Trade in Value Added

Developing New Measures of Cross-Border Trade

THE WORLD BANK

edited by
Aaditya Mattoo, Zhi Wang and Shang-Jin Wei

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AADITYA MATTOO, ZHI WANG AND SHANG-JIN WEI

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Aaditya Mattoo, Zhi Wang and Shang-Jin Wei, Editors

1

Measuring Trade in Value Added when Production is Fragmented across Countries: An Overview

AADITYA MATTOO, ZHI WANG AND SHANG-JIN WEI[1]

What is the 'country of origin' of an iPad? If you order a new model of iPad today from Apple's online store, you will notice that your device will be shipped out of China by a company called Foxconn, so China is officially the country that exports iPads. Of course, the product is designed in California and uses lots of components from Japan, Korea and other countries. When a product is produced by a global production chain in which a number of countries participate in different stages of production and supply different parts and components that make the final product what it is, the concept of 'country of origin' is not very useful. The world is increasingly like this: more and more products traded internationally use parts and components from multiple countries before being assembled into the form of final products. Indeed, between one-half and three-quarters of overall world trade in goods and services consists of trade in intermediate goods (see Chapter 2 by Sébastien Miroudot and Norihiko Yamano).

In this volume, we take stock of what we know about this phenomenon based on a body of active and expanding research. Most of the work reviewed here was presented at a conference at the World Bank on this topic in 2011, and subsequently revised and expanded. First, we explore the implications for economic policies of the increasing divergence between countries that export a given product and the countries that provide the value added that goes into that product. Second, we examine several approaches to estimating domestic and foreign value added in a country's exports (and imports). Third, we present ideas about modifying the existing national and international statistical infrastructure that can lead to better measurement of trade in value added. As this is still an evolving field, we hope that this volume will provide a framework for comparing existing approaches and also inspire new ones.

[1] The views in the papers are those of the authors, and do not necessarily reflect the official position of the institutions with which the authors are associated.

1 IMPLICATIONS FOR ECONOMICS AND ECONOMIC POLICIES

It is important to go beyond official trade statistics and to gauge the true exports in value-added terms for a number of reasons. First, and most fundamentally, it would help us to understand better the changing nature and consequences of international trade. As argued by Gene M. Grossman in Chapter 3, thanks to the dramatic improvements in communication technology, international specialisation is no longer at the level of the good or industry, but at ever finer levels, such as specific tasks. Therefore, new but still largely untested theory is posing traditional questions, such as where production takes place and what effect trade has on factor prices and the distribution of income, not at the level of the industry but at much finer levels of economic activity. Apart from showing the continued importance of factors such as differences in relative factor prices, new determinants of the location of activity are being identified, such as the ease with which a task can be performed at a distance (relating to its prevalence and amenability to codification) and whether tasks are complementary (which affects whether they need to be co-located or can be separated). And new predictions about gains from trade are being generated: offshoring can generate productivity gains that are shared by all domestic factors of production so that the traditional conflict of interest between factors with regard to trade may be alleviated. The accuracy of these predictions can only be assessed if we go beyond trade data based on gross flows. Economic activity is best measured by value added not gross output, as national accountants have known for a long time. As Grossman and Rossi-Hansberg (2008) concluded,

> the globalization of production processes mandates a new approach to trade data-collection, one that records international transactions, much like domestic transactions have been recorded for many years.

Second, and perhaps even more urgent than the positive questions are the normative questions raised by the fragmentation of production across borders. Miroudot and Yamano (Chapter 2) and others have identified a list of policy-relevant issues that crave answers.

- **More accurate understanding of bilateral trade imbalances.** Standard measures of bilateral trade balances are based on gross trade. Consider the Chinese and Japanese trade surpluses against the USA in recent years. These are overstated because Chinese production for exports to the USA uses lots of imported inputs from Japan, Korea, USA and elsewhere. In comparison, US production for its exports to China uses mostly US-made inputs. It is estimated that the true Chinese trade surplus in value-added terms is about 25–40% lower than the surplus measured by gross trade (Maurer and Degain 2010). In contrast, the Japanese surplus against the USA is understated, since Japan also exports value added indirectly by exporting intermediate goods to China and other countries that are used in these countries' exports to the USA.

- **Incidence of trade policies.** Because high-income countries are more likely to be at the upstream end of global production chains, their imports from low-income countries are more likely to contain their own value added (through their exports of machinery and other intermediate inputs to these low-income countries). For example, this is the case for US imports from China and Mexico, both of which are heavy users of the processing exports mode that uses lots of imported inputs from the USA (and other high-income countries) in their exports to the USA. Given this structure, an increase in barriers by the USA on imports from China or Mexico is also likely to hurt US-based firms. The extent to which this is true varies by sector, as the US content in US imports from China and Mexico also varies by sector. Similar statements can be made for trade policies by most other high-income countries. 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% and 80% of European Union value added. In 2006, anti-dumping duties were introduced by the European Commission on shoes imported from China and Vietnam. An analysis in value-added terms would have pointed out that EU value added was in fact subject to anti-dumping duties (National Board of Trade 2007; see also Chapter 2).
- **Employment content of trade.** Policymakers often wish to find out the effect of a given trade policy, say an across-the-board tariff by the USA on imports from China, on employment in China and the USA. This analysis would be misleading if one did not realise either that the gross trade statistics do not accurately reflect true value added from the exporting country or that the importing country's value added could be embedded in the exporting country's gross exports. (Of course, the analysis could also be misleading if one did not realise that the general equilibrium effect on employment in the longer run is different from the partial equilibrium effect in the short run.) The EU shoe industry example can be interpreted in terms of jobs. Traditional thinking in gross terms would regard imports of shoes manufactured in China and Vietnam by EU shoe producers 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 some workers may have indeed lost their jobs in the EU at the assembly stage, there could be a higher number of jobs 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).
- **Trade and competitiveness.** Indicators of competitiveness such as Balassa's (1965) revealed comparative advantage (RCA) has proven to be

useful in many research and policy applications. The problem of multiple counting of certain value-added components in the official trade statistics suggests that the traditional computation of RCA could be noisy and misleading. For example, Koopman *et al* (forthcoming; henceforth KWW2) show that using gross exports data suggests India had a strong revealed comparative advantage in finished metal products (ranked fourth among the 26 countries in the sample). However, when looking at domestic value added in that sector's exports, its ranking in RCA drops precipitously to fifteenth place. This change in rank causes the sector to switch from being a comparative advantage sector to a comparative disadvantage sector for India.

- **Trade and the environment.** Concerns over greenhouse gas emissions and their potential role in climate change have triggered research on how trade openness affects CO_2 emissions. The fragmentation of production requires a value-added view of trade in order to understand where imported goods are produced and thus where CO_2 is generated. For example, initial work by Dean and Lovely (2010) argues that the emergence of global supply chains may have had surprisingly beneficial effects on China's environment. This is because China's exports have been shifting over time towards highly fragmented sectors (such as office and computing machinery and communications equipment) that are less polluting, and away from traditional exports that are less fragmented and also more polluting.

Third, and related to the policy dimension discussed above, is the international surveillance and policy analysis dimension, illustrated in the macroeconomic context by Mika Saito and Ranil Salgado of the International Monetary Fund (Chapter 3). They argue that using accurate value-added trade data would improve exchange rate assessments because real effective exchange rates based on value-added trade weights would more accurately measure competitiveness than those based on gross trade weights. And these assessments would in turn improve our ability to estimate the impact of changes in relative prices, including on global rebalancing. They suggest, for example, that changes in relative prices would result in asymmetric rebalancing effects between downstream and upstream countries (*eg* China and the USA, respectively) in terms of value chains. This is because the larger share of foreign value added in the exports of the downstream country mitigates the impact of exchange rate changes.

Fourth, and perhaps the greatest benefit of measuring value-added trade, is in understanding and responding to the development challenge, as argued by Judith Dean (Chapter 3). She notes that in principle the more production can be split globally and tasks dispersed based on comparative advantage, the more low-income countries can participate in these production chains. More disaggregated value added trade data could help us understand the extent to which developing countries are already participating in global supply chains, and the extent to which global chains are promoting indirect exports from developing countries. The latter could be happening if such chains help small and medium-sized enterprises to overcome financial and other constraints. We could also understand what role developing countries play in such supply chains and why. For example, research by Antras (2005) and Feenstra and Hanson (2005) suggests that improved property rights and better quality control may help developing countries 'move up' the supply chain.

Beyond the issues raised by Dean are certain normative questions. We need to understand better whether and why it matters from a development perspective where you are in the supply chain (or where you add value). This is the counterpart in fragmented production space of the traditional question of whether it matters what you export. Are certain tasks (or types of value adding activities) associated with greater scope for learning-by-doing or knowledge spillovers? In fact, what it means to 'move up' the value chain and whether it is desirable in normative terms is itself an open question that craves analysis with better data. Finally, even if location in the value chain matters, how far can it be influenced by policy? The issue of whether developing countries can mould their production structures into more dynamic forms through policy intervention is again not a new question. But there is an added richness to this question, and even greater empirical challenge in providing credible answers, when we think in terms of tasks rather than entire products.

2 APPROACHES TO DISTILLING VALUE ADDED IN TRADE FROM STANDARD TRADE STATISTICS

A first hint of the relevance of intermediate trade is evident from the behaviour of the gravity model. The gravity model of trade volume is perhaps one of the most successful empirical specifications in international economics both in terms of goodness of fit (typically in excess of 60% even in a cross-sectional context) and in terms of compatibility with leading economic theories (as it can be justified by the theory of differentiated trade, the standard theories of comparative advantage and new theories based on heterogeneous firms). It has been used to analyse a myriad of trade policies, such as the effectiveness of the World Trade Organization in promoting trade (see for example, the debate between Rose (2004) and Subramanian and Wei (2007)). However, as Richard E. Baldwin and Daria Taglioni (Chapter 7) point out, while the gravity model works well for nations and time periods where most exports are consumer goods, it works poorly when trade in components and parts is important. More precisely, the standard practice of using the GDP of the exporting and importing countries as the 'mass' variables in the gravity equation is inappropriate for bilateral flows where trade in intermediate goods is a nontrivial part of overall trade. As long as producer demand deviates from consumer demand, one would need to use something other than, or in addition to, GDP to proxy for the total demand and supply.

Baldwin and Taglioni document the following patterns. First, the estimated coefficients on the log GDPs are lower for nations where parts and components trade is important. Second, the coefficients on log GDPs fall over time, as parts and components trade grows in importance. Third, in those cases where the GDPs of exporters and importers lose explanatory power, one can find a role for demand by third countries.

Two parallel lines of work in the literature attempt to estimate value added in trade. The first attempts to measure the degree of vertical specialisation and imported foreign content in a country's exports using a single country input–output table, and started with the pioneering work of Hummels *et al* (2001) (henceforth HIY).

The second approach traces value added at various stages of production across countries using an inter-country input–output (ICIO) table. It tries to measure one country's exports of value added to a second country, both by excluding foreign value added embedded in parts and components used in the production of the exports, and by adding indirect exports of value added embedded in the first country's exports of components and parts to a third country, which in turn uses them to produce products that are exported to the second country. This approach is described in detail by Robert C. Johnson and Guillermo Noguera.[2] They provide a formal definition for value-added exports: which is value added produced in a country but absorbed in another country. In contrast to HIY's measure of foreign content in exports, they propose a measure of the ratio of value added to gross exports, or the VAX ratio, to measure the intensity of inter-country production sharing. They find that exports of manufactures have lower VAX ratios, and imbalances, at the bilateral level, measured in value-added terms can differ substantially from gross trade imbalances. As an example, they show that the US–China trade imbalance in 2004 is 30–40% smaller when measured in value-added terms.

In the HIY framework for estimating vertical specialisation or foreign content, it is assumed that the input–output coefficients in the production for exports and those in the production for domestic market are the same. This of course does not have to be true in general, but it is especially likely to be violated in processing trade where imported machinery and other imported inputs are extensively used to produce for the export market. Many countries offer outright tariff exemption for imported inputs used in processing exports, or at the very least streamlined customs duty drawbacks. In some countries, processing exports can be a significant part of overall exports. For example, in China, processing exports account for about half of overall exports. Wholly foreign owned firms and Sino-foreign joint ventures are heavy users of the processing export scheme. In Mexico, processing exports

[2] See Johnson and Noguera (2012), reproduced here as Chapter 4.

account for an even greater share, largely due to the prevalence of exports by Maquiladora firms.

One way to address this issue is by tracking separately the two sets of input–output coefficients in production for the export market versus the domestic market. Of course, most countries do not officially publish separate input–output coefficients. Robert Koopman, Zhi Wang and Shang-Jin Wei[3] developed a framework that allows one to estimate these two sets of coefficients by combining information on processing trade share at the sector level from a country's customs data and the country's existing official input–output table. Their methodology has two parts. First, they derive the equations necessary to do the computation. The key part of the derivation is to split the standard input–output (IO) table into two parts: one that focuses on domestic production and trade, and one that focuses on processing exports. This yields four coefficient matrices: one for domestic production used for processing exports, one for domestic production used for processing activity, one for imported inputs used for processing exports, one for imported inputs used for non-processing activities. Second, they develop an approach to estimate these coefficient matrices. The estimation essentially attempts to keep the coefficients as close as possible to those implied by official trade and national account statistics with some proportionality assumptions, while at the same time also satisfying the supply and use balance conditions and adding-up constraints. Koopman *et al* apply their methodology to data from China.

There are four main findings. First, foreign value added in China's overall manufacturing exports was about 50% in 2002, which is more than double what would be obtained by a straightforward application of the method from HIY. Second, the foreign value added in non-processing exports was comparatively small, about 10% in 2002 and 16% in 2007. Third, and most interestingly, those sectors that are labelled as relatively sophisticated or "high-tech', such as electronic devices and communication equipment, have particularly low domestic content (about 30% or less). Finally, the share of domestic value added of Chinese manufacture exports increased to about 60% by 2007, just five years after China joined the World Trade Organization (WTO).

The latter finding is of particular interest. Over time, different forces pull the share of domestic value added in total exports in different directions. On the one hand, with the falling tariff rates and non-tariff barriers, especially since China's accession to the WTO in December 2011, all exporters in China might use more imported inputs, which would lower the share of domestic value added in China's exports as evidenced by the 6% increase of foreign content in China's normal exports. China may also increase the share of those sectors that use more imported inputs, which would also result in a reduction in the domestic value added in its total exports. On the other hand,

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[3]See Koopman *et al* (2012), reproduced here as Chapter 5, and referred to as KWW1 in subsequent discussions.

as domestic producers of intermediate goods become technologically better and stronger, exporters might also choose to source more inputs locally, substituting Chinese-made inputs for previously imported inputs, which would increase the share of domestic value added in China's exports. A concrete channel through which this occurs is that more foreign-owned intermediate input producers have chosen to relocate from abroad to China in recent years, enhancing the capacity in China of producing sophisticated parts and components needed in China's exports. In addition, as China's domestic market grows in size relative to the world market, more producers reorient their sales towards the Chinese market, resulting in a decline in processing exporters (which sell almost exclusively in the world market) relative to ordinary exporters (which sell in both the Chinese and foreign markets) and a decline in the use of imported inputs in the production. While the net effect could go either way, the data uncovered by KWW1 indicate that, on balance, the second effect dominates, and the share of Chinese value added in China's total exports increases over time.

However, KWW1 only address a special case of aggregation bias caused by product and firm heterogeneity when using industry level data. Even if national statistical agencies exceptionally publish the four key input–output matrices at industry-level as Mexico does, as long as different firms and products within an industry have different imported input use intensities, using industry-level data will still generate a bias in the measurement of domestic value added in exports. Many recent firm-level studies show that exporters differ in many dimensions from non-exporters, including in their choice of inputs, and there is large heterogeneity in the import penetration rates among firms, especially between those actively engaged in trade and those that produce only for the domestic market. Exporters are more likely to use more imported inputs than domestic firms.

Kee and Tang (2012) complement the analysis of KWW1 by using firm-level data on exports and imports for Chinese processing exporters over 2000–6. In particular, instead of relying on the standard input–output data and assuming the same input–output coefficients in the production for exports and for domestic sales, the firm-level data could allow for heterogeneous input–output coefficients at the firm level. Of course, we would still need to aggregate the information at some level, otherwise there may be too much individual-level information and insufficient group-level information. If imported inputs by a given firm are primarily used by the firm to produce for exports and contain little Chinese value added, and if the domestically sourced inputs by processing exporters contain no imported value added, then one can compute the share of domestic value added in exports for this group of firms by simply looking at the ratio (exports – imports) / exports. By this methodology, Kee and Tang find that the average share of domestic value added in China's processing exports rose from 52% in 2000 to 60% in 2006. The trend over time is very similar to those reported by KWW1, though the former focus only on processing trade.

Justino De La Cruz, Robert B. Koopman, Zhi Wang and Shang-Jin Wei (Chapter 6) apply KWW1's methodology to Mexico's exports. Mexico uses the processing trade scheme (under the Maquiladora and PITEX programmes) even more extensively than China. In fact, their chapter improves on KWW1, as Mexico has direct measures of the input–output coefficients for processing exports, eliminating the need to estimate them and therefore reducing one margin of error. On average, the share of domestic value added in Mexico's manufactured exports is 34%. Those manufacturing industries whose share of domestic value added is 50% or less account for about 80% of Mexico's total manufacturing exports.

Similarly to Kee and Tang (2012), Nadim Ahmad, Sónia Araújo, Alessia Lo Turco and Daniela Maggioni (Chapter 8) use firm-level data in Turkey to estimate the share of domestic value added in Turkish exports in 2005. The use of firm-level data allows Ahmad *et al* to permit separate input–output coefficients for firms that sell primarily to the domestic market and those that sell primarily to the world market. They estimate that the share of foreign content in Turkey's exports in 2005 was about 27%, which is 6 percentage points higher than the share estimates from the official IO table based on aggregated data at the industry level. However, this number is lower than estimates for China and Mexico, most likely because Turkey engages in fewer processing exports than the other two countries.

These studies demonstrate that estimates based on IO tables and firm-level data each have their advantages and shortcomings in estimating domestic and foreign content in exports. The methods are not substitutes but complementary. Because any empirical work based on real world data has to involve some degree of aggregation (even with the most detailed plant level data), such 'aggregation bias' cannot be completely eliminated; it can only be reduced or minimised. The challenge for empirical researchers is how to minimize the 'aggregation bias' based on the particular research issue at hand and the information available at the time when the research is conducted.

3 CLARIFYING THE CONNECTIONS AND DISTINCTIONS AMONG ALTERNATIVE CONCEPTS RELATED TO TRADE IN VALUE ADDED

Because the research on measuring trade in value added and quantifying the degree of vertical specialisation is active and dynamic, a number of concepts have been proposed. Some of them have similar names but distinct content. It may be useful to take stock of these concepts, pointing out both connections and distinctions.

We have already mentioned the first measure of vertical specialisation, proposed by HIY (2001), which refers to the share of the imported content in a country's exports. This measure, commonly labelled as VS, includes both the directly and indirectly imported input content in exports.

A second measure, also proposed by HIY (2001) and labelled as VS1, looks at vertical specialisation from the export side, and the value of intermediate exports sent indirectly through third countries to final destinations. However, HIY did not provide a mathematical definition for VS1.

A third measure is the value of a country's exported goods that are used as imported inputs by the rest of the world to produce final goods that are shipped back home. This measure was proposed by Daudin *et al* (2011). Because it is a subset of VS1, they call it VS1*.

A fourth measure is value-added exports, which is value added produced in source country s and absorbed in destination country r. Johnson and Noguera (Chapter 4) defined this measure and proposed using the ratio of value-added exports to gross exports, or the 'VAX ratio' as a summary measure of value-added content of trade.

However, the domestic content share in a country's exports and the VAX ratio are, in general, not equal to each other. (In other words, the value of domestic content in exports and the value of a country's value-added exports can be different.) Koopman, Wang and Wei (forthcoming; subsequently referred to as KWW2) propose a methodology that decomposes a country's total exports into four buckets (or nine components in total with a few terms in each bucket). The first bucket gives a country's value-added exports, exactly as defined by Johnson and Noguera (Chapter 4). The second bucket gives the part of a country's domestic value added that is first exported but eventually returned home. The third bucket is the value of foreign value added used in the production of a country's exports. The fourth bucket consists of what they call 'pure double counted terms', arising from intermediate goods being traded back and forth multiple times. Some of the terms in the fourth bucket double count value added originating in the home country, whereas other terms in the fourth bucket double count value added originating in foreign countries.

KWW2 define 'domestic value added in a country's exports' as the sum of the first and second buckets. This concept only looks where the value added is originated, regardless where it is ultimately absorbed. In comparison, a country's 'value-added exports' refers to a subset of 'domestic value added in a country's exports' that is ultimately absorbed abroad.

The 'domestic content of a country's exports' is defined by KWW2 to be even broader than 'domestic value added in a country's exports'. It is the sum of the first and second buckets, and those items in the fourth bucket that reflect pure double counting of value added that originate in the home country. Symmetrically, the 'foreign content of a country's exports' is the sum of the third bucket and those items in the fourth bucket that reflect pure double counting of value added that originates in foreign countries.

Such definitions have two attractive properties. First, KWW2 verify that the 'foreign content of a country's exports' is mathematically identical to the VS measure proposed by HIY (2001) in multi-country settings but without HIY's restrictive assumption of no two-way trade in intermediate inputs. Second, the sum of the domestic and foreign contents of a country's exports is equal to that country's total gross exports.

As stated above, KWW2's approach can completely decompose a country's gross exports into the sum of nine components (or the sum of four buckets). Once one has the decomposition, other measures of vertical specialisation such as VS, VS1 and VS1*, in addition to 'value-added exports', can also be expressed as linear combinations of some subsets of the nine components. In this sense, the KWW2's gross exports accounting method provides a compact and precise way to characterise the relationships among the major existing measures in this literature.

The KWW2 decomposition also provides information on the structure of double counting in gross trade statistics (in addition to the total amount of double counting). The structural information can be useful in delineating a country's position in the global production chain. For example, in some sectors, China and the USA may have a similar number of value-added exports but a different composition of the double counted terms. For China, the double counted terms may show up primarily in the form of the use of foreign components (*eg* foreign product designs or machinery) in the final goods that China exports. For the USA, the double counted terms may show up primarily in the form of domestic value added finally returned and consumed at home (*eg* product designs by Apple that are used in the final Apple products produced abroad but sold in the US market). The ratio of these two types of double counted terms offers a convenient measure of a country's position in the global value chain.

4 SUGGESTIONS FOR OFFICIAL STATISTICAL INFRASTRUCTURES

In the previous section, we reviewed research that takes the existing work by the official statistical agencies as given and seeks the best way to estimate trade in value added by combining information from trade data and national input–output tables. In this section, we discuss proposals for modifying the way official data is collected and reconciled that can improve the accuracy of the estimated trade in value added.

Satoshi Inomata, Norihiko Yamano and Bo Meng (Chapter 9) review the compilation approaches of an inter-country input–output table for selected major economies in Asia (Asia IIO table for short) and the inter-country IO table produced by the OECD (OECD IIO table for short). For some of the covered countries, the underlying data involves a periodic survey of firms that use intermediate imports. The Asia IIO table also harmonises sector definitions for the IO tables of the participating countries by the means of a survey of individual countries' input–output-table-compiling agencies. The Asia IIO table then reconciles the discrepancies to produce a consistent and balanced inter-country input–output table. The OECD IIO table covers more countries (58 countries). A major feature of the OECD IIO table is that information on the flow of intermediate inputs across constituent countries is available by both sectors and end-use categories.

It is well known that international trade statistics do not balance at the global level, giving rise to the humorous anecdote of Earth trading with Mars or the Moon to explain the net surplus (or deficit). At the national level this can generally be ignored, the perspective being that the inconsistencies are in some other country's accounts. But when considering global accounts, and in particular in relation to the estimation of trade in value added, these inconsistencies have to be eliminated. In Chapter 10, Nadim Ahmad, Zhi Wang and Norihiko Yamano demonstrate how this can be accomplished by a three-stage data reconciliation model. In the first stage, their model reconciles total goods and services exports and imports recorded in each country's GDP by expenditure accounts with trade statistics at the product group level recorded in each country's supply and use tables. It results in a consistent time series of country- and product-group-level total exports and imports, which satisfy the condition that world total exports plus a shipping cost margin (including insurance and freight) equal to world total imports. The use of international shipping services is also balanced with its supply from producing industries at the global level. In the second stage, their model benchmarks each country's supply and use tables with each country's GDP by expenditure account, using globally consistent export supply and import demand estimates from the first stage as controls. In the final stage, their model allocates bilateral trade flows to producing/using industries and final users in each country based on international bilateral trade statistics broken down by end-use categories, resulting in a time series of bilateral trade statistics within a global supply–use table that is consistent with global control totals estimated in the first stage. They use mirrored trade statistics as interval constraints in the final stage with a quality-based reliability index for each bilateral trade flow by product group, to arrive at a balanced global table that is consistent with the major components in each country's GDP.

Preliminary empirical tests of the model using WIOD data and aggregate trade statistics from official national accounts, as well as bilateral trade data from OECD, produced encouraging results. Ahmad *et al* show that imposing global consistency and eliminating 'exports to the Moon' will make no significant changes to reported GDPs and other major aggregate national account statistics in the final database.

If estimating value added from IIO tables can be called a 'top-down' approach, Timothy J. Sturgeon, Peter Bøegh Nielsen, Greg Linden, Gary Gereffi and Clair Brown (Chapter 11) suggest two 'bottom up' approaches: product-level global production chain studies and business function surveys.

A product-level study can decompose an individual product into an exhaustive list of components and parts, and trace the country of production of each component/part. The advantage of this approach is that one obtains more detailed information at the component level. However, a major disadvantage of this approach is that there are only a limited number of products for which such an approach is feasible. Another disadvantage is that tallying up all physical inputs would not give a complete list of all inputs for most products, since a range of intangible support functions (R&D, marketing, IT services, etc.) also contribute to the final value of the product and they have a share of domestic value that is between 0 and 1. The second bottom-up approach is to expand a typical survey of firms by asking for information on how and where each business function is sourced (in addition to where each physical component is sourced). The second approach can avoid the shortcoming of the first approach of missing value added in R&D, IT services and other support functions. However, organising a periodic survey of firms across countries for this purpose in a consistent manner is an expensive undertaking and goes beyond what statistical agencies do currently.

Five separate contributions, comprising Chapter 12, by Andreas Maurer, Ronald Jansen, Nadim Ahmad and Robert E. Yuskavage, from five different government institutions, respectively propose additional ideas on how the System of National Accounts (SNA) could be modified to integrate data collection and lead to better measures of trade in value added. There is a consensus among the five contributors that conventional trade measures have major limitations for assessing inter-country linkages and bilateral trade balances. Therefore, developing trade in value-added statistics that could ultimately be included as supplementary measures in the SNA should be supported. For example, both Maurer and Ahmad believe that the OECD and the WTO are now 'in a position to coordinate efforts towards the estimation of trade flows in value-added terms based on official trade statistics and national accounts'. (Maurer; see page 323 of this volume).

There is also a consensus among the five contributors that direct measurement of value-added trade is extremely difficult if not impossible, primarily because the information is not available in business record-keeping systems. Therefore, conventional gross trade statistics should remain as the featured measures of cross-border trade and 'will remain a necessary input for many analytical purposes' (Jansen, this volume; see page 326). While data on value added at the firm level are useful to have, they are too expensive to collect because the current business record-keeping system does not contain such information. (An individual firm does not need to know how much imported content is contained in a domestically sourced intermediate good; a multi-product firm also does not typically track how the value of imported inputs is distributed across its different products or business functions.) As pointed out by Yuskavage (page 333): 'in general, US business firms do not maintain information in their accounting systems that would allow them to readily identify whether their material inputs are from domestic or foreign sources. Firms typically obtain their material inputs from wholesale suppliers and distributors and are not necessarily concerned about the country of origin for these materials.' Because of such difficulties in data collection, he believes (see page 333) that 'the most promising approach to develop comprehensive and consistent value-added trade measures that go beyond case studies of individual high-profile products involves the use of world IO tables'. Jansen (see page 329) advocates linking enterprise survey data to detailed merchandise trade statistics via business registers to improve current official data collection and the international standardisation of the compilation of IO tables as 'two parallel and mutual supportive developments'.

