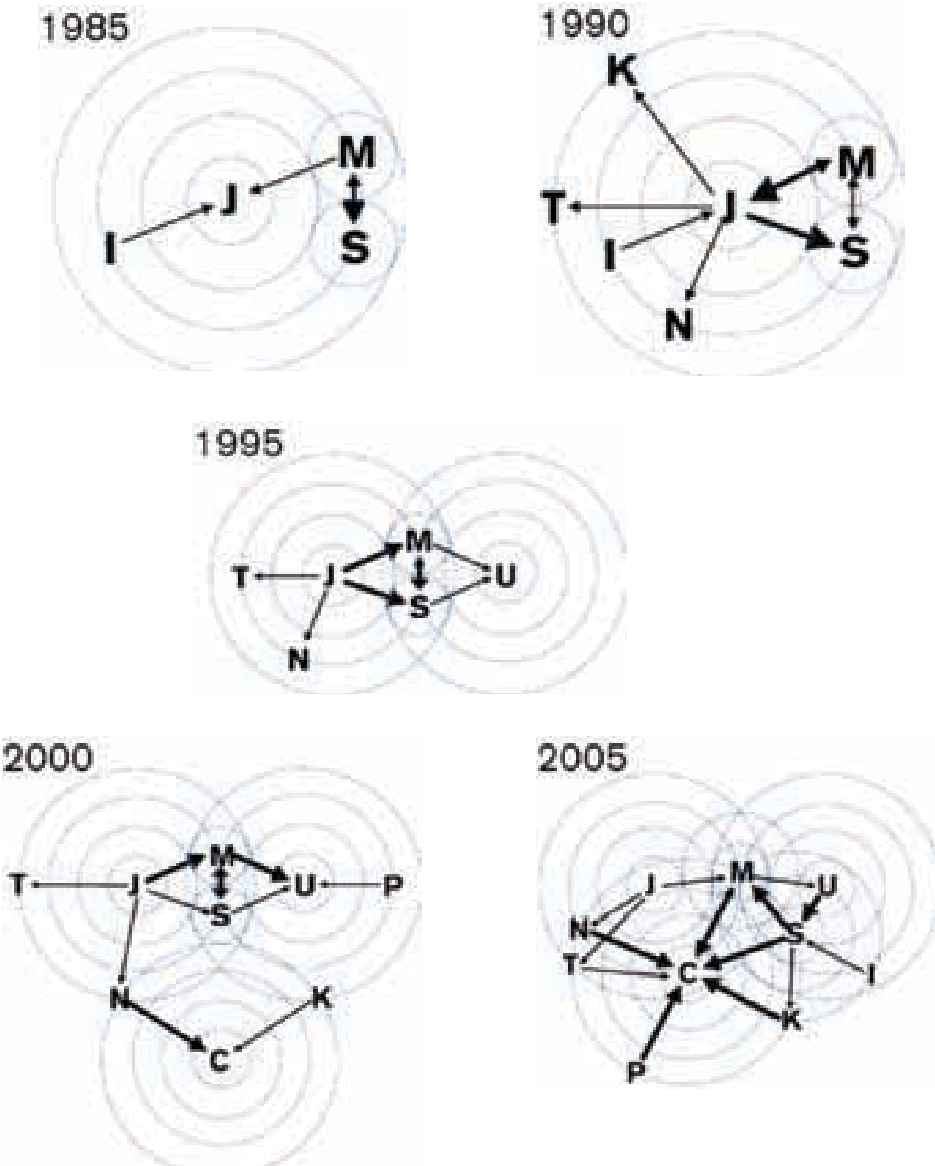
The diagram in Figure 5.3 traces the evolution of production networks in the Asia-US region over the last two decades. The visualization of the calculation results is based on the method presented in Dietzenbacher et al., (2005) with some graphical elaboration developed in Inomata (2008b). Arrows represent 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.