It is clear from the chapters in this volume that measuring the value-added content of trade requires a global input–output table. Such a table would integrate official national accounts and bilateral trade statistics on goods and services into a consistent accounting framework. Conceptually, it is a natural extension and integration of the SNA. In statistical practice, it requires reconciling each individual country's supply and use tables with official bilateral trade statistics. New official statistics of trade in value added could be estimated under such an accounting framework to completely distribute value-added production to their original sources and final destinations at either the countrywide or industry average level. Because supply and use tables and input–output accounts are already a central part of 1993 and 2008 SNA, which by international consensus is the best framework for data gap assessment and GDP estimation,[4] it provides a workable and cost-effective way for national and international statistical agencies to remedy the missing information in current official trade statistics without dramatically changing the existing data-collection practices of national customs authorities.

To mainstream the production of statistics on trade in value-added statistics, beyond knowing the conceptual definitions of the objects we wish to measure, we have to ask how official statistical collection can be amended in a cost-effective way to generate a consistent time-series of IIO tables of acceptable quality.

Existing conceptual work has established a formal and precise relationship between value-added measures of trade and official trade statistics, and allows various value added and double counted components in a country's official gross exports statistics to be correctly identified and estimated. It opens the possibility for the System of National Accounts (SNA) to accept the concept of trade in value added and provides a feasible way for international statistical agencies to report value-added trade statistics regularly in a relatively low cost fashion.

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[4]SNA (1993) recommended using a supply and use table as a coordinating framework for economic statistics, both conceptually and numerically to assure consistency for data drawn from different sources, especially in reconciling GDP estimates from production, expenditure and income sides (see SNA 1993, pp. 343–371).

Some additional effort is useful in this regard, including the following.

(i) Helping more developing countries to generate and publish supply and use tables regularly; for example, a good initial set of countries would be those emerging economies that are in the G20.

(ii) Harmonising supply and use tables across countries: a common industry and product classification needs to be included in national IO statistics.

(iii) Improving classification systems to properly identify intermediate inputs in imported services and dual-use products, such as fuels.

(iv) Improving the allocation of imported inputs (of both goods and services) into sector users within each country by making official use of firm-level data from the current economic census and industry surveys as well as customs transaction level data.

(v) Constructing improved estimates of bilateral trade in services.

An accurate assessment of value added in trade has to go beyond a single country's effort, as it requires information on cross-border input–output relationships. Therefore, an internationally coordinated approach is needed and it could best be achieved with an inter-secretariat approach that brings together a number of international agencies that are able to tap into their existing institutional networks of official statistics. Otherwise, 'practical problems would arise if each country were responsible for compiling its own value-added trade statistics' (Yuskavage; see page 335).

Constructing an annual IIO database is time consuming and resource intensive. An appropriate division of labour among major international agencies is necessary to make the best use of limited resources and avoid duplication of effort. National statistical agencies are the major source of raw data. More technical assistance and capacity building initiatives in developing countries, such as that by the Asian Development Bank,[5] can improve the statistical ability of developing countries to fully implement 1993 SNA recommendations. This is also consistent with UNSD's objective to improve national account and GDP estimation across countries.

On 15 March 2012, the WTO and OECD launched a joint initiative: 'measuring trade in value added'.[6] The work is designed to provide a means to develop these new metrics of trade on an ongoing and long-term basis. In order to improve the quality and timeliness of the estimates, the programme also seeks improvements in the inputs from national authorities. It will capitalise on existing networks and build new ones. The agreement between the OECD and WTO is the most visible example, supported by collaboration with

[5]The Asian Development Bank organised a project with the participation of 17 developing countries (RETA 6483) in the Asia Pacific region to construct supply and use tables for each participating country.

[6]See http://www.oecd.org/trade/valueadded.

other agencies, such as IDE-JETRO and US-ITC. The programme is designed to standardise and routinise the production of statistics on trade in value added, generating the global IIO table and value-added trade estimates periodically, and making them a permanent part of the statistical landscape. The first official release of major trade in value-added indicators was in January 2013.

To summarise, the trade economist community and the trade policy world have reached a near consensus that official trade statistics are deficient and the deficiency grows with the deepening global division of production chains. There has been a burgeoning interest in developing new measures of both value added trade and the structure of double counted trade flows. We may be on the verge of breaking new ground in developing feasible new measures that can illuminate trade policy discussions. We hope this volume makes a contribution to that effort.

REFERENCES

Antras, P. (2005). Property Rights and the International Organization of Production. *American Economic Review Papers and Proceedings* **May**, 25–32.

Daudin, G., C. Rifflart and D. Schweisguth. (2011) Who Produces for Whom in the World Economy? *Canadian Journal of Economics* **44**(4), 1409–1538.

Dean, J. M., and M. E. Lovely (2010). Trade Growth, Production Fragmentation, and China's Environment, in *China's Growing Role in World Trade* (ed. R. Feenstra and S. Wei). Chicago: NBER and University of Chicago Press.

Feenstra, R., and G. Hanson (2005). Ownership and Control in Outsourcing to China: Estimating the Property-Rights Theory of the Firm. *Quarterly Journal of Economics* **120**(2), 729–761.

Grossman, G., and E. Rossi-Hansberg (2008). Trading Tasks: A Simple Theory of Offshoring. *American Economic Review* **98**(5), 1978–1997.

Hummels, D., J. Ishii and K. Yi. (2001). The Nature and Growth of Vertical Specialization in World Trade. *Journal of International Economics* **54**, 75–96.

Kee, H.-L., and H. Tang. (2012). Domestic Value Added in Chinese Exports. Working Paper, World Bank and Tufts University.

Koopman, R., Z. Wang and S.-J. Wei (forthcoming). Tracing Value-Added and Double Counting in Gross Exports. *American Economic Review.* A longer version is available as Working Paper18579.

Maurer, A., and C. Degain (2010). Globalization and Trade Flows: What You See Is Not What You Get! World Trade Organization Staff Working Paper ERSD-2010-12, Geneva.

National Board of Trade (2007). 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, Stockholm.

Rose, A. (2004). Do We Really Know That the WTO Increases Trade? *American Economic Review* **94**(1), 98–114.

SNA (1993). System of National Accounts. United Nations Statistics Division. URL: http://unstats.un.org/unsd/nationalaccount/sna1993.asp.

Subramanian, A., and S.-J. Wei (2007). The WTO Promotes Trade, Strongly but Unevenly. *Journal of International Economics* **72**(1), 151–175.

2

Towards the Measurement of Trade in Value-Added Terms: Policy Rationale and Methodological Challenges

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Since the 1990s, a fundamental change has been taking place in the structure of world production and international trade. Production has become increasingly fragmented across countries that trade intermediate inputs before exporting final products. This reality for businesses is not reflected well in trade statistics, which attribute the full value of a good or service to the last country that contributed to its production, at the end of the 'value chain'.

Misperceptions associated with the inability to identify the country where value added originates can lead to misguided decisions. In the context of stalled multilateral trade negotiations, slow growth and continued economic uncertainty, this is important to provide a better understanding of sources of productivity and competitiveness at the international level and to encourage structural reforms that take into account the new landscape of international trade and global production.

Several papers, workshops and conferences have now addressed the issue of the measurement of trade flows in the context of the fragmentation of world production. At this stage, what seems important is to provide a framework in which international organisations can build on the pioneering work done so far and move forward to provide new data and indicators that answer the concerns raised on standard statistics.

Against this backdrop, this chapter has two objectives. The first one is to present the policy drivers that motivate the production of new trade statistics in value-added terms. The second is to address some of the methodological issues in such work, based on OECD experience in the compilation of a global input–output model of trade and production. The chapter concludes with the main challenges ahead.

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[1] This chapter draws on the work of the OECD Secretariat (Nadim Ahmad, Koen de Backer and Colin Webb) and the WTO Secretariat staff (Christophe Degain, Hubert Escaith and Andreas Maurer). The views expressed are those of the authors and do not necessarily reflect those of OECD or WTO member countries.

1 WHY DO WE NEED NEW TRADE STATISTICS AND INDICATORS TO ACCOUNT FOR GLOBAL PRODUCTION NETWORKS?

1.1 The Issue with Conventional Trade Statistics

With the globalisation of production, there is growing awareness that conventional trade statistics may give a misleading perspective of the importance of trade to economic growth and income and that "what you see is not what you get" (Maurer and Degain 2010). This reflects the fact that trade flows are measured in gross terms, and so the value of products that cross-borders several times for further processing will also be included several times in trade flows.

The past decades have been characterised by declining trade costs as a consequence of technological progress and trade policy reforms. Inventions such as the container ship or the Internet have revolutionised trade in several ways, but an important step was also service trade liberalisation. Key sectors that are part of the global logistics chain (transport, finance, telecommunications, *etc*) have seen their regulatory barriers reduced. This process led to the 'fragmentation' of production (Jones and Kierzkowski 2001), *ie* the possibility for firms to split up the production process in several countries to maximise the benefits of vertical specialisation. The emergence of global production networks and rise of trade in intermediates explain why there is increasing concern with the gross valuation of trade flows in current statistics.

An often cited case study that illustrates the issue well relates to the production of an Apple iPod (Linden *et al* 2009). The study showed that of the $144 (Chinese) factory-gate price of an iPod, less than 10% contributed to Chinese value added, with the bulk of the components (about $100) being imported from Japan, and with much of the rest coming from the USA and Korea. Box 2.1 revisits the Apple example with the iPhone 4.

Box 2.1. Who Bites the Apple? The iPhone Example Revisited.

Several studies have illustrated the concept of value-added trade using Apple's emblematic devices: first the iPod (Linden *et al* 2009) and then the iPhone (Xing and Detert 2010) and the iPad (Linden *et al* 2011). All these high-tech products are assembled in the People's Republic of China, and so make a not insignificant contribution to China's exports. But Chinese value added represents only a small share of the value of these electronic devices, which incorporate components from Germany, Japan, Korea and other economies that manufacture intermediate inputs.

Based on estimates provided by iSuppli and Chipworks, Table 2.1 illustrates this by identifying those countries that provide intermediate inputs into the iPhone 4.

But this does not tell the full story. The table only shows the value of the intermediate inputs produced by the firms, but they themselves will no doubt have used intermediate imports in their production or sourced intermediate

Table 2.1: *Countries that provide intermediate inputs into the iPhone 4.*

Country	Components	Manufacturers	Costs ($)
Chinese Taipei	Touch screen, camera	Largan Precision, Wintek	20.75
Germany	Baseband, power management, transceiver	Dialog, Infineon	16.08
Korea	Applications processor, display, DRAM memory	LG, Samsung	80.05
USA	Audio codec, connectivity, GPS, memory, touchscreen controller	Broadcom, Cirrus Logic, Intel, Skyworks, Texas Instruments, TriQuint	22.88
Other	Other	Misc.	47.75
		Total	187.51

Source: Xing and Detert (2010), iSuppli, Chipworks.

goods from domestic suppliers, who in turn would have used intermediate imports. Identifying these flows is equally important, particularly in the context of the example above, because some of those imports may have originated in China. Moreover, while the country indicated is the country where the firms producing the components are headquartered, these inputs are often produced in other countries. Infineon, for example, has several factories in China. Chinese value added may therefore not only be limited to the assembly costs.

To fully decompose the value added of the iPhone, and therefore ascribe it to individual countries, one cannot rely on a list of component suppliers. Information on all of the suppliers and their suppliers, and their suppliers' suppliers, and so on, is equally important. What is needed therefore is a data set that is able to link production processes within and across countries: in other words, a set of international input–output tables with bilateral trade links (a global input–output table). Naturally, input–output tables developed by statistical offices the world over aggregate firms into groups (sectors) of firms that produce similar products, and thus input–output tables will not be able to reveal the total domestic value added generated by the production of an iPhone in any country. However, they will be able to provide such estimates for the whole economy and indeed by the sectors.

The iPhone example also highlights that, beyond trade flows, more information on royalty payments and income flows is required to answer the question of who benefits from trade. One should also look at ownership: Foxconn, the company that assembles iPhones in China, is a Chinese-Taipei-owned firm and the value added by mainland China in the example is split between wages paid to Chinese workers and income for shareholders in Chinese Taipei.

Three main issues can be identified with conventional trade statistics. The first issue is the implicit multiple counting of intermediate goods and services. When world trade is calculated as an aggregation of all bilateral trade flows measured in gross terms, the value of the same primary or intermediate input is implicitly counted as many times as it crosses a border for further processing, reflecting its embodiment in the good as it goes through the processing chain.

The second issue is perhaps the most important. The gross recording of trade flows and the fact that exports increasingly embody intermediate inputs sourced from abroad makes it difficult to identify the real contribution a given export may make to an economy's material well-being, be that in terms of income or employment creation. Moreover, conventional trade statistics are not able to demonstrate those sectors of the economy where value added originates. In developed economies a large share of the total value added generated by manufactured exports originates in the service sector, disentangling the domestic value chain into its sectoral components can therefore shed new light on the sources of international competitiveness.

One final issue goes beyond 'value added', which has been the focus of most, if not all, of the contributions made so far. Value added in a national accounts sense reflects the compensation of labour and the compensation for produced and non-produced non-financial assets and natural resources used in production. However, measuring flows of value added reflects only part of the 'global trade' story. The fragmentation of production processes often involves fragmentation within a multinational enterprise. In that sense, part of value added, or at least part of what is referred to as operating surplus in the national accounts, may be repatriated to the parent company. This may be a straightforward transfer from the affiliate to the parent (recorded as distributed income) or it may reflect payments for the use of intellectual property products that are not recognised as produced assets in the national accounts. Either way, the point is that even estimates of value added in trade may not provide the full picture of the importance of trade to an economy.

Increasingly, there is recognition that a focus on flows of value added embodied in trade flows provides more meaningful measures of the importance of trade to economic growth. The underlying concept is in and of itself not relatively contentious, and there is widespread agreement that it reflects, for a given export, the percentage or amount of domestic value added that is generated by the export, throughout the production chain. In other words, any given export can be decomposed into value-added contributions from different domestic industries and different foreign industries.

Measuring trade in value added closes the gap between research and statistics. The recent contribution of researchers to the understanding of international economics (the so-called new 'new' trade theory) emphasises the leading role of firms and business strategy in shaping international trade. In today's industrial economy, dominated by global manufacturing and international supply chains, countries do not exchange goods, but 'trade in tasks'.[2] Measuring trade in value added is a significant step in reflecting in official statistics the reality of economics capitalising on advances in academic research and data.

A particular challenge is to disentangle domestic and foreign value added in the context of highly fragmented production networks where 'circular' trade takes place: inputs are shipped abroad and then come back as more processed products. Such a circular trade is particularly important in North America (especially between Mexico and the USA) and in Eastern Asia. National accounts do not provide a measure of domestic and foreign value added in trade flows. Therefore, input–output tables from different countries have to be harmonised and linked to create a global input–output table in order to estimate the share of domestic value added both in exported and in imported goods and services. In addition, when working on bilateral balances in value-added terms, one needs to fully decompose foreign value added according to the ultimate source country. Indeed, part of the value of the imports from the last known exporting country may originate from third countries (and even, as mentioned, include reimports from the domestic economy). This work requires a full set of inter-country input–output tables, where all bilateral exchanges of intermediate goods and services are accounted for.

A last remark is that, despite their shortcomings for understanding international trade linked to global production networks, traditional trade statistics tracking the physical movement of goods (gross accounting) remain fully relevant from an analytical point of view. The concept of 'value added' is useful in order to understand where economic activity and jobs are generated. But, on the demand side, gross trade flows tell us how much consumers have spent on imported goods and services. As consumers pay the full price in a single currency, the gross trade flows also matter in addressing currency or exchange rate issues, although, even here, some care is needed, as the goods and services recorded in conventional trade statistics do not always change ownership, particularly if the products are processed within affiliates of a multinational enterprise or they are, as is increasingly the case, sent abroad for further processing without any cash transaction occurring for the underlying goods to be processed.

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[2]See Lanz *et al* (2011) for more on 'trade in tasks'.

1.2 A Brief Overview of the Literature on Trade in Value Added

Although the literature on trade in value added is quite technical, it has attracted a lot of attention from policymakers. What could first look like a concern for trade statisticians is now understood as a key issue for the policy debate. For example, Word Trade Organization (WTO) Director-General Pascal Lamy notes that[3]

> 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.

Even though global manufacturing through international supply chains may have became a major characteristic of international economy in the past 20 years, reflections about the global nature of production date from much earlier. A first intent to formalise it is attributed to Leontief in the 1960s (Leontief and Strout 1963). However, current reflections on the value-added content of international trade stem from two streams of economic literature.

The first one deals with the importance of trade in intermediate goods and services. This is not a new topic, as Sanyal and Jones noted in their seminal 1982 paper that the bulk of international trade is in intermediate products and that trade in intermediates mainly consists not of raw material or primary inputs but of products that have already received some value added (Sanyal and Jones call them 'middle products'). Today, trade in intermediates accounts for about 56% of world trade in the case of goods and 70% in the case of services (Miroudot *et al* 2009). The growth of trade in intermediates has been highlighted in various recent surveys, in particular in Asia (see for example, Hayakawa 2007). Looking at trade in intermediate goods and services is the first step in the measurement of trade in value added.

Following the definition introduced by Hummels *et al* (2001), the second stream of literature focuses on 'vertical trade'. The latter expression refers to the vertical specialisation of trade, which is the consequence of the international fragmentation of production. There is vertical trade when three conditions are met:

(i) a good (or service) is produced in two or more sequential stages;
(ii) two or more countries provide value added during the production process; and
(iii) at least one country uses imported inputs in the process and some of the output is exported.

When taking into account both direct and indirect imported inputs, as suggested by Hummels *et al* (2001), the vertical specialisation (VS) share of world trade is about 25%.

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[3] '"Made in China" tells us little about global trade', *Financial Times*, 24 January 2011.

The literature on vertical trade aims at measuring sequential trade in vertical production chains by looking at the import content of exports. Trade in value added is a broader concept but shares with this literature a common concern: how can we distinguish the foreign and domestic value added in gross exports. Coefficients from imports and domestic matrices in input–output tables are used to operate this distinction. One issue that has been identified is the use of the same coefficients for the production sold on the domestic market and for exports, particularly in countries with a high level of 'processing trade', such as China (see Koopman *et al* 2008).

The first papers to explicitly refer to the value added of trade (with some empirical measurement) are Daudin *et al* (2009), Johnson and Noguera (2012), Koopman *et al* (2010)[4] and Foster *et al* (2011). The first three studies rely on the Global Trade Analysis Project (GTAP) database to calculate trade flows in value added, while Foster *et al* (2011) is based on preliminary results from the World Input–Output Database (WIOD). Daudin *et al* (2009) identify 'who produces what and for whom' by reallocating the value added contained in final goods to each country participating in their production. In addition to the VS share of Hummels *et al* (2001), the authors calculate the share of exports used as inputs to further exports and the domestic content of imports (that is, domestic value added that comes back to the country through intermediates originally exported and reimported within more processed products). Johnson and Noguera (2012) present similar calculations, but based on a different decomposition of value-added exports. They focus on bilateral trade flows and calculate the ratio of value added to gross exports, a measure of the intensity of production sharing. As an illustration, they show that the US–China bilateral imbalance in 2004 is 30–40% smaller when measured in value-added terms. As opposed to Hummels *et al* (2001), their framework allows two-way trade in intermediates (each country can both import and export intermediates, while in the VS framework the last country exports final goods only).

Koopman *et al* (2010) provide a full decomposition of value-added exports in a single conceptual framework that encompasses all the previous measures. Exports are first decomposed into domestic value added, returned domestic value added (domestic value added that comes back incorporated in foreign inputs produced with domestic inputs) and foreign value added. Domestic value added is then split between exports absorbed by direct importers and indirect exports sent to third countries. By taking into account the returned domestic value added and the indirect exports to third countries, two sources of indirect value-added exports are taken into account and the decomposition is complete (thus matching standard trade data in gross terms when all the decomposed values are aggregated). Foster *et al* (2011) prefer, however, to focus on 'net trade' in value added to account for two-way trade in interme-

[4]See Chapters 4 and 5 in this volume.

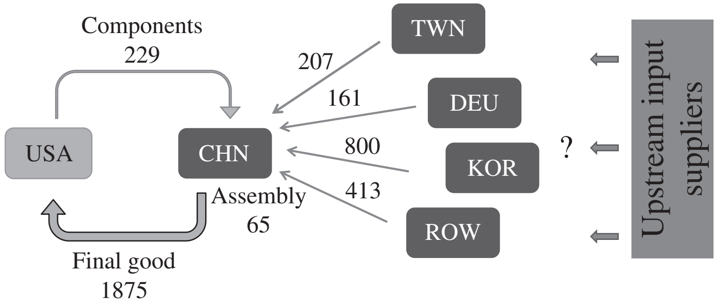

Figure 2.1: *The difference between US exports of intermediate inputs to China and US imports of assembled iPhones.*

Table 2.2: *US trade balance in iPhones.*

US trade balance in iPhones with:	CHN	TWN	DEU	KOR	ROW	World
Gross	−1,646	0	0	0	0	−1,646
Value added	−65	−207	−161	−800	−413	−1,646

diate inputs and to maintain the consistency between a country's net exports in value-added and gross terms.

Between the pioneering work of Hummels *et al* (2001) and these latest studies, the conceptual framework has been greatly enhanced and we now have a better understanding of what constitutes trade in value-added terms. The field is therefore not only extremely relevant, but also mature to be included in official statistics (Escaith 2008).

1.3 Policy Drivers

What can we expect from developing these new statistics on international trade? There are at least six areas where measuring trade in value added brings a new perspective and is likely to impact policy choices; the principal areas are as follows.

Box 2.2. The Balance of Trade in Gross and Value-Added Terms (The iPhone Example Continued)

> It is easy to observe, that all calculations concerning the balance of trade are founded on very uncertain facts and suppositions.
>
> Hume (1985)

To understand how the measurement of trade in value added affects bilateral trade balances, we can use the setting of the iPhone example described in Box 2.1. Assuming that 10 million iPhones are exported from China to the USA, the iPhone trade represents a trade deficit of $1,646 million for the US economy (this is simply calculated as the difference between US exports of intermediate inputs to China ($229 million) and US imports of assembled iPhones ($1,875 million; see Figure 2.1)). In gross terms, there is only a deficit between China and the USA.

In value-added terms, one has to take into account that China adds a small share of domestic value added to the iPhone, corresponding to the value of the assembly work. As highlighted in the list of costs presented in Box 2.1, most of the components of the iPhone are sourced from outside China. Let assume that Chinese assembly costs are $6.50 per iPhone (and are part of the miscellaneous costs in Box 2.1). In value-added terms, Table 2.2 shows that the trade deficit is not only with China but also with Chinese Taipei, Germany, Korea and the rest of the world. The overall trade deficit (vis-à-vis the world) stays unchanged at $1,646 million.

In this example, we do not take into account the suppliers of the suppliers. It is likely that what Chinese Taipei, Germany and Korea manufacture incorporates further foreign inputs. The above calculation would have to be adjusted to fully take into account the value added by each country in the supply chain. This is why we need to add on the above figure upstream input suppliers and why the calculation can only be done if we have all the information about all the producers involved.

- **Global imbalances.** 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 vis-à-vis the rest of the world, but it redistributes the surpluses and deficits across partner countries (see Box 2.2). 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. A WTO report calculates that the US–China trade balance in 2008 would be about 40% lower if calculated in value-added terms.[5] The true imbalance is therefore also with the countries who have 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 would target countries at the end of global value chains on the basis of an inaccurate perception of the origin of trade imbalances.
- **Market access and trade disputes.** Measuring trade in value added sheds new light on today's trade reality, where competition is not between nations but between firms. Competitiveness in a world of global value chains means access to competitive inputs and technology. The

[5] See Maurer and Degain (2010). Koopman *et al* (2010) find that the domestic value added of Chinese exports is on average 60%.

optimum tariff structure in such a situation is flat (little or no escalation) and reliable (contractual arrangements within supply chains, especially between affiliated establishments, tend to be long term). Outsourcing and offshoring of elaborate parts and components can only take place in situations where intellectual property is respected. Moreover, in the context of the fragmentation of production and global value chains, mercantilist-styled 'beggar your neighbour' strategies turn out to be 'beggar thyself' miscalculations. As mentioned, domestic value added is found not only in exports but also in imports: some goods and services are intermediates shipped abroad, whose value comes back to the domestic economy embodied in imports of foreign products. As a consequence, tariffs, non-tariff barriers and trade measures (such as anti-dumping rights) are likely to impact domestic producers 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% and 80% of European Union value added. In 2006, anti-dumping rights were introduced by the European Commission on shoes imported from China and Vietnam. An analysis in value-added terms would have pointed out that EU value added was in fact subject to the anti-dumping rights (Swedish National Board of Trade 2007).

- **The impact of macroeconomic shocks.** The 2008–9 financial crisis was characterised by a synchronised trade collapse in all economies. Many 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 emphasised the 'bullwhip effect' of global value chains (see Escaith *et al* 2010; Lee *et al* 1997). 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 to help policymakers 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.
- **Trade and employment.** Several studies on the impact of trade liberalisation 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 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 can be interpreted in terms of jobs. Traditional thinking in gross terms would regard imports of shoes manufactured in China and Vietnam by EU shoe producers 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 job in the EU at the assembly stage, there is a higher number of jobs 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 embedded in the domestic content of exports reflects the relative development level of participating countries. Industrialised countries tend to specialise in high-skill tasks, which are better paid and capture a larger share of the total value added.[6]

- **Trade and the environment.** Another area where the measurement of trade flows in value-added terms would support policymaking is 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 carbon dioxide (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). An OECD study notes that the current relocation of industrial activities has a high impact on differences in consumption-based and production-based measures of CO_2 emissions (Nakano *et al* 2009).
- **Trade, growth and competitiveness.** Likewise, indicators of competitiveness such as the 'revealed comparative advantage' are affected by the measurement of trade in gross terms. Going back to the iPhone example, China seems to have a comparative advantage in producing iPhones on the basis of traditional trade statistics, while its comparative advantage is in assembly work. Bearing in mind development strategies and the concerns of policymakers to identify export sectors and promote industrial policies, the analysis of the export competitiveness of industries cannot ignore the fragmentation of production and the role of trade in intermediates.

The above examples make a compelling case for the production of trade statistics in value-added terms. There is no doubt that such analysis is highly relevant from a policy perspective. We believe that international organisations should invest resources in the development and improvement of such trade statistics, in cooperation with national statistics offices and research projects. There are several challenges in producing statistics that would fully decompose the value of exports according to the country where it was added,

[6] See WTO and IDE-JETRO (2011) for an illustration with global value chains in East Asia.

but such an exercise could enhance our understanding of trade and all areas where trade matters, starting with growth and jobs creation.

2 HOW TO CALCULATE THE VALUE-ADDED CONTENT OF TRADE?

As emphasised in the previous section, measuring the value-added content of trade requires a global input–output table. Constructing such a table is data-intensive process and presents numerous challenges. In this section, we first describe the work undertaken at the OECD to harmonise single-country input–output (IO) tables and then apply multi-regional input–output model techniques to produce an inter-country input–output database that can be used to estimate trade in value-added terms. The rest of the section discusses techniques to estimate bilateral trade flows of intermediate goods and services and explores how inter-country IO tables and trade statistics can be refined to produce more robust estimates of the value-added content of trade.

2.1 The Construction of Inter-Country Input–Output Tables

The following steps describe how an inter-country input–output table is being built in the OECD. The data sources at OECD are harmonised input–output tables and bilateral trade coefficients in goods and services. The model specification and estimation procedures can be summarised as follows.

(i) Preparation of national IO tables for reference years using the latest published data sources *eg* supply and use tables, national account and trade statistics.

(ii) Preparation of bilateral merchandise data by end-use categories for reference years. The published trade statistics are adjusted for *analytical* purposes (namely, confidential flows, re-exports, exclusion of waste and scrap products and manual adjustment of high-value valuables). Trade coefficients of utility services are estimated based on cross-border energy transfer. Other trade coefficients of service sectors are based on OECD Trade in Services and UN Service Trade statistics. However, many missing flows are filled by econometric model estimates;

(iii) Conversion of cost, insurance and freight (CIF) price-based import figures to free on board (FOB) price-based imports to minimise the inconsistency issues of mirror trade (import = export) in the international IO system.

(iv) Separation of import matrices of each country by *cleaned* trade coefficients.

(v) Total adjustment (missing sectors, trade with rest of the world, *etc*) and minimisation of discrepancy columns using biproportional methods.

Table 2.3: *Country coverage of OECD Input–Output 2009 edition (as of May 2011).*

OECD	Mid-1990s	Early 2000s	Mid-2000s
Australia	1994/95	1998/99	2004/05
Austria	1995	2000	2005
Belgium	1995	2000	2005
Canada	1995	2000	2005
Chile	1996	—	2003
Czech Republic	1995	2000	2005
Denmark	1995	2000	2005
Estonia	1997	2000	2005
Finland	1995	2000	2005
France	1995	2000	2005
Germany	1995	2000	2005
Greece	1995	2000	2005
Hungary	1998	2000	2005
Iceland	—	—	—
Ireland	1998	2000	2005
Israel	1995	—	2004
Italy	1995	2000	2005
Japan	1995	2000	2005
Korea	1995	2000	2005
Luxembourg	1995	2000	2005
Mexico	—	—	2003
Netherlands	1995	2000	2005
New Zealand	1995/96	2002/03	—
Norway	1995	2000	2005
Poland	1995	2000	2005
Portugal	1995	2000	2005
Slovak Republic	1995	2000	2005
Slovenia	—	2000	2005
Spain	1995	2000	2005
Sweden	1995	2000	2005
Switzerland	—	2001	—
Turkey	1996	1998	2002
United Kingdom	1995	2000	2005
USA	1995	2000	2005

Harmonised Input–Output Tables for Reference Years

The OECD has been updating and maintaining harmonised IO tables, splitting intermediate flows into tables of domestic origin and imports, since the mid-1990s, usually following the rhythm of national releases of benchmark IO tables. The process of compiling OECD's IO database greatly depends on cooperation with national statistical institutes. Ideally, national authorities provide the latest supply–use tables and benchmark symmetric input–output tables (SIOTs) at the most detailed level of economic activity possible, with a basic price valuation and, preferably, separating domestically produced and imported intermediate goods and services.

The first edition of the OECD IO Database dates back to 1995 and covered 10 OECD countries with IO tables spanning the period from the early 1970s to the early 1990s. The first updated edition of this database, released in 2002,

Table 2.3: *Continued.*

Non-OECD	Mid-1990s	Early 2000s	Mid-2000s
Argentina	1997	—	—
Brazil	1995	2000	2005
China	1995	2000	2005
Chinese Taipei	1996	2001	2006
India	1993/94	1998/99	2006/07
Indonesia	1995	2000	2005
Romania	—	2000	2005
Russia	1995	2000	—
South Africa	1993	2000	2002
Thailand	—	—	2005
Vietnam	—	2000	—
Malaysia*		2000	
Singapore*	1995	2000	2005

A dash means that the available year data is not available. *Not published (internal use only).

increased the country coverage to 18 OECD countries, plus China and Brazil, and introduced harmonised tables for the mid-1990s. Tables are now available for 46 countries,[7] (33 OECD and 13 non-OECD countries) with tables for the mid-2000s (mainly 2005) now available for most of them (Table 2.3).

The input–output tables show transactions between domestic industries, but as a complement to these tables are supplementary tables that break down total imports by user (industry and category of final demand). Some countries provide these import tables in conjunction with their input–output tables, but in some cases they are derived by the OECD Secretariat in producing input–output tables directly from supply–use tables, which requires the use of assumptions that may have a significant impact on the results of trade in value-added analysis, particularly at the industry level.

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 input–output tables. Improving the way that imports are allocated to users will form a central part of future work of the OECD. This will require a better understanding of how countries estimate their import-flow matrices, and indeed an attempt to motivate better methods of allocation, at the national level, where possible.

The industry classification used in the current version of the IO database is based on ISIC Rev. 3 (Table 2.4), meaning that it is compatible with other industry-based analytical data sets, and in particular with the OECD bilateral trade in goods by industry data set (derived from merchandise trade statistics via the standard Harmonized System to ISIC conversion keys). The system,

[7]For more details, see http://www.oecd.org/sti/input–output.

Table 2.4: *OECD IO industry classification.*

ISIC Rev. 3 code	Description	ISIC Rev. 3 code	Description
01,02&05	Agriculture, hunting, forestry and fishing	40&41	Utility
10–14	Mining and quarrying	45	Construction
15&16	Food products, beverages and tobacco	50–52	Wholesale & retail trade; repairs
17–19	Textiles, textile products, leather and footwear	55	Hotels & restaurants
20	Wood and products of wood and cork	60–63	Transport and storage
21&22	Pulp, paper, paper products, printing and publishing	64	Post & telecommunications
23	Coke, refined petroleum products and nuclear fuel	65–67	Finance & insurance
24	Chemicals	70	Real estate activities
25	Rubber & plastics products	71	Renting of machinery & equipment
26	Other non-metallic mineral products	72	Computer & related activities
27	Basic metals	73	Research & Development
28	Fabricated metal products, except machinery & equipment	74	Other business activities
29	Machinery & equipment, nec	75	Public admin. & defence; compulsory social security
30	Office, accounting & computing machinery	80	Education
31	Electrical machinery & apparatus, nec	85	Health & social work
32	Radio, television & communication equipment	90–93	Other community, social & personal services
33	Medical, precision & optical instruments	95	Private households with employed persons
34	Motor vehicles, trailers & semi-trailers		
35	Other transport equipment		
36&37	Manufacturing nec; recycling (including furniture)		

by necessity (*ie* to maximise inter-country comparability), is relatively aggregated. Differentiating between types of companies within a given sector is, however, essential in order to improve the quality of trade in value-added

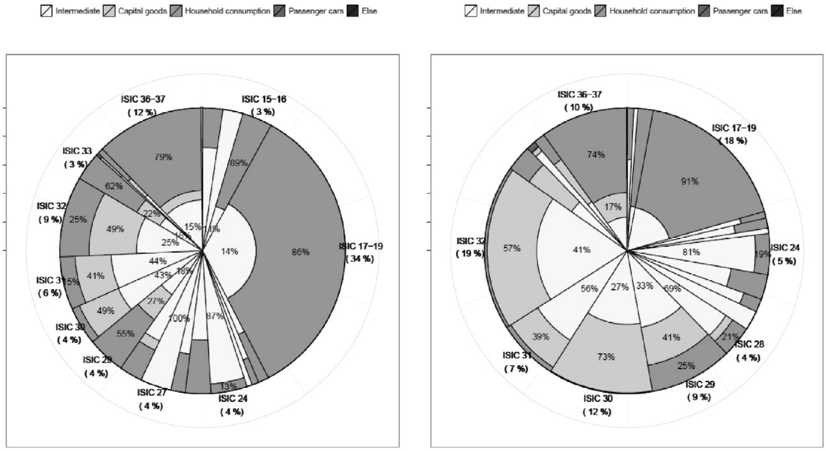

Figure 2.2: *Export share by industry and category: China, 1995 and 2009.*

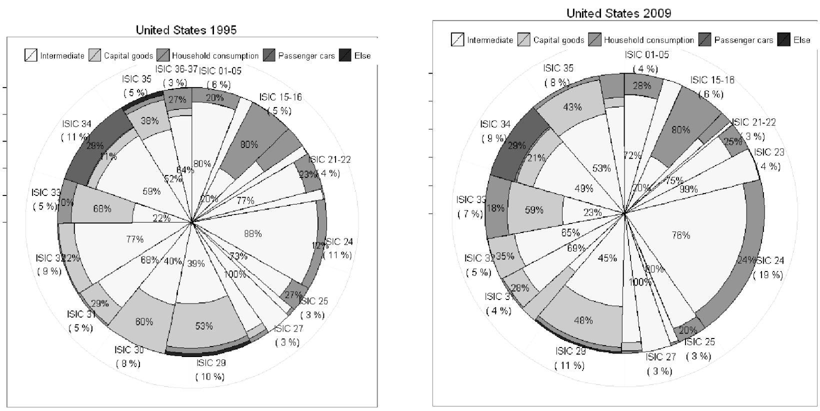

Figure 2.3: *Export share by industry and category: USA, 1995 and 2009.*

results (particularly in the context of exporting and non-exporting companies), and so part of future work will be to explore ways of using microdata that could improve the quality of results (see Ahmad and Araujo 2011).

Measuring Bilateral Trade in Intermediate Inputs

Central to the construction of a global input–output database is the estimation of flows between countries. The OECD has developed a *Bilateral Trade Database by Industry and End-Use Category* (BTDIxE), 1988–2009, 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 (Figure 2.2 for China and Figure 2.3 for USA).

The OECD International Trade by Commodities Statistics (ITCS) database is updated on the basis of annual data submissions received from OECD member countries and, in some cases, from Eurostat. Due to the convergence of OECD ITCS and UNSD Comtrade[8] updating processes, data sharing and other related cooperation between the two organisations, tables can also be computed for non-OECD members as declaring countries, notably the countries which belong to the OECD Enhanced Engagement Programme, namely Brazil, China, India, Indonesia and South Africa.

In ITCS and Comtrade, data are classified by declaring country (*ie* the country supplying the information), by partner country (*ie* origin of imports and destination of exports) and by product (*ie* according to Harmonized System (HS)). In both data sources, trade flows are stored according to the product classification used by the declaring country at the time of data collection. In general, source data are held according to Standard International Trade Classification (SITC) Rev. 2 for the time period 1978–87, the Harmonized System (1988) for 1988–95, HS Rev. 1 (1996) for 1996–2001, HS Rev. 2 (2002) for 2002–2006 and HS Rev. 3 (2007) from 2007 onwards.

To generate estimates of trade in goods by industry and by end-use category, six-digit product codes from each version of HS from ITCS and Comtrade need to be assigned to a unique ISIC Rev. 3 industry and a unique end-use category according to the Broad Economic Categories (BEC) classification, and hence SNA basic classes of goods (see Table 2.5). Thus, eight sets of conversion keys have been estimated using classification correspondence tables, developed internally or available from UNSD.

There are several thorny issues to be considered, including the following.

- Confidential trade: there is currently a different treatment in ITCS and UNSD Comtrade. Standard conversion keys from HS do not account for confidential trade, although if defined at two-digit HS *chapter* level (*eg* the difference between reported two-digit data and sum of six-digit components) it can be allocated to ISIC and BEC codes.
- Re-exports: adjustments are required for re-exports that are significant for major continental trading hubs. Sufficient data are available in order to adjust for reported trade between China and the rest of the world via *Hong Kong*, but not currently for other major hubs such as Belgium, the Netherlands and Singapore, and this will need to be investigated.
- Identifying used/second-hand capital goods: HS codes, and thus reported trade in ITCS and Comtrade, cannot differentiate between new and

[8] See http://unstats.un.org/unsd/comtrade/.

Table 2.5: *Current BEC and SNA classes of goods.*

Classification by Broad Economic Categories	SNA: Use class
1 Food and beverages	
11 Primary	
111 *Mainly* for industry	Intermediate
112 *Mainly* for household consumption	Final Consumption
12 Processed	
121 *Mainly* for industry	Intermediate
122 *Mainly* for household consumption	Final Consumption
2 Industrial supplies not elsewhere specified	
21 Primary	Intermediate
22 Processed	Intermediate
3 Fuels and lubricants	
31 Primary	Intermediate
32 Processed	
321 Motor spirit	*Intermediate/Final Consumption*
322 Other	Intermediate
4 Capital goods (except transport equipment), and parts and accessories thereof	
41 Capital goods (except transport equipment)	Capital
42 Parts and accessories	Intermediate
5 Transport equipment and parts and accessories thereof	
51 Passenger motor cars	*Capital/Final Consumption*
52 Other	
521 Industrial	Capital
522 Non-industrial	Consumption
53 Parts and accessories	Intermediate
6 Consumer goods not elsewhere specified	
61 Durable	Consumption
62 Semi-durable	Consumption
63 Non-durable	Consumption
7 Goods not elsewhere specified	*Not classified*

Source: UNSD, ESA/STAT/AC.124/8, New York, April 2007.

old capital goods (such as second-hand aircraft and ships). Estimating international trade in these flows in a value-added context requires an elaboration of the input–output framework that allows these flows to be recorded in a way that aligns with total global value added produced in a given period.

- Final consumption goods as intermediates: goods identified as consumer goods in the BEC/SNA classes may be used as intermediates in service activities, *eg* pharmaceuticals (medical services) and various foodstuffs (catering services), and it will be important to fine-tune the estimation here using feedback loops with input–output data.
- Unidentified scrap and waste: certain types of waste and scrap do not

have separate six-digit HS codes, *eg* PCs and other electrical equipment exported (often to developing countries) for recycling.

While the development of a database of bilateral trade in intermediate inputs can provide a finer allocation of imports by exporting country to users (intermediate consumption, household final demand, and investment), this is only the first step. Improving the quality of inter-industry trade flows in the global input–output matrix requires further refinements. Two of those considered by the OECD are presented below.

2.2 How Can We Refine the Analysis?

Improving the Quality of the Assumptions Used to Allocate Imports to Users

The Trade by Enterprise Characteristics (TEC) exercise[9] is a joint project of the OECD and Eurostat which disaggregates trade values (imports and exports) according to the characteristics of trading firms. This is achieved by linking customs data and business statistics at the level of the firm and covers virtually the entire population of a country's business and (internationally) trading population. Customs data provide volume and value and HS codes of the products traded at the six-digit level, together with the identification of the business entities involved in the international transaction. This information is then matched with company-level information available in countries' business registers, which contain information on firm size and turnover, activity (industry) and ownership. Linking these two sources of firm-level information allows one to calculate firm-level value added and uncover the characteristics of the firms engaged in value-added creation through exports and/or imports.

Thus, the TEC database provides a unique opportunity to further refine the quality of the import data used in the input–output tables and also to create sub-categories of industry groups that discriminate between export intensive, import intensive, import/export intensive firms and other firms, allowing for a more detailed understanding of international production networks.

One of the challenges in using the TEC database in this way relates to the fact that many exporting and importing companies are classified according to the wholesale sector, even if the wholesaler just reflects the distribution or purchasing arm of a manufacturer. Linking these wholesalers to the manufacturing part of the company therefore will form an important part of the work.

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[9]More information on the TEC exercise can be found in the OECD Statistics Brief No. 16 (2011) and the Eurostat website: http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/International_trade_by_enterprise_%0Acharacteristics. The resulting database, which displays aggregate trade values due to confidential rules, is accessible through the OECD website: http://stats.oecd.org/Index.aspx via the submenu Globalisation/Trade by Enterprise Characteristics.

Constructing Improved Estimates of Bilateral Trade in Services

This is perhaps one of the most challenging statistical issues faced in the construction of a global input–output table, as bilateral raw trade in services data is generally only available for most countries (in a comparable way) at the total services level. Some countries are able to provide breakdowns of trade in services using the Extended Balance of Payments (2002) breakdown (which has recently been revised, EBOPS 2008) but not typically on a bilateral basis.

The EBOPS classification has a very weak correspondence with ISIC industries used in input–output tables. Moreover, when a breakdown is available for EBOPS categories, a large share of trade remains unallocated (on average for OECD countries, disaggregated data total up to 70% of total trade flows). To construct an Estimated Bilateral Trade in Services by Industry database, the OECD is using both econometric estimations (based on gravity modelling) and optimisation techniques to decompose all bilateral trade flows according to the ISIC classification and consistently with imports of intermediate and final services as reported in national accounts. The TEC database also offers considerable potential scope for allocating international trade in services between industries when constructing global input–output tables.

3 CONCLUDING REMARKS: CHALLENGES AHEAD

Estimating trade in value added is clearly of high policy interest and has been the subject of considerable analysis in recent years. There are several projects which aim to produce international input–output tables that can be used to calculate the domestic and foreign content of bilateral trade flows, such as the WIOD project previously mentioned, or the OECD project. There are also existing international IO tables that have been used to analyse trade in value-added terms, in particular the Asian IO tables from IDE-JETRO and the GTAP database. It is therefore important in the future to find some convergence on the way data are collected and estimated, and define best practices for both the data collection and the measurement methods. The identification of 'best practices', a common procedure in official statistics, would greatly reduce the cost of replicating and extending present initiatives.[10] Some of the above-mentioned projects are limited in time, and one concern should be to institutionalise the construction of trade statistics in value-added terms. This is why further cooperation should be encouraged between international organisations, as well as with national statistics offices and other research institutions, in order to complement the work that has already been done and

[10]Some regions, such as Africa and Western Asia, are still absent from a systematic coverage based on official data, despite the fact that they would probably benefit most from a better understanding between vertical trade, trade in tasks and development.

converge to a set of commonly accepted computation methods and imputation techniques that could form, for the time being, the 'best practices' for estimating trade in value added.

Clearly the key challenges in the immediate future concern the quality of trade statistics and the assumptions made to allocate imports to users (industries/consumers). But the challenges do not stop there. There are a number of challenges 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'. But other important changes have been made too, such as the recognition that 'research and development (R&D)' 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.

Moreover, given the considerable advances made in the field, it also seems timely to consider whether the approach could be extended beyond measuring purely trade in value added and consider income flows. In this context there are two important, albeit related, issues that merit consideration. The first reflects payments for the use of intellectual property and the second reflects value added or income generated by foreign-owned firms. Getting some handle on these flows, which are not typically included in general trade statistics but are included in balance of payments statistics, is a logical next step in the work that starts with trade in value added.

Finally, an important question is how the data on trade in value added should be conveyed to policymakers. Out of the construction of a global input–output table, we will have a tool that can be used to measure trade in value-added terms. But, concretely, this tool will be a series of matrices providing coefficients disaggregating trade flows according to the country from which the value added is sourced. While a single figure can summarise exports from country A to country B, switching to value added implies that we need to look at the contribution of all countries to exports from A to B. The challenge, therefore, is to come up with synthetic indicators that can be useful in trade policymaking.

REFERENCES

Ahmad, N., and S. Araujo (2011). Measuring Trade in Value-Added and Income using Firm-Level data. Mimeo.

Ali-Yrkkö, J., P. Rouvinen, T. Seppälä and P. Ylä-Anttila (2011). Who Captures Value in Global Supply Chains? Case Nokia N95 Smartphone, ETLA Discussion Papers 1240, February.

Daudin, G., C. Rifflart and D. Schweisguth (2009). Who Produces for Whom in the World Economy?, Document de travail de l'OFCE 2009-18, July.

Dedrick, J., K. L. Kraemer and G. Linden (2010). Who Profits from Innovation in Global Value Chains?: A Study of the iPod and Notebook PCs'. *Industrial and Corporate Change* **19**(1), 81–116.

Escaith, H. (2008). Nouvelle économie industrielle, commerce international et valeur ajoutée: implications statistiques et comptables, Actes du 12ème colloque de l'Association de comptabilité nationale, INSEE-Méthodes, pp. 225–251. Paris: INSEE.

Escaith, H., N. Lindenberg and S. Miroudot (2010). International Supply Chains and Trade Elasticity in Time of Global Crisis, WTO Staff Working Paper ERSD-2010-08.

Eurostat, IMF, OECD, UNCTAD, UNSD and WTO (2010). *Manual on Statistics of International Trade in Services* (MSITS 2010). Washington DC: United Nations Publications.

Foster, N., R. Stehrer and G. de Vries (2011). Patterns of Net Trade in Value Added and Factors', Paper for the 7th EU-Framework Project 'WIOD: World Input–Output Database: Construction and Applications'.

Johnson, R. C., and G. Noguera (2012). Accounting for Intermediates: Production Sharing and Trade in Value Added. *Journal of International Economics* **86**(2), 224–236.

Jones, R., and H. Kierzkowski (2001). A framework for fragmentation. In *Fragmentation: New Production Patterns in the World Economy* (ed. S. Arndt and H. Kierzkowski), pp. 17–34. New York: Oxford University Press.

Hayakawa, K. (2007). Growth of Intermediate Goods Trade in East Asia. *Pacific Economic Review* **12**(4), 511–523.

Hume, D. (1985). Of the Balance of Trade. In *Essays, Moral, Political and Literary* (ed. E. F. Miller). Indianapolis: Liberty Classics. Original essay published in 1742.

Hummels, D., J. Ishii and K.-M. Yi (2001). The Nature and Growth of Vertical Specialization in World Trade. *Journal of International Economics* **54**(1), 75–96.

Koopman, R., Z. Wang and S.-J. Wei (2008). How Much Chinese Exports Is Really Made in China: Assessing Foreign and Domestic Value Added in Gross Exports. NBER Working Paper 14109.

Koopman, R., W. Powers, Z. Wang and S.-J. Wei (2010). Give Credit to Where Credit is Due: Tracing Value Added in Global Production Chains. NBER Working Paper 16426.

Lanz, R., S. Miroudot and H. Nordås (2011). Trade in Tasks, OECD Trade Policy Working Paper 117. OECD Publishing.

Lee, H. L., V. Padmanabhan and S. Whang (1997). The Bullwhip Effect in Supply Chains. *Sloan Management Review* **38**(3), 93–102.

Leontief, W., and A. Strout (1963). Multiregional Input–Output Analysis. In: *Structural Interdependence and Economic Development* (ed. T. Barna), pp. 119–150. New York: St-Martin's Press.

Linden, G., K. L. Kraemer and J. Dedrick (2009). Who Captures Value in a Global Innovation Network? The Case of Apple's iPod'. *Communications of the ACM* **52**(3), 140–144.

Linden, G., K. L. Kraemer and J. Dedrick (2011). Who Captures Value in the Apple iPad?'. Mimeo, March.

Maurer, A., and C. Degain (2010), Globalization and Trade Flows: What You See Is Not What You Get! World Trade Organization, Staff Working Paper ERSD-2010-12. Economic Research and Statistics Division, Geneva.

Meng, B., N. Yamano and C. Webb (2010). Application of Factor Decomposition Techniques To Vertical Specialisation Measurements, IDE Discussion Paper 276. Institute of Developing Economies.

Miroudot, S., Lanz, R. and A. Ragoussis (2009). Trade in Intermediate Goods and Services. OECD Trade Policy Working Paper 93. OECD Publishing.

Nakano, S., A. Okamura, N. Sakurai, M. Suzuki, T. Tojo and N. Yamano (2009). The Measurement of CO_2 Embodiments in International Trade. Evidence from Harmonised

Input–Output and Bilateral Trade Database. OECD Science, Technology and Industry Working Paper 2009/3.

Parikh, A. (1979). Forecasts of Input–Output Tables Using the RAS Method. *Review of Economics and Statistics* **61**(3), 477–481.

Sanyal, K., and R. Jones (1982). The Theory of Trade in Middle Products. *American Economic Review* **72**(1), 16–31.

Swedish National Board of Trade (2007). 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, Stockholm.

Walmsley, T. L., and C. Lakatos (2008). Regional Input–Output Data. In *Global Trade, Assistance, and Production: The GTAP 7 Data Base* (ed B. G. Narayanan and T. L. Walmsley), Center for Global Trade Analysis, Purdue University.

WTO and Commission des Finances du Sénat (2011). *Actes de la conference 'Mondialisation des chaînes productives industrielles et mesure du commerce en valeur ajoutée'*. Geneva.

WTO and IDE-JETRO (2011). Trade Patterns and Global Value Chains in East Asia. Report. World Trade Organization and Institute of Developing Economies–Japan External Trade Organization, Geneva.

Xing, Y., and N. Detert (2010). How the iPhone Widens the United States Trade Deficit with the People's Republic of China, ADBI Working Paper 257, December.

3

The Importance of Measuring Trade in Value Added

A: Imperatives from International Trade Theory

Gene M. Grossman

1 INTRODUCTION

I have been asked to talk about the importance of measuring trade in value added to international trade theory. To that end, I will briefly review some recent developments in trade theory, with an emphasis (of course) on my own work. I will discuss why the new models have been developed, how they have been constructed, and whether they make a difference to our theoretical conceptualisation of trade. Then I will talk about how these models might be 'tested' or calibrated for use in quantitative exercises. Here, the importance of measuring trade in value-added terms becomes obvious.

2 WHY A NEW THEORY?

The 'old trade theory' associated with the names of Ricardo, Heckscher and Ohlin addressed the determinants of comparative advantage that lead countries to specialise their production in some industries rather than others. The 'new trade theory' of the late 1970s and the 1980s brought a focus on product differentiation and increasing returns to scale, but still the emphasis was on trade in final goods or important intermediates, such as steel and textiles. It was standard to take the industry as the starting point for the analysis (described by a production function for a 'good'), and to treat the object to be traded (automobile, clothing, wine) as technological given. This made sense until the 'second unbundling', to borrow the term coined by Richard E. Baldwin (2006).

Baldwin's first unbundling began centuries ago, but accelerated in the nineteenth century. It was facilitated by technological advances in transportation, which made it possible to separate the production of a good from where it was consumed. Following the industrial revolution and the innovations that it brought, workers became ever more specialised in performing particular tasks in the production of a good. Adam Smith described the British pin factory as a well-known example. The technological mandate for specialisation gave rise to an organisational innovation, namely the industrial 'factory'. Workers came together under one roof to perform their separate tasks and to produce a finished good, be it a final good or an important intermediate. With the improvements in land and sea transport, it became less and less essential that the factory be located close to the ultimate market. The finished goods could be traded across long distances.

But communications at the time were no faster than the transportation. Correspondence was delivered by ship, rail or carriage, much like the finished goods. This made it impractical, if not impossible, to separate geographically the workers involved in producing some good. Production required the coordination of the various tasks. Coordination, in turn, required proximity. If an adjustment had to be made in the efforts of workers performing different tasks, it was not practical to wait a week or a month for the interaction to take place. This remained true, to a lesser extent, even after the telegraph and telephone made rapid communications of certain types possible.

The second unbundling is associated with advances in communication and the IT revolution, and it is still unfolding. With the development of the fax, the email and a common communications protocol, and with high capacity computing power to govern information management, instructions can be delivered [almost] instantaneously, and coordination of production tasks can take place in real time. Workers can perform their tasks in different places, discuss the problems that arise via email or teleconference, make adjustments to product design and distribute new instructions to workers throughout the globe. Now, increasingly, production can be separated from production, just as production was separated from consumption in the first unbundling. Increasingly, international specialisation is no longer at the level of the good or industry, but at ever finer levels, perhaps even the task. Trade theory formerly asked 'Where will a particular be good produced?' Increasingly, it must ask instead 'Where will a particular task be performed?' And, increasingly, the item that is to be traded is itself endogenous; it is possible to perform a greater or smaller number of tasks in a given location, thereby determining the margin at which 'goods' or value added are traded.

3 WHAT NEW THEORY?

A number of authors have developed new models of trade in which the point at which trade takes place is endogenous. These models emphasise a finer division of the production process than was common in earlier trade theory, which incorporated only trade in final goods, or perhaps final goods and a single intermediate. Early examples of the new type of model include Dixit and Grossman (1982) and Feenstra and Hanson (1999). Given the shortness of time, I will mention just a few more recent examples.

Grossman and Rossi-Hansberg (2008) conceptualise the production process as a large number (or continuum) of tasks. Each task must be performed by some factor of production; *ie* there are tasks for unskilled labour, tasks for skilled labour, tasks for capital, etc. Production of a unit of some good requires the performance of all of the tasks that go into its making. Some goods may use tasks performed by skilled labour more intensively, others tasks performed by unskilled labour. So, the model is a lot like the factor-proportions models familiar from neoclassical trade theory, except that the production function for the good has been replaced by a technology specified in terms of tasks. The key assumptions are that

(i) tasks can be performed remotely, so that the production of a good can be internationalised,
(ii) offshoring is costly in the sense that performing a task at a distance requires a greater factor input than if the task is performed nearby, and
(iii) tasks differ in their costs of remote performance.

In this setting, there is ‘trade in tasks’ as well as trade in final goods; in every industry, some tasks are performed locally (near the firm’s headquarters), while others are performed at a distance. The decision of what tasks to perform offshore depends on factor prices in the home and foreign countries and on the communications technology. Improvements in communications reduce the cost of offshoring tasks in all industries and result in a more globalised production process for every good.