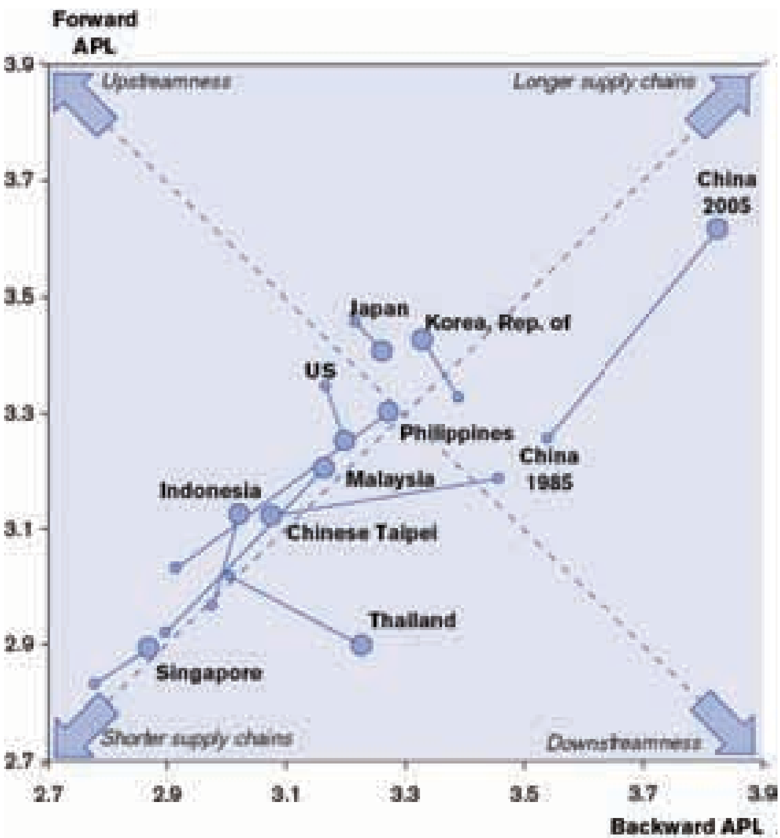
The regional production networks thereafter showed dramatic development. By 2005, the centre of the network had completely shifted to China, pushing the United States and Japan to the periphery. China became the core market for the products of the region from which final consumption goods were produced 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.

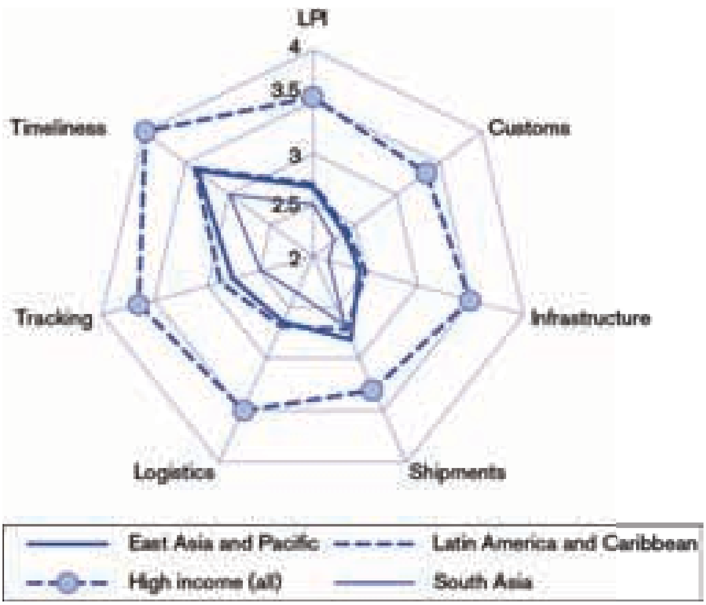
Transport and trade facilitation

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:

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

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

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:

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

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:

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

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: $\mathbf{C}(n) = \Sigma_{i=1}^{n} \frac{1}{n}(1+t)^{i}$ 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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