Whereas our first paper focuses on globalisation of production among countries at different stages of development—different technologies, different factor endowments and different factor prices—our second examines task trade between similar countries (see Grossman and Rossi-Hansberg 2012). Why might countries divide the value added chain if they share similar technologies and similar relative factor endowments? The answer we give is economies of scale. A country may become especially proficient at particular tasks that are performed there often. We study a model in which economies of scale at the task level are the only reason for offshoring, and show how country size interacts with costs of offshoring to determine the international pattern of specialisation.

In a recent paper, Baldwin and Venables (2010) distinguish two types of production processes that affect the economics of fragmentation and globalisation in the presence of shipping costs. If the engineering of a product dictates a ‘spider’ production process, multiple ‘limbs’ (parts) can be produced separately and then brought together to form a ‘body’ (assembly). If the product requires a ‘snake’ production process, the good moves in a linear fashion from upstream to downstream, with value added at each stage. Baldwin and Venables show how offshoring costs bind related stages (or tasks) together in the face of international factor price differences. They examine a stylised model of the spider and the snake to show how the forces that shape the location of different parts of the value chain differ in the alternative configurations of production.

Costinot *et al* (forthcoming) provide an elegant model of what Baldwin and Venables term the snake. In their model, goods move from stage to stage with more value added at each one. At each stage of production, some fraction of output is lost due to production 'errors'. Countries differ only in their proclivities to error, perhaps reflecting the quality of their legal and other institutions. Costinot *et al* use the model to describe the equilibrium organisation of the value chain and the spillover effects of changes in production technologies (error rates) in some country.

Yet another recent trade theoretic paper that addresses the global fragmentation of production is Garetto (forthcoming). She adopts an Eaton–Kortum framework to capture heterogeneity in the ability to produce intermediate inputs. Firms choose whether to outsource each of the many intermediate goods that are needed to produce a final good or to produce the input themselves, and whether to source a good locally or from some foreign country. Organisational choices are governed by the trade-off between mark-up pricing for outsourced parts and the use of a possibly inferior in-house technology, and by the distribution of technologies and factor prices around the globe. Garetto examines the pattern of outsourcing that results and the implications of this globalised production for the gains from trade.

The common feature of this recent trade theory is its emphasis on the determination of the location of value added in a multi-stage or multi-task global production process. The theory addresses traditional questions, like 'where does production take place?' and 'what effect does trade have on factor prices and the distribution of income?', but the realities of world trade have shifted attention from the industry as the subject of analysis to a much finer level of economic activity.

4 DOES IT MATTER?

The new theory focuses on the realities of modern-day global value chains. Does this theory lend any new insights? After all, as Mankiw and Swagel (2006) famously noted,

> [s]ervices offshoring … fits comfortably within the intellectual framework of comparative advantage built on the insights of Adam Smith and David Ricardo.

Surely, the theory suggests a new set of factors that affects the location of economic activity. Grossman and Rossi-Hansberg (2008) emphasise the ease or difficulty with which a task can be performed at a distance, citing Blinder (2006), Autor *et al* (2003) and Leamer and Storper (2001) for discussion of services that must be delivered personally or can be delivered electronically, tasks that are more or less 'routine' and instructions that are 'codifiable' or not. Baldwin and Venables focus on the complementarity between tasks, some of which must be co-located for efficiency, while others can more readily be separated. Grossman and Rossi-Hansberg (2012) argue that tasks that are more costly to offshore may locate in larger countries, while Costinot *et al* (forthcoming) identify a force that drives downstream tasks to the more productive economies. All of these hypotheses about the location of activity are relatively new to trade theory, as these issues do not arise when a complete production process must be carried out in one place.

Perhaps more interesting are the possible implications for the gains from trade. Mankiw and Swagel (2006) conjecture that

> it is obvious to economists that outsourcing simply represents a new form of international trade, which as usual creates winners and losers but involves gains to overall productivity and incomes.

But Grossman and Rossi-Hansberg (2008) point to a 'productivity effect' from offshoring that can mitigate the distributional conflicts from trade. Whereas trade in final goods inevitably creates winners and losers in a world with factor-endowments à la Stolper and Samuelson, Grossman and Rossi-Hansberg show that, in a similar environment, offshoring possibly can generate benefits for all. If domestic factors readily can move from performing tasks that are easy to offshore to other tasks that cannot so readily be performed at a distance, then improvements in communication technologies that facilitate greater offshoring generate aggregate productivity gains that are shared by domestic workers. This feature of task trade makes it different from goods trade in an important respect.

The new theory also suggests some subtle forces that might influence national policy. In the face of learning externalities, a country might wish to focus more on tasks and occupations, and less on industries, than has been true in the past. Education policy that targets human capital development perhaps should take into account the ease of offshoring of the tasks that would be performed by workers with certain skills. In general, trade and industrial policy should be focused less on the industry and more on occupations and tasks.

5 HOW CAN WE TEST AND CALIBRATE?

Some predictions of the new theories have been tested using labour market data. For example, Harrison and McMillan (2011), Ebenstein *et al* (2011) and Change OK?
Hummels *et al* (2011) have examined the distributional effects of offshoring

and have investigated whether there might be a 'productivity effect' of the sort suggested by Grossman and Rossi-Hansberg. But efforts to test the new theories, and to investigate their quantitative implications, have been hampered by the lack of appropriate trade data, as we argued in our 2008 paper.

As the papers presented at this workshop[1] make abundantly clear, trade data based on gross flows is increasingly inadequate as a basis for understanding modern trade. The existence of task trade and global supply chains implies that contributions to the value of a final good come from many places. In order to understand the forces that shape the allocation of activity and also the effects of international specialisation on prices, incomes *etc*, it is critical that we know where production is taking place. But, as national income accountants have known for decade, economic activity is best measured by value added not gross output. Who contributed to the production of a Toyota car or an Boeing jet? What part of the value chain was performed in each country? What was the pattern of task trade? It is simply impossible to know the answers to these questions with information about how many finished cars crossed international borders, or how many sales Boeing made to airlines outside the USA.

Take, for example, the hunt for a productivity effect of offshoring. The theory suggests a link between the pattern and extent of task trade and domestic factor rewards. Researchers investigating this link have been forced to rely on proxies for the amount and sources of foreign value added. Often approximations are used, such as the well known 'proportionality assumption'. Global trade data on a value-added basis would obviate the need for proxies and approximations. Before the second unbundling, gross trade flows accurately measured much of world trade, because goods were predominantly produced in one place. Today, that is no longer true, and the gross flows mask the patterns of specialisation that we need to understand. In short, as Grossman and Rossi-Hansberg concluded in 2008,

> the globalisation of production processes mandates a new approach to trade data collection, one that records international transactions, much like domestic transactions have been recorded for many years.

REFERENCES

Autor, D., F. Levy, and R. Murnane (2003). The Skill Content of Recent Technological Change: An Empirical Exploration. *Quarterly Journal of Economics* **118**(4), 1279–1334.

Baldwin, R. E. (2006). Globalisation: The Great Unbundling(s). In *Globalisation Challenges for Europe*. Helsinki: Office of the Prime Minister of Finland.

[1] The World Bank Workshop on Fragmentation of Global Production and Trade in Value Added.

Baldwin, R. E., and A. Venables (2010). Relocating the Value Chain: Offshoring and Agglomeration in the World Economy, NBER Working Paper 16111.

Blinder, A. S. (2006). Offshoring: The Next Industrial Revolution? *Foreign Affairs* **85**(2), 113–128.

Costinot, A., J. Vogel and S. Wang (forthcoming). An Elementary Theory of Global Supply Chains. *Review of Economic Studies*.

Dixit, A. K., and G. M. Grossman (1982). Trade and Protection with Multistage Production. *Review of Economic Studies* **49**(4), 583–594.

Ebenstin, A., A. Harrison, M. McMillan and S. Phillips (2009). Estimating the Impact of Trade and Offshoring on American Workers Using the Current Population Surveys. NBER Working Paper 15107.

Feenstra, R. C., and G. H. Hanson (1999). The Impact of Outsourcing and High-Technology Capital on Wages: Estimates for the United States. *Quarterly Journal of Economics* **114**(3), 907–941.

Garetto, S. (forthcoming). Input Sourcing and Multinational Production. *American Economic Journal: Macroeconomics*.

Grossman, G. M., and E. Rossi-Hansberg (2008). Trading Tasks: A Simple Theory of Offshoring. *American Economic Review* **98**(5), 1978–1997.

Grossman, G. M., and E. Rossi-Hansberg (2012). Task Trade Between Similar Countries. *Econometrica* **80**(2), 593–629.

Harrison, A., and M. McMillan (2011). Offshoring Jobs? Multinationals and US Manufacturing Employment. *The Review of Economics and Statistics* **93**(3), 857–875.

Hummels, D., R. Jorgenson, J. Munch and X. Chong (2010). The Wage Effects of Outsourcing: Evidence from Danish Matched Worker–Firm Data. NBER Working Paper 17496.

Leamer, E. E., and M. Storper (2001). The Economic Geography of the Internet Age. *Journal of International Business Studies* **32**(4), 641–665.

Mankiw, G., and P. Swagel (2006). The Politics and Economics of Offshore Outsourcing. *Journal of Monetary Economics* **53**(5), 1027–1056.

B: Why Measuring Value-Added Trade Matters for Developing Countries

Judith M. Dean

> By allowing each country that is a member of the supply chain to specialize in the part or component in which it has a comparative advantage, the internationalisation of supply chains creates enormous economic benefits.
>
> Lamy (2010)

In the new millennium, trade economists have argued that the international fragmentation of production should bring significant benefits to developing countries. Unlike intra-industry trade,which is driven by similar incomes and preferences, the fragmentation of production internationally depends upon differences in comparative advantage. The more production can be split globally, and tasks dispersed based on comparative advantage, the more lower-income countries might be able to participate in these chains (Jones *et al* 2005; Arndt and Kierzkowski 2001). Thus, international production fragmentation should encourage trade between industrial and developing countries. The gains from trade should expand for all countries, since stages of production are allocated more efficiently. In addition, developing countries should now be able to expand their activities to include tasks within the production of high-tech or skill-intensive products, instead of waiting until they can efficiently produce the complete product.

Have developing countries received some of the economic benefits from global supply chains? Value-added (VA) trade measures can help us answer this question. We know that the gains from trade (gains from specialisation, exchange, variety, *etc*) cannot be measured directly by the value added in a country's exports. But VA trade measures can contribute greatly to our understanding of global supply-chain trade. In particular, they can help us answer four key questions.

First, do developing countries actually participate in these supply chains? There is some evidence of global production networks in East Asia, and some recent evidence on China's growing role in those chains. But data on participation of other developing countries is still scarce.

Second, even if they do participate, what role do firms in developing countries play in these chains? The oft-cited work of Linden *et al* (2009) analysing the iPod supply chain suggests that China is involved in assembly activities that generate only a tiny part of the value added in the product. Recently, Chinese researchers presented evidence that China was nearly always at the 'end of the value chain', engaged in low-skilled labour-intensive activities in high-tech industries, such as pharmaceuticals and electronics (USITC 2011). Does this mean that China and other developing countries benefit little from global supply-chain trade?

Third, will developing country participation in supply chains generate protectionist sentiment in industrial countries? The fears that China was now competing in high-tech exports with the OECD (*The Economist* 2007) suggest that the benefits of supply-chain trade might be choked off by new trade barriers.

Fourth, will the supply-chain trade come at the cost of the environment? After all, China's rapid growth in supply-chain trade appears to have occurred concurrently with ever-worsening environmental degradation. Even if developing countries do participate and benefit from global supply chains, might protectionism and environmental damage reduce or eliminate benefits in the longer run? Answering these questions about global supply-chain trade requires detail on the structure and nature of these chains. VA trade measures can potentially provide that detail. This chapter explores some of the recent evidence we have on developing country participation and position in global supply chains, and then discusses how VA trade measures could advance that discussion greatly. The chapter then examines how global supply-chain trade may help explain China's 'export similarity' to the OECD, and discusses how more data on VA trade could not only help avoid protectionist responses, but promote more open markets. Finally, the chapter explores some recent evidence that supply-chain trade may have a beneficial impact on the environment in developing countries, and discusses how VA trade data could contribute to that debate.

1 ARE DEVELOPING COUNTRIES PARTICIPATING IN GLOBAL SUPPLY CHAINS?

Until recently, evidence on developing country participation in global production networks has been scarce. A few studies have measured the importance of trade in parts and components in global, East Asian and Chinese trade, or China's growing prominence in such trade. Jones *et al* (2005) found that world trade in parts and components grew by about 9% per year from 1990 to 2000, outstripping total world trade growth of 6.5% per year. Ng and Yeats (2003) found evidence of a strong network of Asian suppliers in the parts and components trade. Estimates for 1984–96 showed that Asian global exports of parts and components grew by more than 500%, compared with Asian total export growth of 300%. Using a similar approach, Athukorala (2009) and Athukorala and Yamashita (2006) found that the East Asian share of global exports of parts and components grew from 29.3% in 1992 to 39.2% in 2003. In fact, the share of components in East Asian intra-regional trade was far higher than its share in extra-regional trade.

While this evidence is suggestive of Asian participation in supply-chain trade, it does not reveal which countries participate in which global chains, nor how tasks within a specific production supply chain are split up across countries. The pioneering study by Hummels *et al* (2001) took a step closer to accomplishing this. These authors combined input–output tables with trade data to measure vertical specialisation (VS), or foreign content, in a number of countries' exports. A high VS share indicates that imported intermediate goods make up a large proportion of the value of a country's exports, potentially indicating a country's greater degree of involvement in global production chains. Hummels *et al* measured not only the imported inputs used directly in producing an export, but also the indirect use of imported inputs in domestic intermediate goods used to produce that export. Their evidence showed that the foreign content of OECD exports grew significantly between the 1970s and 1990s. But their analysis focused mostly on industrial countries.

According to Chinese Official Customs data, about half of China's remarkable trade growth between 1995 and 2008 is attributable to Chinese processing trade–imports of intermediates that are further processed solely for

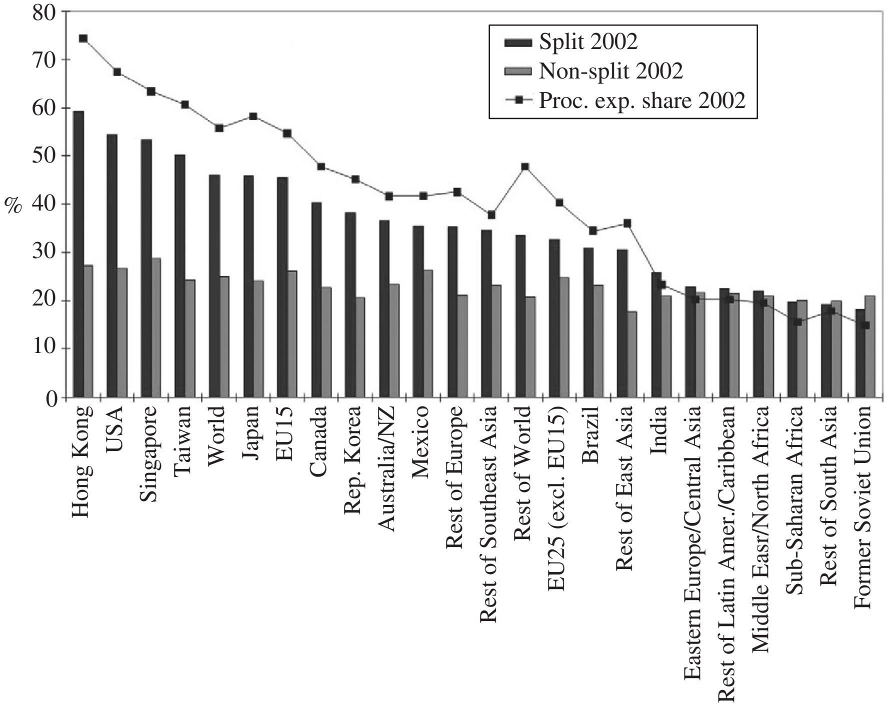

Figure 3.1: *Foreign content share (%) of Chinese exports, 2002.*
Source: Dean *et al* (2011).

export. Dean *et al* (2011) thus focused on measuring the VS share in Chinese exports, building on Hummels *et al*. They developed an improved method of identifying intermediates using both Chinese processing trade data and the UN Broad Economic Classification. Using this method, they found evidence of an extensive Asian network of input suppliers to China. In 2002, for example, Japan and the Tigers[1] accounted for half of China's total imported intermediates, with an additional 10% from other East and Southeast Asian countries. A similar pattern emerged for processing intermediate imports, with nearly 80% of imported intermediates coming from this Asian network.[2]

Dean *et al* then used the official Chinese input–output table, and also a split Chinese input–output table developed by Koopman *et al* (2008) to calculate VS shares for Chinese exports by destination and by industry. The split table allows for the relatively high imported intermediate intensity of processing

[1]Hong Kong, Singapore, South Korea and Chinese Taipei.

[2]Dean *et al* (2009) describe in more detail the types of imported intermediates sourced from different supplier countries.

exports compared with normal exports or domestic sales. As Figure 3.1 shows, using either the official or the split IO tables, China's exports to industrial countries were found to have high foreign content, in contrast to its exports to developing countries.

Together these findings suggest a picture of global supply chains in which intermediates are produced in Japan and the Four Tigers, then exported to China for processing, and ultimately exported by China to the USA and Europe. They also provide some evidence that supply-chain trade may indeed be larger between industrial and developing countries. But these VS measures only begin to tell us broadly about one part of the global supply chain for one country.

VA trade measures can add much detail to this picture. Measuring VA trade in a specific product or industry could show which countries are participating in the production process and the stage at which they enter into the process. The structure of different industry chains could be traced more clearly, from the innovation stages of a product to its completion. This would allow a clearer view of the interdependence between specific industrial and developing countries. Data over time could reveal when specific countries first become part of a specific global chain. Although VA trade does not measure the gains from trade, it could provide some indication of whether, and to what extent, developing countries are able to participate in the new trade opportunities that international fragmentation offers.

More disaggregated VA trade data might also allow analysis of the role of global chains in promoting indirect exports from developing countries. It is often argued that small- and medium-scale enterprises (SMEs) in developing countries are not able to obtain financing for exporting directly, or to surmount other informational obstacles to participate in global markets. However, global supply chains might help promote SME participation in exporting, by opening up opportunities to contract as suppliers to global chains. SMEs could then participate in global trade indirectly, and allow the lead firms in the supply chain to handle the management, information and financing issues (OECD 2008).

2 WHAT ROLE DO DEVELOPING COUNTRIES PLAY IN GLOBAL SUPPLY CHAINS?

What determines the position of a country within a supply chain? How can China and other developing countries 'move up' within a global supply chain? Trade theory would suggest that differences in comparative advantage should explain the allocation of tasks across countries. Thus, changing factor endowments should play a key role in any shift in a country's firms to different activities within a supply chain.

Research by Antras (2005), Feenstra and Hanson (2005) and others suggests that improved property rights and better quality control may also help developing countries move up the supply chain.[3] When a product embodies extensive research and development (R&D) or intellectual property, and is new, firms may be less likely to offshore tasks, or to offshore them only through affiliates. This is due to the risk that intermediate goods may not be made to exact specification if contracted to independent firms, and/or that contracts and property rights may not be enforced. Once a product is more standardised, firms are both more likely to offshore tasks, and more likely to do so using independent contracts.

Positive spillovers from participation in supply chains might also help developing countries move up the chain. Firms initially performing the least skilled tasks may learn through interaction with other firms in the chain, and be able to move to higher value activities. Indian software firms in the 1990s, for example, were largely in the middle to lower end of the software development chain, engaged in contract programming, coding and testing (Lateef 1997). Yet now some Indian firms engage in business and technology consulting, systems integration, product engineering, custom software development and other more skill-intensive activities.[4]

The vertical specialisation data from Dean *et al* (2011) offer some support for the role of comparative advantage. Their VS share data show wide variation in foreign content across industries. With the split input–output table, for example, foreign content estimates for 2002 Chinese exports were over 90% for computers and telecommunications equipment, suggesting that China was at the end of the value chain in IT-related sectors. In contrast, foreign content in Chinese metal products, general industrial machinery and paper (more capital-intensive sectors) was about 40–50%, and in textile production (a relatively labour-intensive sector) was only about 25%.

Recent work by Dean and Fung (2009) offers some evidence on whether variation in vertical specialisation across China's industries can be explained by R&D intensity. Using the Dean *et al* VS measures and a two-step estimation process, they analyse the amount of processing trade in a sector and the foreign content of that processing trade. Results show a strong negative correlation between R&D intensity and the share of Chinese processing exports in an industry's exports. Given the level of processing exports, Dean and Fung find that R&D-intensive industries have relatively high foreign content in their processing exports. They also find that the possibility of producing via a *foreign affiliate* increases the share of processing exports, even for relatively R&D-intensive industries. Together these results show some support for the idea that R&D intensive industries are more likely to retain control over most stages of the production chain, by either producing most of them domestically or producing them via a foreign affiliate.

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[3]For a survey of the literature, see Spencer (2005).

[4]One example would be InfoSys, http://www.infosys.com/about/what-we-do/Pages/index.aspx.

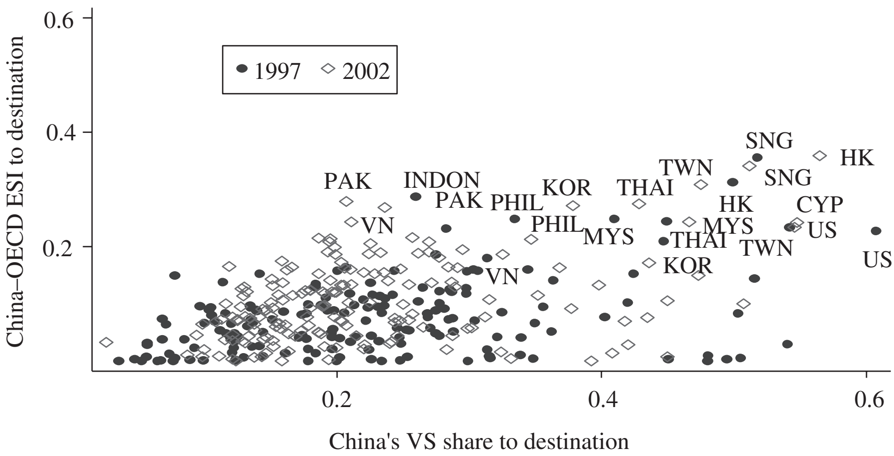

Figure 3.2: *Export similarity and vertical specialisation, 1997 and 2002.*
Source: Dean *et al* (2011). ESI, Export Similarity Index.

Once again, measuring VA trade at the country–industry level could provide a much more comprehensive assessment of roles within production chains. These measures could help reveal which countries' firms are engaged in which stages or tasks within a production chain. Over time, these data could help trace out changes in specialisation within a chain, or entrance into new supply chains. This might help us see whether developing countries are moving to higher value activities within specific global supply chains, and if so which ones. Such data could allow tests for the role of factor accumulation, property rights improvements and spillovers in explaining the position of developing countries at a point in time, and changes in their position over time.

3 HAS DEVELOPING COUNTRY PARTICIPATION IN SUPPLY CHAINS TRIGGERED PROTECTIONISM?

During the last decade, international controversy and protectionist sentiment arose in response to the perception that China was suddenly competing directly with the USA and other industrial countries in high-tech, sophisticated exports. Provocative research by Rodrik (2006) and Schott (2008) suggested that the bundle of goods exported by China to the USA closely resembled the export bundles of higher income, OECD countries and not developing countries at similar income levels. One interpretation of these results was that China has somehow leapfrogged over its traditional comparative advantage.

A closer look suggests that international production fragmentation is a key factor in understanding this dramatic increase in the 'sophistication' of Chinese exports to the USA. The study by Dean, *et al* (2011) found that Chinese exports to richer countries had a higher foreign content than Chinese exports to poorer countries. In addition, they found that a large share of Chinese imported inputs were sourced from Japan, with additional smaller shares sourced from the EU and the USA. Thus, Chinese exports to the USA might resemble those of other OECD countries because much of their value originated in the OECD. Examining exports to nearly 200 destinations in 1997 and 2002, Dean *et al* found that Chinese and OECD exports differed dramatically *across* destinations. Where Chinese exports were similar to those of the OECD, they had high foreign content (Figure 3.2). This suggested that 'sophistication' arose from being part of a global supply chain. Econometric testing revealed that a higher share of foreign content in Chinese exports had a significant, positive impact on the similarity between Chinese and OECD exports.

VA trade measures could help generate light instead of heat regarding global competition. With detailed data by sector, one could trace the sources of intermediates and semi-finished goods imported into a developing country like China. This would allow an assessment of how much domestic content is actually reimported by industrial countries in the form of finished goods from developing countries operating at the final stage in a production chain. The pattern of VA exports and imports would reveal much more about comparative advantage differences. Thus, some of what looks like export similarity in the gross export data would be revealed as differences in specialisation across tasks within a production chain.

VA trade measures would also make more clear the interconnectedness of global production, and the importance of firms in each country in the supply chain. By providing information on these kinds of interdependence, VA trade data might encourage more open trade policy and more international effort towards trade facilitation.

4 WILL GROWTH IN SUPPLY-CHAIN TRADE BE HARMFUL TO THE ENVIRONMENT?

China's enormous trade and income growth since the mid-1990s has been concurrent with severe and growing environmental problems. One notable article described China as 'choking on growth' (Kahn and Yardley 2007). While major improvements have been made in pollution regulation during this time (OECD 2005), and some progress has been made in achieving cleaner water and air, '[r]elative shortage of resources, a fragile ecological environment and insufficient environmental capacity [have become] critical problems hindering China's development' (Ministry of Environmental Protection 2006). Thus, it is no surprise that China's experience has fuelled the popular view that trade growth is harmful to the environment (Gardner 2008).

Yet recent work by Dean and Lovely (2010) argues that global supply-chain trade may have had beneficial effects on China's environment. A close look

Table 3.1: *Export shares, processing trade and pollution intensity by Chinese industrial sector, 2006.*

ISIC Rev. 3 Two Digit Sector		Share of total mfg exports	Proc. exports (% of sector exports)	COD*	SO_2^*	Smoke*	Dust*
Top 5 manufacturing industries by export shares	Communications equipment	16.95	83.55	0.03	0.02	0.01	0.01
	Office and computing machinery	14.69	95.94	0.03	0.02	0.01	0.01
	Textiles	8.06	20.28	0.53	0.50	0.21	0.01
	Wearing apparel	7.83	24.76	0.25	0.27	0.13	0.01
	Machinery	7.22	32.56	0.04	0.07	0.05	0.03
Top 5 manufacturing industries by pollution intensities	Non-metallic minerals	1.79	10.88	0.12	3.79	2.49	10.30
	Paper	0.53	56.82	5.34	1.47	0.72	0.04
	Food products and beverages	2.26	24.12	1.09	0.41	0.33	0.02
	Wood	1.07	17.72	0.44	0.95	0.76	0.32
	Basic metals	4.83	13.87	0.08	0.85	0.33	0.48

*kilograms per thousand yuan output (1995 yuan values). COD, chemical oxygen demand.
Source: derived from Dean and Lovely (2010), and updated by the authors.

at the data reveals that Chinese industries with the largest share of manufacturing exports are not highly polluting. Meanwhile, those industries that are highly polluting account for relatively small shares of Chinese exports (Table 3.1). In fact, Chinese exports have been shifting over time towards highly fragmented sectors (office and computing machinery and communications equipment) and away from traditional exports that are less fragmented. Dean and Lovely find strong support for the fact that sectors heavily involved in processing exports are less polluting than those involved in ordinary exports.

Dean and Lovely argue that the growth of processing trade could be beneficial for China's environment in two ways. First, China has the opportunity to shift some resources into tasks within these relatively clean, relatively high-tech industries, and out of relatively dirtier industries. Second, as foreign investment grows within these fragmented industries, the costs of carrying out tasks within China should fall. This should expand the ranges of tasks undertaken in China. If the relatively dirtier tasks were originally done there, this expansion would bring in relatively cleaner tasks, lowering the average pollution intensity of Chinese activities within the fragmented industry. In addition, if the foreign-invested enterprises responsible for most of this trade bring greener technologies than those used by domestic producers, this will tend to make trade even cleaner. Dean and Lovely's econometric analysis suggests that the amount of Chinese involvement in global supply-chain trade—proxied by the extent of processing exports—has played a key role in explaining the drop in the pollution intensity of Chinese exports over time. They find foreign direct investment inflows have contributed significantly to this decline, both indirectly through expanding processing exports and directly, presumably through cleaner technologies.

More detailed analysis of these hypotheses at the industry level is hampered by the lack of good data on the actual range of activities or tasks done in China within an industry, and a measure of how that range of tasks expands. In the absence of these data, proxies such as the extent of processing exports are used. But this proxy captures neither foreign content relative to domestic content nor information on the position of the country's firms within the production chain. VA trade flows could begin to fill this gap, by more clearly showing the foreign content of imported intermediates and the value added in a developing country's exports within an industry or a product. Tracing this over time would provide a better proxy of changes in the range of activities/tasks undertaken, and allow a more direct assessment of changes in average pollution intensity of those tasks.

5 CONCLUSION

Developing countries have the potential for large benefits from the international fragmentation of production. Participation in global supply chains opens up opportunities for diversification of productive activities into goods which would normally be outside a country's comparative advantage. The ability to produce stages or tasks within these production chains expands the scope of a country's comparative advantage, widening the gains from specialisation. Participation may also generate spillovers, through interaction with other members of the production chain or through learning by doing, that raise productivity. Increasing involvement in global supply chains may also mean two new channels through which trade might benefit the environment: shifting the composition of production and exports towards the cleaner, fragmented industries; taking on cleaner tasks within an industry over time.

VA trade measures do not directly capture the gains to developing countries from global supply-chain trade. But they can increase our ability to measure how much developing countries are participating in these chains, what tasks they undertake and how those tasks change over time. By tracing out the changing trade patterns between industrial and developing countries, and underscoring the interdependence of firms, they can also help to promote more open markets and better trade facilitation. Finally, by providing better measures of the range of activities carried out in specific countries, they can help in testing the potential environmental benefits of supply-chain trade.

REFERENCES

Antras, P. (2005). Incomplete Contracts and the Product Cycle. *American Economic Review* **95**, 1054–1073.

Arndt, S., and H. Kierzkowski (eds) (2001). *Fragmentation*. Oxford: Oxford University Press.

Athukorala, P. (2009). The Rise of China and East Asian Export Performance: Is the Crowding-Out Fear Warranted? *The World Economy* **32**, 234-266.

Athukorala, P., and N. Yamashita (2006). Production Fragmentation and Trade Integration: East Asia in a Global Context. *North American Journal of Economics and Finance* **17**, 233–256.

Dean, J. M., and K. C. Fung (2009). Explaining China's Position in the Global Supply Chain, Joint Symposium on US–China Advanced Technology Trade and Industrial Development, 23–24 October 2009, Tsinghua University. Manuscript.

Dean, J. M., and M. E. Lovely (2010). Trade Growth, Production Fragmentation, and China's Environment, in *China's Growing Role in World Trade* (ed. R. Feenstra and S. Wei). Chicago: NBER and University of Chicago Press.

Dean, J. M., M. E. Lovely and J. Mora (2009). Decomposing China–Japan–US Trade: Vertical Specialization, Ownership, and Organizational Form. *Journal of Asian Economics* **20**, 596–610.

Dean, J. M., K. C. Fung and Z. Wang (2011). Measuring Vertical Specialization: The Case of China. *Review of International Economics* **19**, 609–625.

The Economist (2007). Leapfrogging or Piggybacking? The Economies of India and China Are Not As Sophisticated as They Appear. 8 November. URL: http://www.economist.com/node/10053145.

Feenstra, R., and G. Hanson (2005). Ownership and Control in Outsourcing to China: Estimating the Property-Rights Theory of the Firm. *Quarterly Journal of Economics* **120**(2), 729–761.

Gardner, T. (2008). Rich World Behind Much of Global Pollution. Reuters, 21 October. URL: http://www.reuters.com/article/2008/10/21/us-pollution-global-rich-idUSTRE49K9BB20081021.

Hummels, D., J. Ishii and K.-M. Yi (2001). The Nature and Growth of Vertical Specialization in World Trade. *Journal of International Economics* **54**, 75–96.

Jones, R. W., H. Kierzkowski and C. Lurong (2005). What Does Evidence Tell Us about Fragmentation and Outsourcing? *International Review of Economics and Finance* **14**, 305–316.

Kahn, J., and J. Yardley (2007). Choking on Growth, Part I. *New York Times*, 26 August. URL: http://www.nytimes.com/2007/08/26/world/asia/26china.html.

Koopman, R., Z. Wang and S.-J. Wei (2008). How Much of Chinese Exports Is Really Made in China? Assessing the Domestic Value-Added When Processing Trade is Pervasive", NBER Working Paper 14109.

Lateef, A. (1997). Linking Up With The Global Economy: A Case Study of the Bangalore Software Industry. New Industrial Organization Programme, ILO Discussion Paper 96/1997.

Linden, G., K. Kraemer and J. Dedrick (2009). Who Captures Value in a Global Innovation Network? The Case of Apple's iPod. *Communications of the ACM* **52** 140–144.

Ministry of Environmental Protection, 2006. *Environmental Protection in China 1996–2005*. Information Office of the State Council, Beijing, People's Republic of China. URL: http://www.china.org.cn/english/MATERIAL/170257.htm.

Ng, F., and A. Yeats (2003). Major Trade Trends in East Asia: What Are Their Implications for Regional Cooperation and Growth? World Bank, Policy Research Working Paper 3084.

OECD (2005). *Governance in China*. Paris: OECD Publishing.

OECD (2008). *Enhancing the Role of SMEs in Global Value Chains*. Paris: OECD Publishing.

Rodrik, D. (2006). What's So Special about China's Exports? *China and the World Economy* **14**, 1–19.

Schott, P. (2008). The Relative Sophistication of Chinese Exports. *Economic Policy* **53**, 5–40.

Spencer, B. (2005). International Outsourcing and Incomplete Contracts. *Canadian Journal of Economics* **38**, 1107–1135.

USITC (2011). Proceedings of the Joint Symposium on US–China Advanced Technology Trade and Industrial Development. *Journal of International Commerce and Economics* **3**, 1–239.

C: Implications for Macroeconomic Policy

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1 WHY IMPROVING VALUE-ADDED TRADE MEASUREMENT IS IMPORTANT

Using accurate value-added trade data would improve exchange rate assessments. Real effective exchange rates based on value-added trade weights would reveal more accurate measures of competitiveness of a country than those based on gross trade weights. Switching to value-added trade weights could have potentially important implications; for example, some exchange rates that might be considered 'misaligned' using gross trade weights may no longer be so using value-added trade weights (or vice versa).

Real effective exchange rates based on value-added trade would improve our estimates of the impact of changes in relative prices, including that on global rebalancing. For instance, the International Monetary Fund (2011) finds that a downstream (as opposed to upstream) position in a supply chain cushions the impact of relative price changes on both exports and imports. This reflects the higher foreign content in the downstream country's exports, which mitigates the impact of exchange rate changes (more detail is given below).

Decomposing foreign value added (FVA) in exports by source country would help us understand how disruptions to supply chains can have spillover effects. Disruptions of trade flows could be either policy induced, such as preferential/regional trade agreements, or naturally caused, such as the recent earthquake in Japan. In either case, being able to track FVA by source would help us to understand the impact of disruptions in supply chains. Disruption of imports from a trading partner (*eg* Japan) does not necessarily mean that gross exports of a country (*eg* China) will fall by the share of that trading partner's value added in the country's exports (*eg* by Japan's value-added share in China's gross exports). The extent of the impact would depend on the nature of the shock and the availability of substitutes. Hence, the analysis needs to be supplemented by more disaggregated and higher frequency data than input–output data. Nevertheless, using value-added trade data would be a good starting point.

Bilateral balances, if discussed for political economy considerations, are better measured with value-added, rather than gross, trade data. For example, the US trade balance with China has received a lot of attention in recent years. Indeed, the US bilateral trade deficit with China accounts for a large fraction of the overall US trade deficit: about 35% (Table 3.2). Many countries, however, export intermediate goods to China that are then processed and exported as goods to the USA (similarly, US exports contain FVA from China and other countries). Excluding FVA contained in exports to and from China reduces the size of US bilateral trade deficit to close to 20% of overall deficit.

Table 3.2: *US trade balance (percent of GDP).*

	1995	2008
World	−2.3	−5.8
Asia	−1.8	−3.0
of which China	−0.5	−2.0
of which China excl. FVA[1]	−0.4	−1.4
of which China excl. FVA from Asia[2]	−0.4	−1.7
Memorandum:		
US bilateral trade balance with China		
US data	−0.5	−2.0
imports data only	−0.4	−1.9
Chinese data	−0.1	−1.2

[1]FVA contained in exports to and from China is excluded. [2]FVA from Asia contained in exports to and from China is excluded.
Source: Direction of Trade Statistics (DOTS); World Economic Outlook (WEO); OECD IO tables; and IMF staff estimates.

Table 3.3: *China's external balance, 2008 (percent of GDP).*

	Gross	VA[1]
Trade balance	8.0	8.0
exports	31.7	23.0
imports	−23.8	−15.1
Current account balance	9.6	9.6
Memorandum:		
FVA contained in exports	8.7	0.1

[1]FVA contained in exports are excluded and imports are assumed to contain no domestic value added.
Source: DOTS; WEO; OECD IO tables; and IMF staff estimates.

2 WHY IT IS *NOT* IMPORTANT

Macroeconomists focus on overall balances, not bilateral ones: for the former, gross trade data already give us the correct information. For example, FVA contained in China's exports is almost equivalent to China's trade surplus in 2008, about 8% of GDP (Table 3.3). Does this mean that the trade balance, the current account balance and hence the saving-investment gap should be adjusted downwards, for example, implying that discouraging net savings in China is the wrong policy recommendation? No! If we were to record exports excluding FVA, then we should also make corresponding adjustments on the import side, leaving external balances the same. Similarly, if we were to record imports excluding domestic value added (DVA), then corresponding adjustments must be made on the export side. With these changes, however, the balance of payments statistics will record value-added flows that are different from the actual gross transactions. Is this feasible or even desirable, espe-

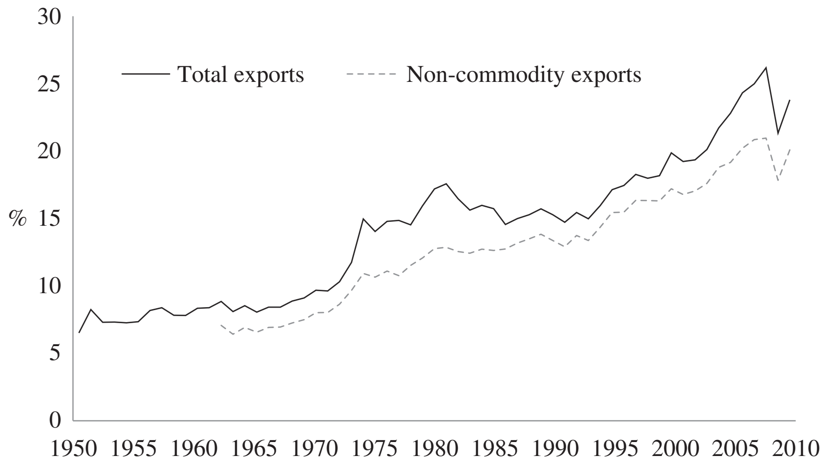

Figure 3.3: *World exports relative to production (percent of GDP).*

Sources: DOTS, WEO and UN Comtrade. The ratio for 1949–61 is calculated based on 15 major exporters.

cially when gross trade data already provide us with correct overall external balances? In summary, value-added trade data can be used to complement, and not necessarily substitute for, the gross trade data.

The reminder of this chapter summarises relevant findings of International Monetary Fund (2011).

3 CHANGING PATTERNS OF GLOBAL TRADE

The growth of trade relative to output in the last few decades was in large part driven by the emergence and growth of global supply chains. As a share of global output, trade is now more than four times its level in the early 1950s (Figure 3.3). This partly reflects trade liberalisation since then, which led to significantly lower trade barriers in advanced economies, followed more recently by developing countries. Along with lower trade barriers, technology-led declines in transportation and communication costs also facilitated the fragmentation of production beyond national borders. These developments led supply chains to become regional, as in the case of ‘Factory Asia’ (Baldwin 2008) or even global, as in the case of the iPod (Dedrick *et al* 2010). A convergence in income levels and factor endowments across countries also played a role in the growth of trade (relative to output), especially that of intra-industry trade.

The FVA share in gross exports has almost doubled since 1970, and the growth in FVA share has accelerated in recent years. Updates by IMF staff on the

Table 3.4: *Share of foreign value added in gross exports.*

	Hummels *et al* (2001)[1]		Update[2]	
	1970	1990	1995	2005
FVA share of gross exports	0.18	0.24	0.27	0.33
Growth in FVA share		31.3		21.5
Contribution of FVA exports to growth in exports/GDP	32.5	55.9		

[1]Twenty-eight countries are included in Hummels *et al* (2001): Australia, Canada, China, EU15, Hong Kong SAR, Indonesia, Japan, Korea, Mexico, Taiwan Province of China (Chinese Taipei), Malaysia, Singapore, Thailand and the USA. [2]The 34 countries included in the update are EU15, Australia, Brazil, Canada, Switzerland, China, Czech Republic, Hungary, Indonesia, India, Israel, Norway, New Zealand, Poland, Russian Federation, Slovak Republic, Slovenia, Taiwan Province of China (Chinese Taipei), Turkey and the USA.
Sources: Hummels *et al* (2001); IMF staff estimates using OECD input–output tables.

work by Hummels *et al* (2001) show that the foreign content embedded in gross exports have increased on average from 18% in 1970 to 33% in 2005 (Table 3.4).[2] Growth in FVA share also accelerated in recent years; the growth rate was 10% per decade during 1970–90, but was 20% per decade during 1995–2005.

Advanced economies and emerging market economies (EMEs) play different roles in global supply chains. Advanced economies tend to be upstream in the supply chain. This position is reflected in relatively small FVA in exports and relatively large contributions to value added in exports of downstream countries (Koopman *et al* 2010). By contrast, EMEs tend to be downstream in the supply chain, with relatively large shares of imported content in their exports (Figure 3.4). The different positions in the supply chain lead to differing implications for the sensitivity of trade patterns. For example, at the aggregate level, the impact of a exchange rate fluctuations on trade is more cushioned for downstream countries than upstream ones (more details are given below).

The Asia supply chain is more integrated than those in North America or Europe. In the Asian supply chain, goods in process cross borders several times, including through the hub (Japan), before reaching their final destination (Table 3.5). For instance, about 15% of Japanese value added embodied in Chinese products goes through other countries in Asia before reaching China. In contrast, in other regions, almost all foreign input is imported directly from the hub: the USA in the North American Free Trade Agreement (NAFTA) coun-

[2]The update (last two columns) is based on 34 countries, while the original figures by Hummels *et al* (2001) for 1970–90 (first two columns) are based on 28 countries.

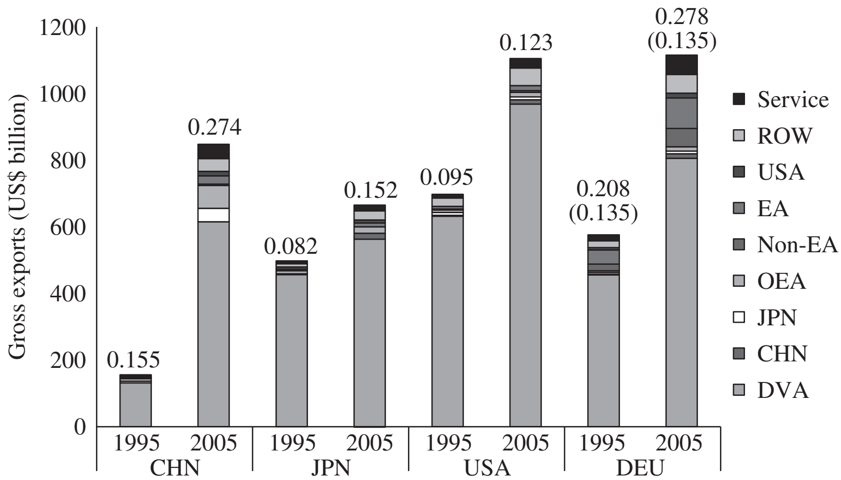

Figure 3.4: *Foreign contents in gross exports.*

Sources: IMF staff estimates using OECD input–output tables, Comtrade and OECD STAN data. Shares above the bar chart indicate FVA share in gross exports. Shares in parentheses exclude FVA from the euro area.

Table 3.5: *Hub's VA contained in gross exports.*

	Total	In imports from the hub[1]	In imports from the neighbours[2]
China	8.0	6.8	1.2
Mexico	31.3	31.0	0.3
EU accession	17.5	17.3	0.2

[1]For China, Mexico and EU accession countries, hubs are Japan, the USA and the EU, respectively. [2]For China: Australia, Hong Kong, India, Indonesia, Korea, Malaysia, the Philippines, Singapore, Taiwan (Chinese Taipei), Thailand, Vietnam and the rest of East Asia are included. For Mexico: Canada, Brazil and Latin America are included. For EU accession countries: EFTA, and Russia are included.
Source: IMF staff estimates using Koopman *et al* (2010).

tries and EU15 in Europe.[3] The greater integration of production in the Asia renders it potentially more vulnerable to disruptions of trade flows, whether policy induced, such as preferential trade agreements, or naturally caused, such as the recent Japan earthquake.

The emergence of global supply chains has allowed EMEs to enhance the technology content of their exports, including inputs embedded in high-tech exports

[3]NAFTA refers to the North American Free Trade Agreement countries: Canada, Mexico and the USA. EU15 is the 15 member states of the European Union prior to 2004.

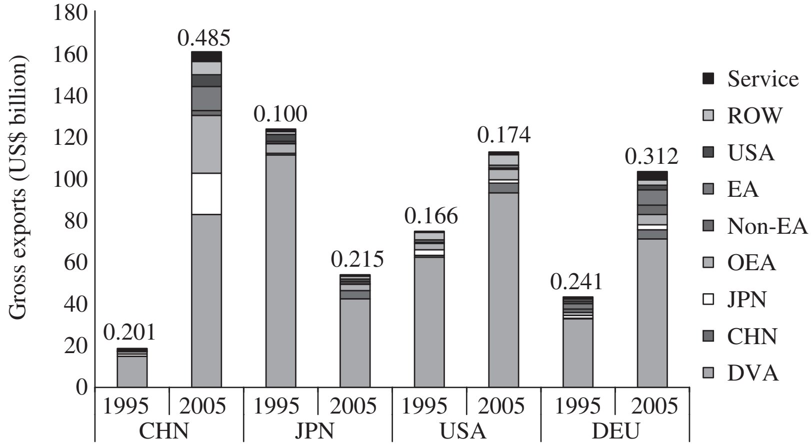

Figure 3.5: *Foreign contents in gross exports: high-tech sectors.*

Sources: IMF staff estimates using OECD input–output tables, Comtrade and OECD STAN data. Shares above the bar chart indicate FVA share in gross exports.

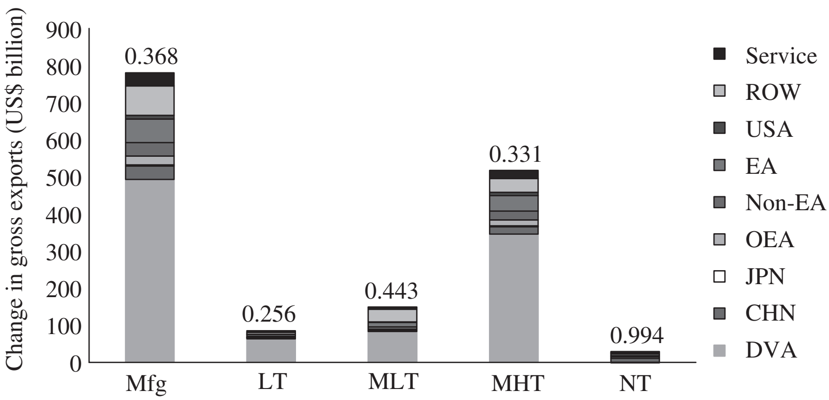

Figure 3.6: *Source of change in exports of advanced countries (1995–2005).*

Sources: IMF staff estimates using OECD input–output tables, Comtrade and OECD STAN data. Shares above the bar chart indicate the change in FVA exports in the overall change in exports. Mfg, manufacturing; LT, low technology; MLT, medium-low technology; MHT, medium-high technology; HT, high technology; EA, EU accession countries.

of advanced countries.[4] The share of high-tech exports such as computers and office equipment has increased remarkably in China since 1995, boosted

[4]The classification is based on the OECD measure of trade by technology intensity (Organisation for Economic Co-operation and Development 2005).

Table 3.6: *Simulated long-run impacts of relative price shocks on external balances: base year* = 2008 *(percent of national GDP, unless otherwise noted).*

	10% appreciation				10% depreciation			
	China		Euro Area[1]		Japan		USA	
	Pre-shock	Post-shock[2]	Pre-shock	Post-shock[2]	Pre-shock	Post-shock[2]	Pre-shock	Post-shock[2]
Current account balance	9.6	5.9	−1.7	−4.7	3.2	6.4	−4.7	−2.4
of which trade balance	8.0	4.2	−0.6	−3.6	0.8	3.9	−5.8	−3.5
exports	31.7	28.9	17.0	15.1	15.3	17.5	9.1	10.2
imports	−23.8	−24.7	−17.5	−18.6	−14.5	−13.5	−14.9	−13.8
Memorandum items (percent change from pre-level):								
exports (%)		−10.9		−12.7		17.0	13.7	
imports (%)		1.7		4.5		−4.5		−6.7
nominal GDP (%)		−2.3		−1.8		2.2		1.0

[1]Euro Area trade data was obtained from the IMF Direction of Trade Statistics. [2]Trade levels implied in the long run by simulated relative international price shocks are in absence of other shocks.
Sources: WEO, DOTS and IMF staff estimates.

by processing trade and with significant imported contributions from Japan and other Asian countries (Figure 3.5). China is also moving upstream in the value-added chain, with imports from China contributing significantly to high-tech exports of advanced countries (Figure 3.6). With China and other EMEs increasing their presence in sectors traditionally dominated by advanced economies, the similarity in export structures has increased over time and so has competitive pressure.

Changes in relative prices would result in non-symmetric rebalancing effects between downstream and upstream countries, as different sizes of FVA shares at the sectoral (and aggregate) level lead to different adjustment patterns. We have examined the impact of relative price changes on trade structures of four key players in global trade, namely China (downstream country), the Euro Area, Japan and the USA (upstream countries). At the *aggregate* level, a downstream (as opposed to upstream) position in a supply chain cushions the impact of a relative price change on both exports and imports (Table 3.6). This reflects the higher FVA in the exports of the downstream country mitigating the impact of exchange rate changes. At the *sectoral* level, the impact on technology intensity of exports is different for each country (Figure 3.7). In China, the impact is most prevalent in both high-tech and medium-tech exports, while elsewhere medium-high-tech exports change the most. Adjustments are smaller for sectors with larger FVA shares, though the size of the sector in each country also matters. Finally, relatively more adjustment in the trade balance seems to take place outside of the supply chain, as exports to supply chain partners are more resilient to relative price changes (Figure 3.8).

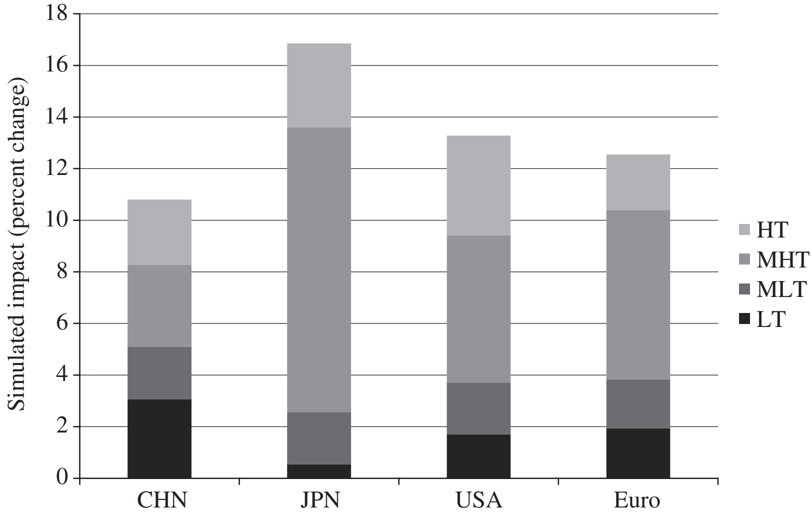

Figure 3.7: *Simulated impact of exports by sector.*

Sources: UN Comtrade and IMF staff estimates.

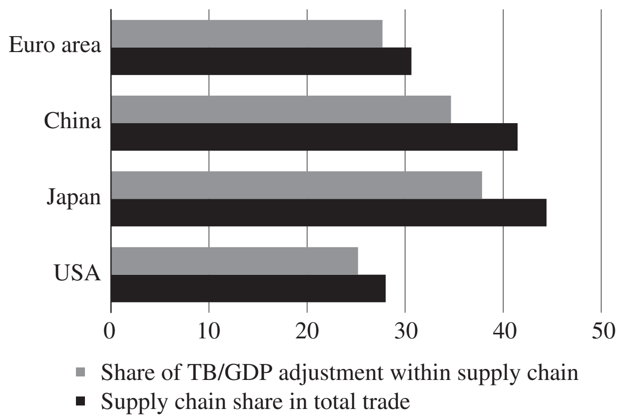

Figure 3.8: *Contribution to adjustment in trade balance.*

Sources: UN Comtrade and IMF staff estimates. Supply chain contribution to adjustment in trade balance is smaller than its importance as a trading partner would suggest.

REFERENCES

Baldwin, R. (2008). Managing the Noodle Bowl: The Fragility of East Asian Regionalism. *Singapore Economic Review* **53**(3), 449–478.

Dedrick, J., K. L. Kraemer and G. Linden (2010). Who Profits from Innovations in Global

Value Chains: A Study of the iPod and Notebook PCs. *Industrial and Corporate Change* **19**(1), 81–116.

Hummels, D, J. Ishii and K.-M. Yi (2001). The Nature and Growth of Vertical Specialization in World Trade. *Journal of International Economics* **54**, 75–96.

International Monetary Fund (2011). Changing Patterns of Global Trade. IMF Policy Paper. URL: http://www.imf.org/external/pubs/cat/longres.aspx?sk=25104.0.

Koopman, R., W. Powers, Z. Wang and S.-J. Wei (2010). Give Credit Where Credit Is Due: Tracing Value Added in Global Production Chains. NBER Working Paper 16426, September.

Organisation for Economic Co-operation and Development (2005). *Measuring Globalisation: OECD Handbook on Economic Globalisation Indicators* (Paris: OECD).

4

Accounting for Intermediates: Production Sharing and Trade in Value Added

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Trade in intermediate inputs accounts for as much as two-thirds of international trade. By linking production processes across borders, this input trade creates two distinct measurement challenges. First, conventional gross trade statistics tally the gross value of goods at each border crossing, rather than the net value added between border crossings. This well-known 'double-counting' problem means that conventional data overstate the domestic (value-added) content of exports. Second, multi-country production networks imply that intermediate goods can travel to their final destination by an indirect route. For example, if Japanese intermediates are assembled in China into final goods exported to the US, then Chinese bilateral gross exports embody third party (Japanese) content. Together, 'double-counting' and multi-country production chains imply that there is a hidden structure of trade in value added underlying gross trade flows.

In this chapter, we compute and analyse the value-added content of trade. To do so, we require a global bilateral input–output table that describes how particular sectors in each destination country purchase intermediates from both home and individual foreign sources, as well as how each country sources final goods. Because these bilateral final and intermediate goods linkages are not directly observed in standard trade and national accounts data sources, we construct a synthetic table by combining input–output tables and bilateral

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trade data for many countries. Using this table, we split each country's gross output according to the destination in which it is ultimately absorbed in final demand. We then use value added to output ratios from the source country to compute the value added associated with the implicit output transfer to each destination. The end result is a data set of 'value-added exports' that describes the destination where the value added produced in each source country is absorbed.

These data on the value-added content of trade have many potential uses. Most directly, we compare them to gross bilateral trade flows to quantify the scope of production sharing. This approach to measuring production sharing yields comparable figures for many countries and sectors and respects the multilateral structure of production sharing. Further, because we use the national accounts definition of intermediates, our measures are easily translated into models.[2] This is important because the value-added content of trade is a key theoretical object and calibration target in many trade and macroeconomic models. For example, value-added exports can be used to calibrate 'openness' and bilateral exposure to foreign shocks in international business cycle research.[3] For trade research, value-added flows could be used to calibrate gravity-style trade models to allow for differences in trade patterns for final and intermediate goods.[4] They could also be employed to calibrate many-country models of multi-stage production and vertical specialisation, as in Yi (2003, 2010). And these applications only scratch the surface.

Our approach to measuring the value-added content of trade draws on an older literature on input–output accounting with multiple regions. Our method of tracking the flow of intermediate inputs across borders was initially developed by Trefler and Zhu (2010), who in turn built on the older multiregional input–output literature (see Isard 1951; Moses 1955, 1960; Miller 1966). Trefler and Zhu use their procedure to track the movement of each intermediate input across each border and then use this information to calculate the factor content of trade, *ie* the amount of primary factors such as labour that are embodied in the trade of intermediate and final goods. In contrast, we use their tracking procedure as a first stage in calculating the value-added content of trade, *ie* the value of primary factors that are embodied in the trade of intermediate and final goods.[5]

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[2]This contrasts with alternative approaches, such as using data on trade in parts and components (see, for example, Yeats 2001) or trade between multinational parents and affiliates (see, for example, Hanson *et al* 2005).

[3]See Bems *et al* (2010) for elaboration of this argument.

[4]See Noguera (2011) for an analysis of estimated trade elasticities in gravity models with and without intermediate goods.

[5]Belke and Wang (2006) and Daudin *et al* (2011) also develop value-added trade computations along the lines of those used in this chapter. See also Powers *et al* (2009) on splitting up the value chain within Asia.

Our work is also related to an active literature on measuring vertical specialisation and the domestic content of exports.[6] Aggregating across sectors and export destinations for each source country, the ratio of value added to gross exports can be interpreted as a metric of the domestic content of exports.[7] Our domestic content metric generalises the work by Hummels *et al* (2001), who compute the value-added content of exports under the restrictive assumption that a country's exports (whether composed of final or intermediate goods) are entirely absorbed in final demand abroad. That is, it rules out scenarios in which a country exports intermediates that are used to produce final goods absorbed at home. By using input–output data for source and destination countries simultaneously, we are able to relax this assumption. While this generalisation results in only minor adjustments in aggregate domestic content measurements in our data, we demonstrate that relaxing this assumption is critically important for generating accurate bilateral value-added flows.

Turning to our empirical results, we find that the ratio of value added to gross exports (VAX ratio) varies substantially across countries and sectors. Across sectors, we show that VAX ratios are substantially higher in agriculture, natural resources, and services than in manufactures. This is mostly due to the fact that the manufacturing sector purchases inputs from non-manufacturing sectors, and therefore contains value added generated in those sectors. Across countries, the composition of trade drives aggregate VAX ratios, with countries that export Manufactures having lower aggregate VAX ratios. Aggregate VAX ratios do not covary strongly with income per capita, however, due to two offsetting effects. While richer countries tend to export manufactures, which lowers their aggregate VAX ratios, they also export at higher VAX ratios within the manufacturing sector.[8]

Moving from aggregate to bilateral data, VAX ratios differ widely across partners for individual countries. For example, US exports to Canada are about 40% smaller measured in value-added terms than gross terms, whereas US exports to France are essentially identical in gross and value-added terms. These gaps arise for two main reasons. First, bilateral ('back-and-forth') production sharing implies that value-added trade is scaled down relative to gross trade. And these scaling factors differ greatly across bilateral partners. Second, multilateral ('triangular') production sharing gives rise to indirect trade that occurs via countries that process intermediate goods. For some country pairs, bilateral VAX ratios are larger than 1, as bilateral value-added exports exceed gross exports.

[6]See NRC (2006) for the US; Dean *et al* (2007), Chen *et al* (2008) and Koopman *et al* (2008) for China. See also Hummels *et al* (2001) and Miroudot and Ragoussis (2009) for changes in domestic content over time for mainly OECD countries.

[7]Bilateral or sector level ratios of value added to exports do not have this domestic content interpretation.

[8]VAX ratios within manufactures are correlated with income because richer countries tend to export in sub-sectors with relatively high VAX ratios.

These adjustments imply that bilateral trade imbalances often differ in value-added and gross terms. For example, the US–China imbalance is approximately 30–40% smaller when measured on a value-added basis, while the US–Japan imbalance is approximately 33% higher. These adjustments point to the importance of triangular production chains within Asia.

To illustrate the mechanisms at work in generating these results, we present two decompositions. In the first decomposition, we show that most of the variation in bilateral value added to export ratios arises due to production sharing, not variation in the composition of goods exported to different destinations. The second decomposition splits bilateral exports according to whether they are absorbed in the destination, embedded as intermediates in goods that are reflected back to the source country or redirected to third countries embedded as intermediates in goods ultimately consumed there. Variation in the degree of absorption, reflection and redirection across partners is an important driver of variation in bilateral value added to export ratios.

The rest of the chapter is structured as follows. Section 1 presents the general accounting framework, defines our value-added trade measures, and discusses the interpretation of value added to export ratios. Section 2 describes the data sources and assumptions we use to implement the accounting exercise. Section 3 presents our empirical results and Section 4 concludes.

1 THE VALUE-ADDED CONTENT OF TRADE

In this section, we introduce the accounting framework and demonstrate how intermediate goods trade generates differences between gross and value-added trade flows. We begin the section by presenting a general formulation of the framework with many goods and countries that we use in the calculations below. To aid intuition, we then exposit several results in stripped-down versions of this general framework. Results from these simple models carry over to the general model. We close by discussing the relationship between our framework and two related lines of work on regional input–output linkages and measurement of the factor content of trade.

1.1 The Value-Added Content of Trade

Assume there are S sectors and N countries. Each country produces a single differentiated tradeable good within each sector, and we define the quantity of output produced in sector s of country i to be $q_i(s)$. This good is produced by combining local factor inputs with domestic and imported intermediate goods. It is then either used to satisfy final demand (equivalently, 'consumed') or used as an intermediate input in production.

The key feature of the global input–output framework is that it tracks bilateral shipments of this output for final and intermediate use separately.

Tracking these flows requires four-dimensional notation denoting source and destination country as well as source and destination sectors for shipments of intermediates. Let the quantity of final goods from sector s in country i absorbed in destination j be $q_{ij}^c(s)$ and the quantity of intermediates from sector s in country i used to produce output in sector t in country j be $q_{ij}^m(s,t)$.

The global input–output framework organises these flows via market clearing conditions. Markets clear in quantities: $q_i(s) = \sum_j q_{ij}^c(s) + \sum_j \sum_t q_{ij}^m(s,t)$. If we evaluate these quantity flows at a common price, say $p_i(s)$, then we can rewrite the market clearing condition in value terms as

$$y_i(s) = \sum_j c_{ij}(s) + \sum_j \sum_t m_{ij}(s,t), \tag{4.1}$$

where $y_i(s) \equiv p_i(s)q_i(s)$, $c_{ij}(s) \equiv p_i(s)q_{ij}^c(s)$ and $m_{ij}(s,t) \equiv p_i(s)q_{ij}^m(s,t)$ are the value of production, final demand and intermediate goods shipments. Gross bilateral exports, denoted $x_{ij}(s)$, include goods destined for both final and intermediate use abroad: $x_{ij}(s) = c_{ij}(s) + \sum_t m_{ij}(s,t)$. Then (4.1) equivalently says that output is divided between domestic final use, domestic intermediate use and gross exports.

To express market clearing conditions for many countries and sectors in a compact form, we define a series of matrices and vectors. Collect the total value of production in each sector in the $S \times 1$ vector y_i and allocate this output to final and intermediate use. Denote country i's final demand for its own goods by $S \times 1$ vector c_{ii}, and shipments of final goods from i to country j by the $S \times 1$ vector c_{ij}. Further, denote use of intermediate inputs from i by country j by $A_{ij}y_j$, where A_{ij} is an $S \times S$ input–output matrix with elements $A_{ij}(s,t) = m_{ij}(s,t)/y_j(t)$. A typical element describes, for example, the value of steel (s = steel) imported by Canada (j = Canada) from the USA (i = USA) used in the production of automobiles (t = autos) as a share of total output of automobiles in Canada. Gross exports from i to j ($i \neq j$) are then $x_{ij} = c_{ij} + A_{ij}y_j$.

With this notation in hand, we collect information on intermediate goods sourcing and final goods flows in vector/matrix form:

$$A \equiv \begin{pmatrix} A_{11} & A_{12} & \dots & A_{1N} \\ A_{21} & A_{22} & \cdots & A_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ A_{N1} & A_{N2} & \dots & A_{NN} \end{pmatrix}, \qquad y \equiv \begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_N \end{pmatrix}, \qquad c_j \equiv \begin{pmatrix} c_{1j} \\ c_{2j} \\ \vdots \\ c_{Nj} \end{pmatrix}.$$

Then, we write the $S \times N$ goods market clearing conditions as

$$y = Ay + \sum_j c_j. \tag{4.2}$$

This is the classic representation of an input–output system, where total output is split between intermediate and final use. Whereas a typical input–output system focuses on sectoral linkages within a single economy, this system is expanded to trace intermediate goods linkages across countries and sectors. We therefore refer to A as the global bilateral input–output matrix.

Using this system, we can write output as

$$y = \sum_j (I - A)^{-1} c_j. \tag{4.3}$$

To interpret this expression, $(I - A)^{-1}$ is the 'Leontief inverse' of the input–output matrix. The Leontief inverse can be expressed as a geometric series:

$$(I - A)^{-1} = \sum_{k=0}^{\infty} A^k.$$

Multiplying by the final demand vector, the zero-order term c_j is the direct output absorbed as final goods, the first-order term $[I + A]c_j$ is the direct output absorbed plus the intermediates used to produce that output, the second-order term $[I + A + A^2]c_j$ includes the additional intermediates used to produce the first round of intermediates (Ac_j) and the sequence continues as such. Therefore, $(I - A)^{-1}c_j$ is the vector of output used both directly and indirectly to produce final goods absorbed in country j.

Equation (4.3) thus decomposes output from each source country i into the amount of output from the source used to produce final goods absorbed in country j. To make this explicit, we define

$$\begin{pmatrix} y_{1j} \\ y_{2j} \\ \vdots \\ y_{Nj} \end{pmatrix} \equiv (I - A)^{-1} c_j, \tag{4.4}$$

where y_{ij} is the $S \times 1$ vector of output from i used to produce final goods absorbed in j.

These output transfers are conceptually distinct from gross exports. Gross exports $x_{ij}(s)$ are directly observed as a bilateral shipment from sector s in country i to country j. In contrast, bilateral output transfers are not directly observed, but rather constructed using information on the global input requirements for final goods absorbed in each country. Importantly, as inputs from a particular country and sector travel through the production chain, they may be embodied in final goods of any sector or country. For example, inputs exported from country i to country j may be embedded in country j's final goods that are absorbed in a third country k, or inputs produced by sector s may be embodied in final goods from sector t. These possibilities give rise to important differences in the structure of bilateral output transfers versus bilateral trade.

Our system of equations (4.1)–(4.4) tracks the flow of each intermediate input across each border. These equations and the resulting tracking method are identical to what appears in Trefler and Zhu (2010). Having developed the method, they then applied it to calculating the factor content of trade. We explain this application at the end of Section 1.2. Our interest here is different: we wish to calculate the value-added content of international trade.

To calculate the value added associated with these implicit output transfers, define the ratio of value added to output for each sector within country i as $r_i(t) = 1 - \sum_j \sum_s A_{ji}(s,t)$. This value-added ratio, expressed here as 1 minus the share of domestic plus imported intermediates in total output, is equal to payments to domestic factors as a share of gross output. In other words, this is the ratio of GDP to gross output at the sector level.

With this notation in hand, we can now define value-added exports and the value added to export ratio ('VAX ratio') as a measure of the value-added content of trade.

Definition 4.1 (value-added exports). The total value added produced in sector s in source country i and absorbed in destination country j is $\text{va}_{ij}(s) = r_i(s) y_{ij}(s)$. Total value added produced in i and absorbed in j is then $\text{va}_{ij} = \sum_s \text{va}_{ij}(s)$.

Definition 4.2 (VAX ratio). The sector-level bilateral value added to export ratio is given by $\text{va}_{ij}(s)/x_{ij}(s)$. The aggregate bilateral value added to export ratio is $\text{va}_{ij}/\iota x_{ij}$, where ι is a $1 \times S$ vector of ones.

1.2 Discussion

We turn to special cases to interpret value-added trade flows and the value-added content of trade. We use a two-country model to develop intuition for the value-added content of trade calculations and link our analysis to previous work on the domestic content of exports (equivalently, vertical specialisation) by Hummels *et al* (2001). We then use a stylised three-country model to demonstrate how the framework tracks value added through the multi-country production chain, even if that value added travels to its final destination via third countries. We also discuss the interpretation of VAX ratios in multi-sector models. We conclude by setting our framework in the context of related literature on regional input–output linkages and the measurement of the factor content of trade.

Two Countries, One Sector per Country

Suppose that there are now only two countries, and each country produces a single differentiated aggregate good. Then the analogue to the output decomposition (4.3) is

$$\begin{pmatrix} y_1 \\ y_2 \end{pmatrix} = \left[I - \begin{pmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{pmatrix} \right]^{-1} \begin{pmatrix} c_{11} \\ c_{21} \end{pmatrix} + \left[I - \begin{pmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{pmatrix} \right]^{-1} \begin{pmatrix} c_{12} \\ c_{22} \end{pmatrix}. \quad (4.5)$$

This system describes how the gross output of each country is embodied in final consumption in each of the two countries. To unpack this result, we solve for the breakdown of country 1's production:

$$y_1 = y_{11} + y_{12}, \tag{4.6}$$

with

$$y_{11} = M_1\left(c_{11} + \frac{\alpha_{12}}{1-\alpha_{22}}c_{21}\right) \quad \text{and} \quad y_{12} = M_1\left(\frac{\alpha_{12}}{1-\alpha_{22}}c_{22} + c_{12}\right),$$

where

$$M_1 \equiv \left(1 - \alpha_{11} - \frac{\alpha_{12}\alpha_{21}}{1-\alpha_{22}}\right)^{-1} \geqslant 1$$

is an intermediate goods multiplier that describes the total amount of gross output from country 1 required to produce one unit of country 1's net output.[9]

The first term (y_{11}) is the total amount of country 1's output that is required to produce final goods absorbed in country 1. This term includes both output dedicated to satisfy country 1's demand for its own final goods ($M_1 c_{11}$), as well as output needed to satisfy country 1's demand for country 2 final goods ($M_1(\alpha_{12}/(1-\alpha_{22})c_{21})$).[10] The second term ($y_{12}$) has a similar interpretation in terms of country 2's demand.[11] Because (4.6) geographically decomposes country 1's output, we can translate this into a decomposition of value added: $\text{va}_1 = \text{va}_{11} + \text{va}_{12}$, where $\text{va}_{ij} = [1 - \alpha_{11} - \alpha_{21}]y_{ij}$ is value added generated by country i that is absorbed in country j.

There are four output concepts underlying flows from country 1 to country 2: final goods c_{12}; gross exports x_{12}; implicit output transfers y_{12}; and value-added exports va_{12}. We pause here to clarify the relationship between them. To begin, note that $x_{12} = c_{12} + \alpha_{12}y_2$, so $c_{12} \leqslant x_{12}$ when there are exported intermediates. Further, using the output decomposition for country 2 ($y_2 = y_{22} + y_{21}$), we decompose gross exports as $x_{12} = \alpha_{12}y_{21} + (c_{12} + \alpha_{12}y_{22})$. Multiplying both sides of the expression by $(1-\alpha_{11})^{-1}$ then translates exports into the gross output required to produce them.[12] It is

[9]This multiplier is greater than 1 because output is 'used up' in the production process. Without exported intermediates ($\alpha_{12} = 0$), this multiplier would be $(1-\alpha_{11})^{-1}$. The additional term reflects the fact that intermediate goods sourced from country 2 contain output produced by country 1.

[10]Exporting final goods c_{21} requires producing $(1-\alpha_{22})^{-1}c_{21}$ units of country 2 output, which itself requires $\alpha_{12}(1-\alpha_{22})^{-1}c_{21}$ units of country 1's output as intermediates. To produce this country 1 output requires M_1 times $\alpha_{12}(1-\alpha_{22})^{-1}c_{21}$ units of country 1's output overall, because some output is used up in the production process.

[11]To highlight how the output decomposition depends on cross-border intermediate linkages, note that if $\alpha_{12} = 0$, the output decomposition would be $y_{11} = (1-\alpha_{11})^{-1}c_{11}$ and $y_{12} = (1-\alpha_{11})^{-1}c_{12}$. In this counterfactual case, output of country 1 is only used to produce final goods originating in country 1.

[12]This follows from manipulation of the market clearing condition for country 1: $y_1 = (1-\alpha_{11})^{-1}(c_{11} + x_{12})$.

straightforward to show that $y_{12} = (1-\alpha_{11})^{-1}(c_{12}+\alpha_{12}y_{22})$. Therefore, $y_{12} = (1-\alpha_{11})^{-1}x_{12} - (1-\alpha_{11})^{-1}\alpha_{12}y_{21}$. So the implicit output transferred from country 1 to country 2 is equal to the gross output required to produce exports minus the gross output that is reflected back by being embedded in country 2 goods that are absorbed by country 1.[13] Finally, we note that $\text{va}_{12} \leqslant y_{12}$, because the value added to output ratio is bounded above by 1.

To directly compare value-added exports to gross exports, we compute the VAX ratio:

$$\begin{aligned}\frac{\text{va}_{12}}{x_{12}} &= \frac{(1-\alpha_{11}-\alpha_{21})y_{12}}{x_{12}}\\ &= \frac{1-\alpha_{11}-\alpha_{21}}{1-\alpha_{11}}\left(\frac{x_{12}-\alpha_{12}y_{21}}{x_{12}}\right),\end{aligned} \tag{4.7}$$

where the second line follows from the discussion in the previous paragraph. The difference $x_{12}-\alpha_{12}y_{21}$ is exports minus reflected intermediates, or equivalently the portion of exports genuinely consumed abroad. The VAX ratio will always be less than 1, so value-added exports are scaled down relative to gross exports.

The VAX ratio for a country can be thought of as a metric of the 'domestic content of exports'. Indeed, it is closely related to previous approaches to measuring domestic content in the literature. To see this, note that the VAX ratio has two components. The first component, $(1-\alpha_{11}-\alpha_{21})/(1-\alpha_{11})$, is equivalent to a metric of domestic content developed in Hummels *et al* (2001).[14] This metric captures the value added associated with the gross output needed to produce exports as a fraction of total exports. The Hummels–Ishii–Yi metric is equal to the VAX ratio only when country 2 does not use imported intermediates ($\alpha_{12} = 0$), and therefore country 1 exports final goods alone.[15] In contrast, with two-way trade in intermediates the Hummels–Ishii–Yi metric overstates the amount of domestic value added that is generated per unit of exports.[16] The second component of the VAX ratio allows some exports to be dedicated to producing goods that are ultimately consumed at home. That

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[13]Note that if $\alpha_{12} = 0$, then $y_{12} = (1-\alpha_{11})^{-1}x_{12}$, so the gross output required to produce exports equals the actual amount of output transferred from country 1 to country 2.

[14]Hummels *et al* focus their discussion on measuring vertical specialisation or the 'import content of exports', which is given by $\alpha_{21}(1-\alpha_{11})^{-1}$. Domestic content is then 1 minus the import content of exports. Though we discuss these concepts here in a scalar case, they generalise in a straightforward way to models with many sectors.

[15]The condition $\alpha_{12} = 0$ is necessary and sufficient for equality between the two metrics when there is one aggregate sector, except in pathological cases. With more than one sector, restricting country 1 to export only final goods ($\alpha_{12}(s,t) = 0$ for all s,t) is sufficient, but not necessary.

[16]Footnote 18 in Trefler and Zhu (2010) provides a related discussion of how the factor content of trade differs depending on whether one assumes intermediates are traded or not.

is, it allows for a portion of exports to be reflected back to the source rather than absorbed abroad.

Three Countries, One Sector per Country

While the two-country framework illustrates the basic discrepancy between value-added and gross trade flows, additional insights emerge as one introduces a third country to the mix. We focus on a special, algebraically straightforward case that illustrates how the accounting framework tracks the final destination at which value added by a given country is consumed, even if this value circulates through a multi-country production chain en route to its final destination. We construct the special case to approximate a stylised account of production chains between the USA and Asia.[17]

Let country 1 be the USA, country 2 be China and country 3 be Japan. Further, assume that China imports intermediates from the USA and Japan and exports only final consumption goods only to the USA. For simplicity, we assume that the USA and Japan do not export any final goods, and only export intermediates to China. This configuration of production can be represented as

$$\begin{pmatrix} y_1 \\ y_2 \\ y_3 \end{pmatrix} = \begin{pmatrix} \alpha_{11} & \alpha_{12} & 0 \\ 0 & \alpha_{22} & 0 \\ 0 & \alpha_{32} & \alpha_{33} \end{pmatrix} \begin{pmatrix} y_1 \\ y_2 \\ y_3 \end{pmatrix} + \begin{pmatrix} c_{11} \\ c_{22} + c_{21} \\ c_{33} \end{pmatrix}. \tag{4.8}$$

This then can be solved to yield the following three-equation system:

$$y_1 = \underbrace{\frac{1}{1-\alpha_{11}} c_{11} + \frac{\alpha_{12}}{(1-\alpha_{11})(1-\alpha_{22})} c_{21}}_{y_{11}} + \underbrace{\frac{\alpha_{12}}{(1-\alpha_{11})(1-\alpha_{22})} c_{22}}_{y_{12}},$$

$$y_2 = \underbrace{\frac{1}{1-\alpha_{22}} c_{21}}_{y_{21}} + \underbrace{\frac{1}{1-\alpha_{22}} c_{22}}_{y_{22}},$$

$$y_3 = \underbrace{\frac{\alpha_{32}}{(1-\alpha_{33})(1-\alpha_{22})} c_{21}}_{y_{31}} + \underbrace{\frac{\alpha_{32}}{(1-\alpha_{33})(1-\alpha_{22})} c_{22}}_{y_{32}} + \underbrace{\frac{1}{1-\alpha_{33}} c_{33}}_{y_{33}}.$$

This system provides the implicit output transfers needed to calculate value-added flows.

Two points are interesting to note. First, as in the two-country case above, US demand for US output has both a direct component $(1/(1-\alpha_{11}))c_{11}$ and an indirect component $(\alpha_{12}/(1-\alpha_{11})(1-\alpha_{22}))c_{21}$ that accounts for the fact that US imports of final goods from China include embedded US content. Thus, a

[17] This example was inspired by Linden *et al* (2007), who trace the iPod production chain. The iPod combines US intellectual property from Apple with a Japanese display and disk drive, which is manufactured in China. These components are assembled in China and the iPod is shipped to the USA.

larger share of US output is ultimately absorbed at home than bilateral trade statistics would indicate. Correspondingly, Chinese bilateral exports overstate the true Chinese content shipped to the USA due to bilateral US–China production sharing.

The second point is that, although Japan does not export directly to the USA, the USA does import Japanese content embedded in Chinese exports to the USA. This effect is the result of multi-country production chains, and was absent in the two-country case analysed above. In the equation for Japan (country 3), this effect appears as $(\alpha_{32}/(1-\alpha_{33})(1-\alpha_{22}))c_{21}$.

Because Chinese exports to the USA contain both US and Japanese content, the bilateral VAX ratio of China–US trade is

$$\frac{\mathrm{va}_{21}}{x_{21}} = 1 - \left(\frac{\mathrm{va}_{31} + \alpha_{12} y_{21}}{x_{21}}\right) < 1. \tag{4.9}$$

This illustrates that the bilateral VAX ratio removes both the Japanese value added (va_{31}) and US intermediate goods ($\alpha_{12} y_{21}$) from Chinese exports to the USA.[18] Turning to Japan, it has positive value-added exports to the USA and zero direct bilateral exports. Therefore, the bilateral VAX ratio for Japan–US trade is undefined, or practically infinite for small bilateral exports. This extreme ratio illustrates another general lesson. Though the aggregate VAX ratio is bounded by 1 for each country, bilateral VAX ratios may be greater than 1 when an exporter sends intermediates abroad to be processed and delivered to a third country. Thus, bilateral VAX ratios pick up the influence of both bilateral and multilateral production sharing relationships.

When bilateral VAX ratios vary across partners, bilateral value-added balances do not equal bilateral trade imbalances. To illustrate this, we define $tb_{12} \equiv x_{12} - x_{21}$ and $\mathrm{va}\,b_{12} \equiv \mathrm{va}_{12} - \mathrm{va}_{21}$ to be bilateral US–China trade and value-added balances. In this special case, where the configuration of production is given by (4.8), these balances are related as follows:

$$tb_{12} + \alpha_{32} y_{21} = \mathrm{va}\,b_{12}. \tag{4.10}$$

That is, $tb_{12} < \mathrm{va}\,b_{12}$. So, assuming the USA runs a trade deficit with China in this example, it will run a smaller deficit with China in value-added terms due to the fact that Chinese bilateral trade contains Japanese content ($\alpha_{32} y_{21}$). As a corollary, the USA's bilateral balance with Japan will be distorted in the opposite direction.

[18] US imports from China contain US content because the US exports intermediates to China and imports final goods from China. Thus, US intermediates are reflected back to the USA and constitute a portion of the value added that the USA purchases from itself.

To generalise this result, we can write any given bilateral value-added balance as

$$\begin{aligned}\text{va}\, b_{ij} &= \frac{\text{va}_{ij}}{x_{ij}} x_{ij} - \frac{\text{va}_{ji}}{x_{ji}} x_{ji} \\ &= \tfrac{1}{2}(x_{ij} + x_{ji})\left[\frac{\text{va}_{ij}}{x_{ij}} - \frac{\text{va}_{ji}}{x_{ji}}\right] + \frac{1}{2}\left(\frac{\text{va}_{ij}}{x_{ij}} + \frac{\text{va}_{ji}}{x_{ji}}\right)[x_{ij} - x_{ji}]. \qquad (4.11)\end{aligned}$$

The first term adjusts the value-added balance due to differences in VAX ratios between exports and imports. When the VAX ratio for exports is high relative to imports, the value-added balance is naturally pushed in a positive direction. Note here that this is true even if gross trade is balanced. The second term adjusts the value-added balance based on the average level of VAX ratios. Starting from an initial imbalance, the value-added balance is scaled up or down relative to the trade balance, depending on whether VAX ratios are greater than or less than 1 (on average). So, differences in VAX ratios between partners within a bilateral relationship and the absolute level of the VAX ratios between partners both influence the size of the adjustment in converting gross imbalances to value-added terms.

Two Countries, Many Sectors

The interpretation of aggregate value-added exports and VAX ratios developed in the one-sector examples in previous sections carries over to the many-country, multi-sector framework. One important distinction between the one-sector and multi-sector frameworks is that the VAX ratio at the sector level cannot be interpreted as the domestic content of exports. To explain its interpretation, we turn to an example with two countries and many sectors.[19]

With two countries ($i, j = \{1, 2\}$) and many sectors, the VAX ratio for sector s in country 1 can be written as

$$\frac{\text{va}_{12}(s)}{x_{12}(s)} = \frac{r_1(s) y_{12}(s)}{x_{12}(s)}.$$

Then the sectoral VAX ratio depends on the value added to output ratio within a given sector ($r_1(s)$) and the ratio of gross output produced in a sector that is absorbed abroad ($y_{12}(s)$) to gross exports from that sector ($x_{12}(s)$). The role of the value added to output ratio is straightforward: all else being equal, sectors with low value added to output ratios (*eg* manufacturing) will have low VAX ratios relative to other sectors.

The role of differences in $y_{12}(s)$ versus $x_{12}(s)$ across sectors is more subtle. To sort this out, we note that we can link y_{12} and the export vector x_{12} as

[19]The many-country version of the framework can always be collapsed to an equivalent two-country framework, in which input–output linkages among countries in the rest of the world are subsumed into the ‘domestic’ input–output structure of the rest-of-the-world composite.

in Section 1.2. Specifically, $x_{12} = (I - A_{11})y_{12} + A_{12}y_{21}$. Rearranging this expression yields $y_{12} = (I - A_{11})^{-1}[x_{12} - A_{12}y_{21}]$. This is the many sector, matrix analogue to computations embedded in Equation 4.7, wherein y_{12} is the gross output needed to produce exports less reflected intermediates. This decomposition points to two ways in y_{12} could differ from x_{12}.

First, suppose that $A_{12}y_{21}$ is a vector of zeros, so that exports are 100% absorbed abroad.[20] This implies that $y_{12} = (I - A_{11})^{-1}x_{12}$. All that remains here separating exports and gross output for individual sectors is the domestic input–output structure. Generically, $y_{12}(s) \neq x_{12}$, so variation in this ratio across sectors influences sector-level value added.

One important implication of this is that the sectoral VAX ratio captures information on how individual sectors engage in trade. For example, consider a situation in which producers in one sector sell intermediates to purchasers in another sector, who in turn produce goods for export.[21] In this case, the intermediate goods suppliers engage in trade indirectly. Hence, we observe no direct exports from the intermediate goods supplier, but do observe value-added exports because value added from that sector is embedded in the purchaser's goods. Thus, value-added exports from a particular sector may be physically embodied in goods exported from that sector or embodied in exports of other sectors. High ratios of value-added exports to gross trade (possibly above 1) at the sector level are evidence of indirect participation in trade. Low ratios instead indicate that a given sector's gross exports embody value added produced outside that sector.

Second, suppose now that A_{12} is not composed of zeros, but rather that country 1 exports intermediates to country 2 that are used to produce goods that are absorbed in country 1, captured by the term $A_{12}y_{21} > 0$. In this case, the sectoral VAX ratio is influenced by how individual sectors fit into cross-border production chains. For example, if we shut down all domestic input–output linkages, setting A_{11} to zero, then $y_{12} = x_{12} - A_{12}y_{21}$. Then the sectoral VAX ratio depends on the sector's connection to foreign production chains. Specifically, the VAX ratio will be depend on what share of output is absorbed abroad versus the share used to produce foreign goods that are ultimately absorbed at home. If exports are largely absorbed abroad (*ie* $y_{12}(s)/x_{12}(s) \approx 1$), one would see a relatively high VAX ratio.

[20]If A_{12} is a matrix of zeros, so that country 1 exports only final goods, this obviously holds. This can also hold for cases in which elements of A_{12} are positive, so long as the corresponding elements y_{21} are zero. For example, country 1 could export intermediates to country 2, so long as the sector purchasing those intermediates only produces output for consumption in country 2.

[21]For example, the 'raw milk' sector in our data has near zero exports, but raw milk is sold to the 'dairy products' sector, which does export. With two sectors, where 1 is the dairy products and 2 is the milk sector, this could be represented as an A_{11} matrix with one non-zero element $\alpha_{11}(2,1)$ and export vector with $x_{12}(1) > 0$ and $x_{12}(2) = 0$. This structure implies $y_{12}(1)/x_{12}(1) = 1$ and $y_{12}(2)/x_{12}(2) = \infty$.

Though these influences are difficult to separate empirically in general cases, we discuss evidence below that sheds light on the relative importance of these channels.

Regional Input–Output Models and the Factor Content of Trade

The framework above is intimately related to two strands of literature in regional science and factor content of trade.

First, we draw on an extensive literature on regional input–output models. These models, outlined in seminal work by Isard (1951), Moses (1955, 1960) and Miller (1966), provide frameworks for analysing linkages across regions within countries that can be extended across borders (as above). Among this literature, Moses (1955) is the closest antecedent, as he uses proportionality assumptions to allocate inputs purchased from other regions, as we do, to build a multi-region model of the USA.[22] One shortcoming of this line of work is that it typically assumes that the regional system is 'open' vis-à-vis the rest-of-the-world, in the sense that shipments to regions not included in the model are entirely absorbed there. This assumption is a multi-region analogue of the assumptions under which the Hummels–Ishii–Yi domestic content calculation is equal to the value-added content of trade.[23]

Second, the value-added framework above shares a common structure with a recent parallel literature on measuring the factor content of trade. Reimer (2006) and Trefler and Zhu (2010) both outline procedures to compute the net factor content of trade when inputs are traded, and use these factor content measures to study the Vanek prediction. To draw out the similarities, note that one can think of computing both factor contents and value-added contents using a two-step procedure. First, one needs to compute the output transfers, specified above, that indicate how much output from each source country and sector are absorbed in final demand in a given destination. Second, one needs to use source country information on either factor contents (*eg* quantities of factors used to produce one dollar of output) or value added to output ratios to compute the factors or value added that is implicitly being traded.[24]

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[22]Isard (1951) suggests this technique as well, but does not pursue an empirical application himself.

[23]Powers *et al* (2009) work with a model of this type for Asia.

[24]Let us trace out the calculation explicitly. Trefler and Zhu define T_i to be an $(NS \times 1)$ vector of trade flows arranged as follows: $T_i = [\dots, -x_{i-1,i}^{\mathrm{T}}, x_i^{\mathrm{T}}, -x_{i+1,i}^{\mathrm{T}}, \dots]^{\mathrm{T}}$, where $x_i = \sum_{j \neq i} x_{ij}$ is an $(S \times 1)$ vector of total exports from country i to the rest of the world and $x_{j,i}$ is an $(S \times 1)$ vector of bilateral trade flows from $j \neq i$ to i. Further, they define B to be an $F \times SN$ matrix of factor requirements for each good: $B \equiv [B_1, \dots, B_i, \dots, B_N]$, where B_i is the $F \times S$ matrix of factor requirements for country i, with F denoting the number of factors. The factor content of trade for country i is then $B(I-A)^{-1}T_i$. To link this to our framework, we note that the calculation $(I-A)^{-1}T_i$ returns a vector of (signed) output transfers. In particular, $(I-A)^{-1}T_i = [\dots, -y_{i-1,i}^{\mathrm{T}}, y_{xi}^{\mathrm{T}}, -y_{i+1,i}^{\mathrm{T}}, \dots]^{\mathrm{T}}$, where $y_{xi} \equiv \sum_{j \neq i} y_{ij}$ is the total output produced in country i that is absorbed abroad, and $y_{j,i}$ is the output produced in

Despite this similarity in the underlying structure of value-added and factor content calculations, we emphasise that there are important conceptual differences between factor contents and value added. For one, the theoretical driving forces of trade in value added may be very different from trade in factors. Costinot *et al* (2011) point out that differences in absolute endowments across countries influence where countries are located in the value chain, so absolute (as opposed to relative) factor endowments are a source of comparative advantage underlying trade in value added.[25] This is just one example of a general point: the empirical shift from factor content to value-added content embodies a deeper conceptual shift in how we think about trade.

2 DATA

Our data source is the GTAP 7.1 database assembled by the Global Trade Analysis Project at Purdue University. This data is compiled based on three main sources: World Bank and IMF macroeconomic and Balance of Payments statistics; United Nations Commodity Trade Statistics (Comtrade) Database; and input–output tables based on national statistical sources. To reconcile data from these different sources, GTAP researchers adjust the input–output tables to be consistent with international data sources.[26] The GTAP data includes bilateral trade statistics and input–output tables for 94 countries plus 19 composite regions covering 57 sectors in 2004.[27] Regarding sector definitions, there are 18 Agriculture and natural resources sectors, 24 manufactures sectors and 15 services sectors.

In the data, we have information on six objects for each country:

1. y_i is a 57×1 vector of total gross production;

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country $j \neq i$ that is absorbed in country i. Thus, as suggested above, one can think of first computing output transfers embedded in trade flows, and then computing the factor requirements needed to produce those output transfers. See Johnson (2008) for an extended discussion of these calculations.

[25] Like absolute endowments, absolute productivity differences are also a source of comparative advantage in the Costinot *et al* model.

[26] See the GTAP website at http://www.gtap.agecon.purdue.edu/ for documentation of the source data. Since raw input–output tables are based on national statistical sources, they inherit all the shortcomings of those sources. For example, import tables are often constructed using a ‘proportionality’ assumption whereby the imported input table is assumed to be proportional to the overall aggregate input–output table.

[27] GTAP assigns composite regions ‘representative’ input–output tables, constructed from input–output tables of similar countries. Composite regions do not play an important role in our results, accounting for 5% of world trade and 3% of world value added. To measure bilateral services trade, GTAP uses OECD data where available and imputes bilateral services trade elsewhere. Because services account for less than 18% of exports for the median country, our results are likely to be insensitive to moderate mismeasurement of services trade.

2. c_{Di} is a 57×1 vector of domestic final demand;
3. c_{Ii} is a 57×1 vector of domestic final import demand;
4. A_{ii} is a 57×57 domestic input–output matrix, with elements $A_{ii}(s,t)$;
5. A_{Ii} is a 57×57 import input–output matrix, with elements $A_{Ii}(s,t) = \sum_{j \neq i} A_{ji}(s,t)$;
6. $\{x_{ij}\}$ is a collection of 57×1 bilateral export vectors for exports from i to j.

The definition of 'final demand' is based on the national accounts, including consumption, investment and government purchases. We value each country's output at a single set of prices, regardless of where that output is shipped or how it is used. This ensures that the value of production revenue equals expenditure.[28] Following input–output conventions, we use 'basic prices', defined as price received by a producer (minus tax payable or plus subsidy receivable by the producer).[29]

Note that we do not directly observe the bilateral input–output matrices A_{ji} and final demand vectors c_{ji} that are needed to assemble the global input-output matrix. Rather, we need to allocate total imported intermediate use A_{Ii} and imported final demand c_{Ii} to individual country sources. To do so, we use bilateral trade data and a proportionality assumption. Specifically, we assume that, within each sector, imports from each source country are split between final and intermediate in proportion to the overall split of imports between final and intermediate use in the destination. Further, conditional on being allocated to intermediate use, we assume that imported intermediates from each source are split across purchasing sectors in proportion to overall imported intermediate use in the destination.

Formally, for goods from sector s used by sector t, we define bilateral input-output matrices and consumption import vectors:

$$A_{ji}(s,t) = A_{Ii}(s,t)\left(\frac{x_{ji}(s)}{\sum_j x_{ji}(s)}\right) \quad \text{and} \quad c_{ji}(s) = c_{Ii}(s)\left(\frac{x_{ji}(s)}{\sum_j x_{ji}(s)}\right).$$

These assumptions imply that all variation in total bilateral intermediate and final goods flows arises due to variation in the composition of imports across partners. For example, we would find that US imports from Canada are intermediate goods intensive because most imports from Canada are goods that are on average used as intermediates (*eg* automobile parts).

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[28]In other words, while quantity choices may reflect price differences across destinations or uses that arise due to transport costs, tariffs and markups, we value the resulting quantity flows at a single set of prices.

[29]In our framework, the level of value added differs from the one used in national accounts. We calculate value added as output at basic prices minus intermediates at basic prices, whereas the national accounts calculate value added as output at basic prices minus intermediates at purchaser's prices.

The proportionality assumptions above are the standard approach to dealing with the fact that data on A_{ji} and c_{ji} are not collected in national accounts.[30] Initially adopted in early work on regional input–output accounts by Moses (1955), they have also been used by Belke and Wang (2006), Daudin *et al* (2011) and Trefler and Zhu (2010) to construct global input–output tables as in this chapter. Several recent papers have explored the consequences of relaxing some proportionality assumptions using alternative data sources, and appear to find that relaxing these assumptions has small effects on aggregate VAX ratios or factor contents.[31]

In the main calculation, we also assume that production techniques and input requirements are the same for exports and domestically absorbed final goods. This assumption is problematic for countries that have large export-processing sectors. These processing sectors (almost by definition) produce distinct goods for foreign markets with different input requirements and lower value added to output ratios than the rest of the economy. Ignoring this fact tends to overstate the value-added content of exports.

As an alternative calculation, we relax this assumption for China and Mexico, two prominent countries with large export-processing sectors (roughly two-thirds of exported Manufactures originates in these sectors) and key trading partners with the USA.[32] We present supplementary calculations below that adjust the value-added content of exports using an adaptation of a procedure from Koopman *et al* (2008). The basic idea is to measure the share of exports and imports that flow through the export-processing sector, and then impute separate input–output coefficients for the processing sector so as to be consistent with these flows. Details of the procedure are presented in the appendix in Section 5. We then compute the value-added content of trade using a new input–output system that includes these amended tables.[33]

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[30]Proportionality assumptions are so common in input–output accounting that many countries, including the USA, even construct the import matrix (A_{Ii}) itself using a proportionality assumption in which imported inputs are allocated across sectors in the same proportion as total input use (aggregating over imported and domestic inputs). Some countries augment this data with direct surveys of input use in constructing imported input use tables. However, no countries (to our knowledge) directly collect information on bilateral sources of inputs used in particular sectors.

[31]Puzzello (2012) compares factor content calculations with and without the proportionality assumption using IDE-JETRO regional input–output tables for Asia. Koopman *et al* (2010) compute value-added content using disaggregate data classified under the BEC system to estimate bilateral intermediate goods flows. While relaxing proportionality seems to have small aggregate consequences, it may simultaneously have large effects on value-added trade at the sector level. This remains to be explored.

[32]For Mexico, we classify exports originating from maquiladoras as processing exports. For China, we use estimates from Koopman *et al* (2008) constructed from Chinese trade statistics, obtained from Zhi Wang (personal communication).

[33]We perform this calculation at a higher level of aggregation than our baseline calcula-

3 EMPIRICAL RESULTS

3.1 Multilateral Value-Added Exports

Table 4.1 reports aggregate VAX ratios for each country, grouped by region.[34] Across countries, value-added exports represent about 73% of gross exports. The magnitude of the adjustment varies both across and within regions. At the regional level, VAX ratios are lowest for Europe (broadly defined) and East Asia, and higher in the Americas, South Asia and Oceania, and the Middle East and Africa. Looking within regions, the new EU members (*eg* Estonia, Hungary, Slovakia and the Czech Republic) stand out as having low VAX ratios in Central-Eastern Europe, while Japan stands out with a high VAX ratio relative to East Asia.

For China and Mexico, we report two separate calculations of the VAX ratio in the table, one computed without adjusting for processing trade and a second adjusted for processing trade.[35] VAX ratios for both China and Mexico fall substantially when we adjust for export processing trade, from 0.70 to 0.59 for China and from 0.67 to 0.52 for Mexico. This brings the ratios for China and Mexico in line with other emerging markets, such as South Korea or Hungary, and is evidence of the low value added to export ratios within each country's processing sector.[36]

Moving down a level of disaggregation, we report VAX ratios for three composite sectors by country in Table 4.1 as well. The three sectors are agriculture and natural resources, manufacturing and services. VAX ratios are typically greater than or equal to 1 in the agriculture and natural resources and services sectors, and markedly less than 1 in manufacturing. This cross-sector variation is primarily due to differences in the manner in which each sector engages in trade, rather than differences across sectors in the degree of participation in cross-border production sharing. Further, differences in value added to output ratios across sectors are also an important source of variation.

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tion, with three composite sectors. We believe the results are not very sensitive to aggregation, as aggregate value-added flows are nearly identical in the original, unadjusted data whether computed using 57 sectors or 3 composite sectors.

[34]We omit ratios for composite regions from the table.

[35]In the calculation adjusted for processing trade in China and Mexico, VAX ratios in all countries change relative to the unadjusted benchmark calculation. The absolute size of the changes in aggregate VAX ratios is very small, with a median of 0.016 and 90% of changes less than 0.053. Therefore, we report only one set of ratios for all countries other than China and Mexico.

[36]For the processing sector, we estimate that China's VAX ratios is 0.13, while Mexico's VAX ratio is 0.08. These ratios measure the value added produced within the processing sector as a share of processing exports. These ratios represent a lower bound on the domestic content of processing exports, since the processing sector purchases intermediates from other domestic sectors.

To sort through these influences, we refer back to Section 1.2. Recall that sectoral VAX ratios tend to be low when exports are used to produce foreign goods that are ultimately absorbed at home. If we assume that all output is absorbed abroad, then the output needed to produce exports would be

$$\tilde{y}_{ix} = (I - A_{ii})^{-1}\Big(\sum_{j \neq i} x_{ij}\Big),$$

where $\tilde{y}$ is used to signify that this is a counterfactual value and

$$\tilde{y}_{ix} = \sum_{j \neq i} \tilde{y}_{ij}.$$

Then the counterfactual sectoral value added to export ratios would be

$$\frac{r_i(s)\tilde{y}_{ix}}{x_i(s)}, \quad \text{with } x_i(s) = \sum_{j \neq i} x_{ij}.$$

In our data, this counterfactual calculation yields ratios that are very close to the actual VAX ratios. As such, differences across sectors in the degree of foreign absorption of exports does not appear to drive the VAX ratios. Further, we note that differences in value added to output ratios also cannot explain the full variation in VAX ratios across sectors. In the data, the value added to output ratio in manufactures is roughly 0.25 lower than in agriculture and natural resources and services sectors. This goes part of the way towards explaining differences in VAX ratios across sectors, but falls substantially short.

The remaining driver of variation in VAX ratios across sectors is cross-sector variation in the extent to which sectoral output is directly exported versus indirectly exported, embodied in other sectors' goods that are then exported. Recall that we observe gross exports from a given sector (*ie* $\sum_j x_{ij}(s) > 0$) only if output from that sector crosses an international border with no further processing. With this in mind, it is obvious that sector-level VAX ratios are greater than 1 when a sector exports value added embodied in another sector's gross output and exports. In the data, it appears that manufactures, which are directly exported, embody substantial value added from the other sectors. One implication of this fact is that the composition of aggregate value-added flows differs from that of gross trade. Figure 4.1 summarises this fact by plotting the share of manufactures and services in both types of trade for the ten largest exporters. The role of manufactures in value-added trade is diminished, while that of services is increased by a roughly equivalent amount.[37] The upshot is that services are far more exposed to international commerce than one would think based on gross trade statistics.

[37]'Agriculture and natural resources' constitutes a roughly equal share of value added and gross trade.

To organise the inter-country variation in the data, we construct a 'between-within' decomposition of the aggregate VAX ratio. The decomposition is constructed relative to a reference country as follows:

$$\mathrm{VAX}_i - \overline{\mathrm{VAX}} = \underbrace{\sum_s [\mathrm{VAX}_i(s) - \overline{\mathrm{VAX}}(s)]\left(\frac{\omega_i(s) + \bar{\omega}(s)}{2}\right)}_{\text{within term}} + \underbrace{\sum_s [\omega_i(s) - \bar{\omega}(s)]\left(\frac{\mathrm{VAX}_i(s) + \overline{\mathrm{VAX}}(s)}{2}\right)}_{\text{between term}}, \quad (4.12)$$

where s denotes sector, i denotes country and $\omega(s)$ and $\mathrm{VAX}(s)$ are the export share and VAX ratio in sector s. Bars denote reference country variables, which are constructed based on global composites.[38] In this decomposition, the within term varies primarily due to differences in VAX ratios within sectors across countries, while the between term is influenced mainly by differences in the sector composition of trade. To isolate compositional shifts between manufactures and non-manufactures, we calculate the decomposition using two composite sectors, pooling services plus agriculture and natural resources into a single composite non-manufacturing sector.

Cross-country variation in aggregate VAX ratios is to a large extent driven by variation in the composition of exports. To illustrate this, we plot VAX deviations ($\mathrm{VAX}_i - \overline{\mathrm{VAX}}$) against the between and within terms separately in Figure 4.2.[39] In part (a), the between term is a strong and tight predictor of a country's aggregate VAX ratio. In contrast, the within term is actually weakly negatively correlated with the aggregate VAX ratio in part (b), and this relationship is relatively noisy. This visual impression is naturally confirmed by a simple variance decomposition. If we split the covariance of the between and within terms equally, the between term 'accounts for' nearly all the variation in the aggregate VAX ratio.[40] The between term is dominant because of the large differences in VAX ratios across sectors. Countries that export predominantly manufactures, the sector with the lowest VAX ratio, tend to have low aggregate VAX ratios as well.

[38] Reference country VAX ratios for each sector are the ratios of value-added exports to gross exports for the world as a whole. Export shares are the share of each sector in total world exports.

[39] The regression line in part (a) is $\mathrm{VAX}_i - \overline{\mathrm{VAX}} = 0.26 \times$ between term, with robust standard error 0.04 and $R^2 = 0.36$. The regression line in part (b) is $\mathrm{VAX}_i - \overline{\mathrm{VAX}} = -0.11 \times$ within term, with robust standard error 0.06 and $R^2 = 0.04$.

[40] Specifically, the variance breaks down as follows: var(agg. VAX) = 0.01, var(within) = 0.03, var(between) = 0.04, and cov(within, between) = −0.03. Due to the negative covariance between the two terms, the variance decomposition is sensitive to how one chooses to assign the covariance. The scatter plots in Figure 4.2 can be thought of as representing a situation in which one assigns the covariance equally to the two terms.

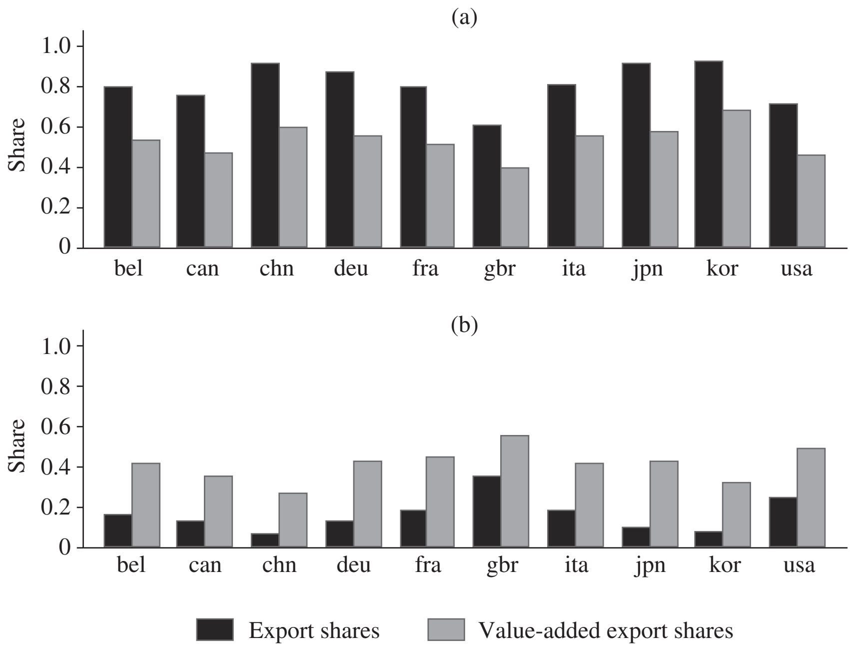

Figure 4.1: *Composite sector shares of gross exports and value-added exports, by country (2004): (a) manufactures; (b) services.*

Despite this strong composition effect, aggregate VAX ratios are only weakly related to the overall level of economic development. Part (a) of Table 4.2 shows that a one log point increase in income per capita is associated with a fall in domestic content of 0.8 percentage points, though this correlation is not significantly different from zero at conventional significance levels.[41] This weak aggregate correlation is a manifestation of two offsetting effects. First, richer countries tend to have exports concentrated in manufactures, which has a relatively low VAX ratio. Second, richer countries tend to export with higher VAX ratios than poorer countries within composite sectors, particularly within manufactures.

To illustrate these offsetting effects, we project the between term and the within term separately on exporter income to quantify the relative contribution of each to the overall correlation. In part (a) of Table 4.2, we see that there is a strong negative correlation of the between term with exporter income. That is, countries systematically shift towards manufacturing (which has lower value added to output on average) as they grow richer and this

[41] The p-value for a two-sided test that the correlation does not equal zero is 14%. In this regression, we omit outliers Belgium, Luxembourg and Singapore. If these three countries are included, the correlation roughly doubles in size and becomes highly significant.

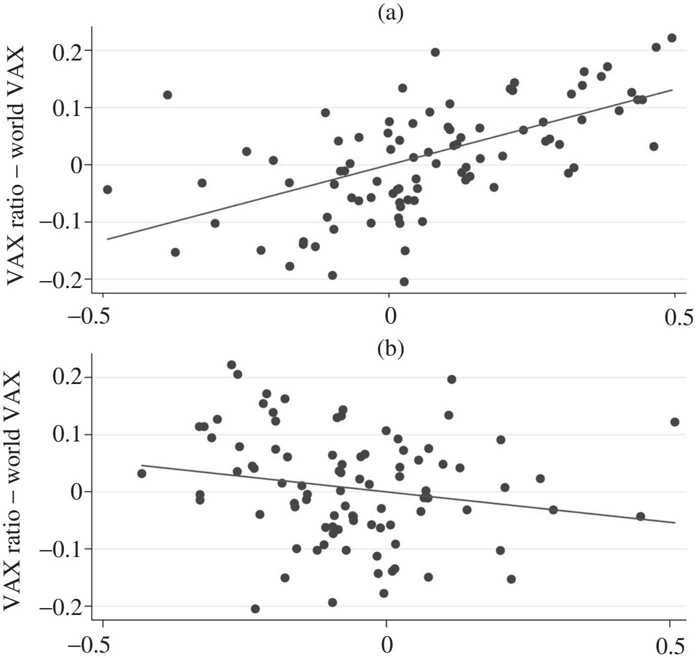

Figure 4.2: *Between–within decomposition of aggregate VAX ratios, by country (2004).* (a) Between term; (b) within term.

depresses the aggregate VAX ratios. The effect of this on overall VAX ratios is obscured because the within term is significantly positively correlated with exporter income. This positive correlation is mostly due to the fact that rich countries have higher VAX ratios within Manufactures. Part (b) of Table 4.2 shows the correlation of VAX ratios for manufactures with income per capita and splits this into between and within terms as above.[42] The positive correlation between manufactures VAX ratios and income is itself driven by a positive composition ('between') effect, wherein richer countries tend to specialise in manufacturing sectors with high VAX ratios.

3.2 Bilateral Value-Added Exports and Balances

For a particular exporter, bilateral VAX ratios differ widely across destinations. For concreteness, we graphically present bilateral value added to trade ratios for the two largest exporters, the USA and Germany, in Figure 4.3. In the

[42]VAX ratios for the non-manufactures composite are positively correlated with income per capita, but the correlation is not significant. Therefore, we do not report these results separately.

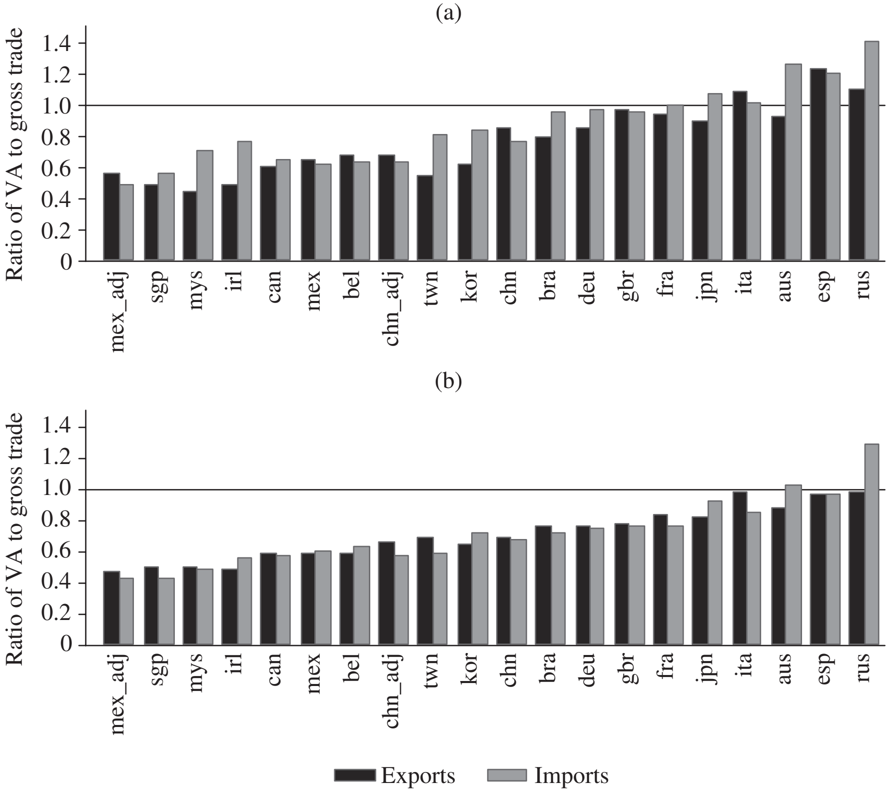

Figure 4.3: *Value added to gross trade ratios for the USA and Germany, by partner (2004).*

(a) US bilateral trade; (b) Germany bilateral trade.

figure, value added to import ratios are VAX ratios for each country exporting to the USA/Germany, while value added to export ratios are recorded for US/German exports to each country.[43]

Looking at the USA, there is wide variation in VAX ratios. For some partners, value-added exports are quite close to gross exports. For example, the difference between gross and value-added exports to the United Kingdom amounts to only 3% of gross exports. For others, gross trade either overstates or understates the bilateral exchange of value added. Value-added exports to Canada

[43]We display data for the 15 largest trade partners for each country plus additional countries selected for illustration purposes, including adjusted and unadjusted bilateral VAX ratios for China and Mexico. In line with the aggregate results, adjusting for processing trade lowers bilateral VAX ratios vis-à-vis these countries but has only modest effects on ratios for other countries.

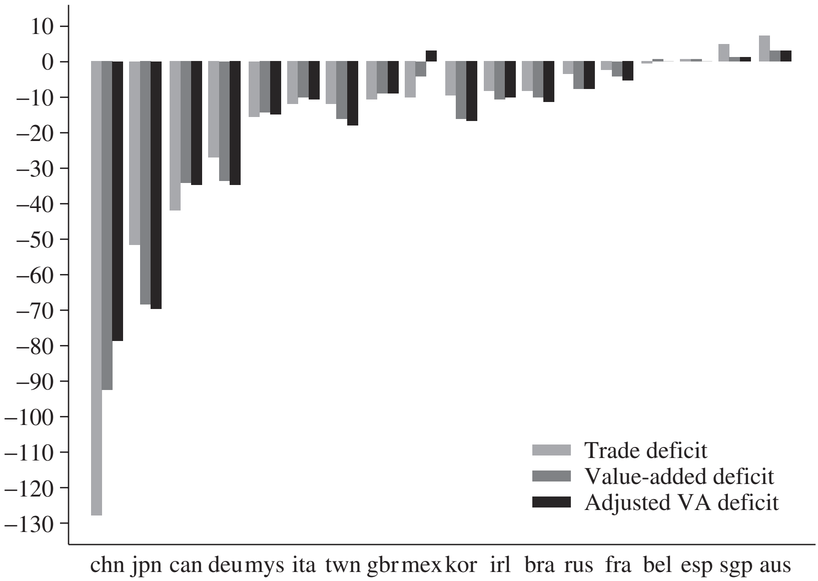

Figure 4.4: *Bilateral trade and value-added balances for the USA, by partner (2004).*

are US$77 billion (40%) smaller than gross exports, and value-added exports to Mexico are US$40–50 billion (36–44%) smaller. Value-added trade falls by a similar proportional amount, between 30% and 50%, relative to gross trade for countries like Ireland, Korea and Taiwan (Chinese Taipei), which are well-cited examples of production sharing partners. At the other end of the spectrum, several countries have VAX ratios towards the USA above 1. For example, countries on Europe's eastern periphery (see Russia) have bilateral VAX ratios above 1 mainly because they supply intermediates to Western European countries that then end up being consumed in the USA. Further, commodity producers (see Australia) also often have ratios above 1.

The US data are representative of general patterns in the data.[44] Looking at Germany, discrepancies between value added and gross trade also vary in meaningful ways across partners. Value-added trade is scaled down quite substantially for the vast majority of its large European partners, in contrast to the USA. This surely is an indication of the integrated structure of production within the European Union and its neighbours. Consistent with anecdotal evidence, this is most pronounced for the Czech Republic and Hungary. Geography appears to play a substantial role, as trade with partners of similar income levels, such as the USA and Japan, is relatively less distorted.

[44]The median bilateral VAX ratio in the data is 0.91, and the 10th-to-90th percentile range is 0.59 to 2.07. Approximately 40% of the bilateral VAX ratios are greater than 1.

One consequence of these trade adjustments is that bilateral trade balances differ when measured in gross versus value-added terms. Figure 4.4 displays three measures of bilateral balances for the USA: the bilateral trade balance, the bilateral value-added balance and the bilateral value-added balance adjusted for processing exports in China and Mexico. In interpreting this figure, it is important to keep in mind that multilateral trade balances equal the multilateral value-added balance for each country. Therefore, a decline in the bilateral value-added balance relative to the gross trade balance for one country necessarily implies an increase for some other country.

Comparing these alternate measures, there are large shifts in bilateral balances in Asia. Most prominently, the US deficit with China falls by roughly 30–40% (US$35–50 billion), while the deficit with Japan rises by around 33% (US$17–18 billion). The end result is that the value-added balances (adjusted for processing trade) are nearly equal for Japan and China. Looking elsewhere within Emerging Asia, US deficits with Taiwan (Chinese Taipei) and South Korea also rise and US surpluses with Australia and Singapore fall. Together, adjustments in these five countries (Australia, Japan, Singapore, South Korea and Taiwan) nearly exactly add up to the fall in the US–China deficit, which points to triangular production sharing within Asia, with these countries feeding intermediates to China that are then embodied in Chinese exports to the USA.

To understand these adjustments, we focus on the US–China and US–Japan balances with reference to the decomposition of the value-added balance in Equation (4.11). First, looking at China, the VAX ratio for US exports to China exceeds the VAX ratio for imports by about 8% in the unadjusted calculation and 4% in the adjusted calculation. This tends to raise the value-added balance relative to the trade balance, though only modestly (by US$10 billion without adjustment and US$5 billion with adjustment).[45] Second, the value-added content of both bilateral US exports and imports to/from China are well below 1. The simple average VAX ratio across exports and imports is 0.80 without adjustment and 0.66 with adjustment. If VAX ratios for both exports and imports were equal to this average level, this would imply value-added deficits 20% or 34% smaller than the gross deficits. This second ‘level effect’ accounts for most of the adjustment from gross to value-added balances for China (between US$25 billion and US$44 billion of the total change). In contrast, for Japan, this level effect is virtually nil, as the simple average VAX ratio is near 1 (literally, 0.98 without adjustment and 1.00 with adjustment). The US deficit with Japan rises in value-added terms mainly because the ratio of value-added imports to gross imports is high relative to the ratio of value-added exports to gross exports (the VAX ratio for imports is 0.16 higher than for exports in both calculations).

[45] If gross trade were (counterfactually) balanced between the USA and China, the value-added balance would show a surplus due to this force alone.

3.3 Inspecting the Mechanism: Bilateral Decompositions

To demonstrate that production sharing drives variation in bilateral VAX ratios, we construct two decompositions in the data. The first decomposition splits variation in bilateral VAX ratios into components arising from differences in the composition of exports across destinations and differences in bilateral production sharing relations. The second decomposition looks directly at how output circulates within cross-border production chains by (approximately) splitting bilateral exports into components absorbed and consumed in the destination, reflected back and ultimately consumed in the source, and redirected and ultimately consumed in a third destination.

To construct the first decomposition, we express the bilateral VAX ratio as

$$\frac{\mathrm{va}_{ij}}{\iota x_{ij}} = \frac{\iota(I - A_{ii} - A_{Ii})y_{ij}}{\iota x_{ij}} = \underbrace{\frac{\iota(I - A_{ii} - A_{Ii})(I - A_{ii})^{-1}x_{ij}}{\iota x_{ij}}}_{\text{bilateral HIY (BHIY)}} + \underbrace{\frac{\iota(I - A_{ii} - A_{Ii})(y_{ij} - (I - A_{ii})^{-1}x_{ij})}{\iota x_{ij}}}_{\text{production sharing adjustment (PSA)}}. \tag{4.13}$$

The first term is equivalent to the Hummels–Ishii–Yi measure of the domestic content of exports calculated using bilateral exports. For a given source country, it varies only due to variation in the composition of the export basket across destinations.

The second term is a production sharing adjustment. This adjustment depends on the difference between the amount of country i output consumed in j, y_{ij}, and the gross output from i required to produce bilateral exports to j, $(I - A_{ii})^{-1}x_{ij}$. When $y_{ij} < (I - A_{ii})^{-1}x_{ij}$, the VAX ratio is smaller than the bilateral HIY benchmark. This situation arises when country i's intermediate goods shipped to country j are either reflected back to country i embedded in foreign produced final goods or intermediate goods used to produce domestic final goods, or redirected to third destinations embedded in country j's goods. When $y_{ij} > (I - A_{ii})^{-1}x_{ij}$, the VAX ratio is larger than the HIY benchmark. This situation arises when country i ships intermediates to some third country that then (directly or indirectly) embeds those goods in final goods absorbed in country j.

To quantify the role of each term in explaining bilateral VAX ratios, we decompose the variance of the bilateral VAX ratio for each exporter across destinations, $\mathrm{var}_i(\mathrm{va}_{ij}/\iota x_{ij})$, into variation due to the BHIY term versus the PSA Term. Table 4.3 reports the share of the total variance accounted for by the BHIY and PSA terms for representative exporters.[46] The production sharing adjustment (PSA term) evidently dominates the decomposition. This

[46] In the table, we split the covariance equally between the BHIY and PSA terms. Because the covariance is small, our conclusions are not sensitive to how we split the covariance.

implies that variation in production sharing relations across partners, not export composition across destinations, drives the bilateral VAX ratio. In other words, bilateral VAX ratios are determined not by what an exporter sends to any given destination, but rather by how those goods are used abroad. In concrete terms, even though the USA sends automobile parts to both Canada and Germany, the US VAX ratio with Canada is lower than with Germany because Canada is part of a cross-border production chain with the USA.

To look at production chains more directly, we construct a second decomposition that splits bilateral exports according to whether they are absorbed, reflected or redirected by the destination to which they are sent. We construct the decomposition using the division of bilateral exports into final and intermediate goods along with the output decomposition for the foreign destination:

$$\begin{aligned} \iota x_{ij} &= \iota(c_{ij} + A_{ij}y_j) \\ &= \underbrace{\iota(c_{ij} + A_{ij}y_{jj})}_{\text{absorption}} + \underbrace{\iota A_{ij}y_{ji}}_{\text{reflection}} + \underbrace{\sum_{k\neq j,i} \iota A_{ij}y_{jk}}_{\text{redirection}} . \end{aligned} \tag{4.14}$$

The first term captures the portion of bilateral exports absorbed and consumed in destination j, including both final goods from country i and intermediates from i embodied in country j's consumption of its own goods. The second term captures the reflection of country i's intermediates back to country i embodied in country j goods. The third term is the summation of country i's intermediates embodied in j's goods that are consumed in all other destinations, *ie* redirected to third destinations.[47]

We report the results of this decomposition for informative bilateral pairs in Table 4.4. Looking at the upper left portion of the table, we see that Japan's exports to China are primarily either absorbed in China or redirected to the USA. Comparing Japan's trade with China to that with the USA, we see that Japanese exports to the USA are nearly exclusively absorbed by the USA, indicating minimal bilateral US–Japan production sharing. In contrast, looking at the upper right panel, we see that large portions of US exports to Canada and Mexico are reflected back to the USA for final consumption. Looking at the lower left panel, we see that sharing a common border with two different countries does not necessarily imply tight bilateral production sharing relationships. German exports to France are primarily absorbed there, while

[47] This decomposition is only approximate, because the output split used in constructing the decomposition is influenced by the entire structure of cross-border linkages. Nonetheless, this decomposition is informative as it returns shares that are consistent with the zero order and first round effects of the Leontief matrix inversion (*ie* $[I + A]$) describing how final goods absorbed in each destination are produced. We prefer the decomposition in the text to this alternative 'first-order approximation' of the production structure because it adds up to bilateral exports.

nearly half of exports to the Czech Republic are reflected or redirected. Finally, in the lower right corner, we see that Korea is engaged in triangular trade with the USA and other destinations via China. In contrast, a larger share of Korean exports to Japan are eventually consumed there. These results are consistent with our priors regarding the role of China as a production sharing hub in Asia.[48]

4 CONCLUDING REMARKS

Intermediate goods trade is a large and growing feature of the international economy. Quantification of cross-border production linkages is therefore central to answering a range of important empirical questions in international trade and international macroeconomics. This requires going beyond specific examples or country/regional studies to develop a complete, global portrait of production sharing patterns. This chapter provides such a portrait using input–output and trade data to compute bilateral trade in value added. We document significant differences between value added and gross trade flows, differences that reflect heterogeneity in production sharing relationships. We look forward to applying this data in future work to deepen our understanding of the consequences of production sharing.

5 APPENDIX

The basic idea behind the adjustment for processing trade is to split the aggregate economy into separate processing and non-processing units, each with its own input–output structure. Both sectors use domestic and imported intermediates, but they differ in terms of intermediate input intensity and the source (domestic versus imported) of intermediates. Furthermore, all output in the export-processing sector is exported.

From the input–output data, we observe the domestic intermediate use matrix m_{ii} and import use matrix as m_{Ii} for the economy as a whole. From trade data, we observe total exports originating from, and imported intermediates used by, the processing sector, denoted x_i^{P} and $\bar{m}_{Ii}^{\mathrm{P}}$, respectively. Output in the non-processing sector, denoted y_i^{N}, is calculated by subtracting x_i^{P} from total output in the input–output accounts. We seek separate intermediate use matrices for the two sectors $\{m_{ii}^{\mathrm{N}}, m_{ii}^{\mathrm{P}}, m_{Ii}^{\mathrm{N}}, m_{Ii}^{\mathrm{P}}\}$ and value added by

[48] These decompositions are computed without adjusting for processing trade in China. Adjusting for processing trade tends to amplify reflection and redirection effects. Thus, our table understates the amount of redirection within Asia and reflection in US–Mexico trade.

sector $\{\text{va}_i^{\text{N}}, \text{va}_i^{\text{P}}\}$ that satisfy

$$m_{ii} = m_{ii}^{\text{N}} + m_{ii}^{\text{P}}, \tag{4.15}$$

$$m_{Ii} = m_{Ii}^{\text{N}} + m_{Ii}^{\text{P}}, \tag{4.16}$$

$$y_i^{\text{N}} = \text{va}_i^{\text{N}} + \iota[m_{ii}^{\text{N}} + m_{Ii}^{\text{N}}], \tag{4.17}$$

$$x_i^{\text{P}} = \text{va}_i^{\text{P}} + \iota[m_{ii}^{\text{P}} + m_{Ii}^{\text{P}}], \tag{4.18}$$

$$\bar{m}_{Ii}^{\text{P}} = m_{Ii}^{\text{P}} \iota^{\text{T}}, \tag{4.19}$$

where ι is a conformable row vector of ones and ι^{T} is its transpose.[49]

If there are N sectors, then there are $4(N \times N) + 2N$ unknowns and only $2(N \times N) + 3N$ constraints, so we cannot solve directly for the unknown coefficients. We therefore follow Koopman *et al* (2008) and use a constrained minimization routine to impute the unknown coefficients, where the objective function minimises squared deviations between imputed values and target values. Target values are set by splitting intermediate use and value added across processing and non-processing sectors according to their shares in total output.

With the resulting split tables, we use bilateral trade data as in the main text to construct bilateral sourcing matrices and the global input–output table.[50] In performing the calculation, we use processing trade shares from Koopman *et al* (2008) for China. For Mexico, we obtain trade data for the maquiladora sector from the Bank of Mexico.[51] Due to concerns about the quality of disaggregate data and the accuracy of the imputation procedure for individual sectors, we aggregate the data to three composite sectors prior to imputing coefficients. Because bilateral value added trade results are essentially identical in the main data when computed with fifty-seven sectors or three composite sectors, we believe aggregation does not result in diminished accuracy.

REFERENCES

Belke, A., and L. Wang (2006). The Degree of Openness to Intra-regional Trade: Towards Value-Added Based Openness Measures. *Jahrbucher fur Nationalokonomie und Statistik* **226**(2), 115–138.

Bems, R., R. C. Johnson and K.-M. Yi (2010). Demand Spillovers and the Collapse of Trade in the Global Recession. *IMF Economic Review* **58**(2), 295–326.

Chen, X., L. Cheng, K C Fung and L. Lau (2008). The Estimation of Domestic Value-Added and Employment Induced by Exports: An Application to Chinese Exports to

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[49]These constraints differ from those used by Koopman *et al* (2008) in that we use the domestic and import intermediate use matrices separately, whereas they pool this information into a single overall use matrix.

[50]In the resulting system, China and Mexico effectively have $2N$ sectors, where each of the N sectors is separated into processing and non-processing sub-sectors.

[51]Data are available at http://www.banxico.org.mx/.

the United States. In *China and Asia: Economic and Financial Interactions*, edited by Yin Wong Cheung and Kar Yiu Wong. Routledge.

Costinot, A., J. Vogel and S. Wang (2011). An Elementary Theory of Global Supply Chains. NBER Working Paper 16936.

Daudin, G., C. Rifflart and D. Schweisguth (2011). Who Produces for Whom in the World Economy? *Canadian Journal of Economics* **44**(4), 1403–1437.

Dean, J. M., K. C. Fung and Z. Wang (2007). Measuring the Vertical Specialization in Chinese Trade. USITC Office of Economics Working Paper 2007-01-A.

Hanson, G. H., R. J. Mataloni and M. J. Slaughter (2005). Vertical Production Networks in Multinational Firms. *The Review of Economics and Statistics* **87**(4), 664–678.

Hummels, D., J. Ishii and K.-M. Yi (2001). The Nature and Growth of Vertical Specialization in World Trade. *Journal of International Economics* **54**, 75–96.

Isard, W. (1951). Interregional and Regional Input–Output Analysis: A Model of a Space-Economy. *The Review of Economics and Statistics* **33**, 318–328.

Johnson, R. C. (2008). Factor Trade Forensics: Intermediate Goods and the Factor Content of Trade. Mimeo, Dartmouth College.

Johnson, R. C., and G. Noguera (2012). Accounting for Intermediates: Production Sharing and Trade in Value Added. *Journal of International Economics* **86**(2), 224–236.

Koopman, R., Z. Wang and S.-J. Wei (2008). How Much of Chinese Exports is Really Made in China? Assessing Domestic Value-Added when Processing Trade Is Pervasive. NBER Working Paper 14109.

Koopman, R., W. Powers, Z. Wang and S.-J. Wei (2010). Give Credit Where Credit Is Due: Tracing Value Added in Global Production Chains. NBER Working Paper 16426.

Linden, G., K. Kraemer and J. Dedrick (2007). Who Captures Value in a Global Innovation System? The Case of Apple's iPod. Mimeo, Personal Computing Industry Center, UC Irvine.

Miller, R. (1966). Interregional Feedback Effects in Input–Output Models: Some Preliminary Results. *Papers in Regional Science* **17**(1), 105–125.

Miroudot, S., and A. Ragoussis (2009). Vertical Trade, Trade Costs and FDI. OECD Trade Policy Working Paper 89.

Moses, L. (1955). The Stability of Interregional Trading Patterns and Input–Output Analysis. *The American Economic Review* **45**, 803–826.

Moses, L. (1960). A General Equilibrium Model of Production, Interregional Trade, and Location of Industry. *The Review of Economics and Statistics* **42**, 373–397.

Noguera, G. (2011). Augmented Gravity: Accounting for Production Sharing. Mimeo, Columbia Business School.

NRC (2006). Analyzing the US Content of Imports and the Foreign Content of Exports. Washington, DC: National Research Council, The National Academies Press.

Powers, W., Z. Wang and S.-J. Wei (2009). Value Chains in East Asian Production Networks: An International Input–Output Model Based Analysis. USTIC Working Paper 2009-10-C.

Puzzello, L. (2012). A Proportionality Assumption and Measurement Biases in the Factor Content of Trade. *Journal of International Economics* **87**(1), 105–111.

Reimer, J. (2006). Global Production Sharing and Trade in the Services of Factors. *Journal of International Economics* **68**, 384–708.

Trefler, D., and S. C. Zhu (2010). The Structure of Factor Content Predictions. *Journal of International Economics* **82**, 195–207.

Yeats, A. J. (2001). Just How Big Is Global Production Sharing? In *Fragmentation: New Production Patterns in the World Economy* (ed. S. Arndt and H. Kierzkowski), Chapter 7. Oxford University Press.

Yi, K.-M. (2003). Can Vertical Specialization Explain the Growth of World Trade? *Journal of Political Economy* **111**, 52–102.
Yi, K.-M. (2010). Can Multi-Stage Production Explain the Home Bias in Trade? *American Economic Review* **100**(1), 364–393.

Table 4.1: *VAX ratios by country and sector.*

Country	Code	Aggregate	Composite Sector: Ag.& Nat.R.	Manuf.	Services
Central & Eastern Europe					
Albania	alb	0.79	2.10	0.44	0.97
Armenia	arm	0.67	1.21	0.46	1.12
Azerbaijan	aze	0.86	1.14	0.18	1.08
Belarus	blr	0.69	5.69	0.35	4.25
Bulgaria	bgr	0.63	0.85	0.38	1.17
Croatia	hrv	0.71	1.04	0.52	0.92
Czech Republic	cze	0.59	1.52	0.43	1.51
Estonia	est	0.53	1.07	0.34	0.94
Georgia	geo	0.77	1.23	0.38	1.44
Hungary	hun	0.54	0.96	0.38	1.39
Kazakhstan	kaz	0.78	0.53	0.50	3.26
Kyrgyzstan	kgz	0.70	0.78	0.49	1.01
Latvia	lva	0.64	0.84	0.51	0.96
Lithuania	ltu	0.63	0.95	0.46	1.23
Poland	pol	0.70	1.34	0.52	1.57
Romania	rou	0.70	2.58	0.48	1.95
Russian Federation	rus	0.87	0.99	0.41	2.49
Slovakia	svk	0.55	1.29	0.39	1.77
Slovenia	svn	0.64	2.26	0.44	1.59
Ukraine	ukr	0.67	0.92	0.27	2.67
North & South America					
Argentina	arg	0.84	1.27	0.40	2.26
Bolivia	bol	0.85	1.08	0.24	1.79
Brazil	bra	0.86	0.95	0.51	3.27
Canada	can	0.70	1.00	0.44	1.97
Chile	chl	0.80	0.92	0.46	2.31
Colombia	col	0.86	0.92	0.51	2.16
Costa Rica	cri	0.69	0.68	0.37	2.23
Ecuador	ecu	0.90	0.90	0.37	3.30
Guatemala	gtm	0.79	0.82	0.43	1.83
Mexico	mex	0.67	0.69	0.65	0.93
Mexico (adjusted)	mex_adj	0.52	0.88	0.41	1.27
Nicaragua	nic	0.74	1.12	0.38	2.04
Panama	pan	0.84	1.06	0.36	0.91
Paraguay	pry	0.84	0.91	0.28	1.07
Peru	per	0.93	0.99	0.72	1.78
USA	usa	0.77	0.86	0.49	1.58
Uruguay	ury	0.71	1.31	0.42	1.30
Venezuela	ven	0.89	1.06	0.29	5.54

Source: authors' calculations based on GTAP Database Version 7.1. Data is for 2004.

Table 4.1: *Continued.*

Country	Code	Aggregate	Composite Sector		
			Ag.& Nat.R.	Manuf.	Services
South Asia & Oceania					
Australia	aus	0.86	0.87	0.50	1.64
Bangladesh	bgd	0.75	5.06	0.43	2.66
India	ind	0.81	1.80	0.46	1.68
New Zealand	nzl	0.82	1.56	0.43	1.60
Pakistan	pak	0.82	4.70	0.39	2.18
Sri Lanka	lka	0.66	1.10	0.42	1.31
Western Europe					
Austria	aut	0.67	2.09	0.49	1.01
Belgium	bel	0.48	0.54	0.32	1.29
Cyprus	cyp	0.77	1.18	0.64	0.79
Denmark	dnk	0.73	1.27	0.53	1.01
Finland	fin	0.72	3.83	0.50	1.52
France	fra	0.73	1.17	0.47	1.79
Germany	deu	0.74	1.56	0.47	2.52
Greece	grc	0.77	1.44	0.56	0.82
Ireland	irl	0.66	2.05	0.46	1.11
Italy	ita	0.77	2.18	0.53	1.77
Luxembourg	lux	0.40	0.83	0.43	0.39
Malta	mlt	0.63	0.71	0.62	0.64
Netherlands	nld	0.69	0.96	0.43	1.29
Norway	nor	0.87	0.91	0.47	1.41
Portugal	prt	0.68	2.25	0.46	1.17
Spain	esp	0.75	1.19	0.46	1.32
Sweden	swe	0.72	1.94	0.43	1.84
Switzerland	che	0.67	0.74	0.44	1.43
United Kingdom	gbr	0.79	1.05	0.51	1.24
East Asia					
Cambodia	khm	0.62	3.86	0.40	1.26
China	chn	0.70	4.11	0.46	2.75
China (adjusted)	chn_adj	0.59	3.90	0.40	1.97
Hong Kong	hkg	0.73	49.74	0.38	0.84
Indonesia	idn	0.79	1.47	0.45	2.39
Japan	jpn	0.85	2.70	0.53	3.93
Korea	kor	0.63	2.53	0.46	2.62
Lao	lao	0.74	1.97	0.33	0.91
Malaysia	mys	0.59	1.53	0.41	1.87
Philippines	phl	0.58	1.55	0.44	2.15
Singapore	sgp	0.37	0.40	0.25	0.80
Taiwan (Chinese Taipei)	twn	0.58	1.36	0.39	3.18
Thailand	tha	0.60	3.64	0.38	1.52
Vietnam	vnm	0.58	1.04	0.35	1.26

Source: authors' calculations based on GTAP Database Version 7.1. Data is for 2004.

Table 4.1: *Continued.*

Country	Code	Aggregate	Composite Sector: Ag.& Nat.R.	Composite Sector: Manuf.	Composite Sector: Services
Middle East & Africa					
Botswana	bwa	0.88	0.91	0.57	1.17
Egypt	egy	0.81	2.69	0.43	0.79
Ethiopia	eth	0.76	1.03	0.18	0.80
Iran	irn	0.95	1.09	0.26	1.74
Madagascar	mdg	0.75	0.91	0.50	1.02
Malawi	mwi	0.72	0.56	0.49	3.70
Mauritius	mus	0.72	0.87	0.59	0.86
Morocco	mar	0.78	1.26	0.50	1.12
Mozambique	moz	0.76	1.25	0.35	1.49
Nigeria	nga	0.94	0.95	0.59	0.92
Senegal	sen	0.73	1.04	0.48	1.02
South Africa	zaf	0.80	0.62	0.45	2.96
Tanzania	tza	0.81	1.07	0.26	1.19
Tunisia	tun	0.69	1.43	0.38	1.45
Turkey	tur	0.76	1.25	0.51	1.46
Uganda	uga	0.83	0.89	0.35	1.24
Zambia	zmb	0.78	1.02	0.25	9.29
Zimbabwe	zwe	0.69	0.58	0.44	2.69
Medians by Region					
Central & Eastern Europe	0.68	1.10	0.43	1.42	
East Asia	0.62	1.97	0.40	1.87	
Middle East & Africa		0.77	1.03	0.45	1.21
North & South America	0.84	0.95	0.42	1.97	
South Asia & Oceania		0.81	1.68	0.43	1.66
Western Europe	0.72	1.19	0.47	1.29	
Overall		0.73	1.09	0.44	1.46

Source: authors' calculations based on GTAP Database Version 7.1. Data is for 2004.

Table 4.2: *Aggregate and manufacturing VAX decompositions.*

(a) Aggregate VAX decomposition

	$VAX_i - \overline{VAX}$	Within term	Between term
Log income per capita	−0.008	0.028**	−0.036***
	(0.005)	(0.011)	(0.013)
R^2	0.02	0.07	0.08
N	90	90	90

(b) Manufacturing VAX decomposition

	$VAX_i - \overline{VAX}$	Within term	Between term
Log income per capita	0.018***	−0.007	0.025***
	(0.006)	(0.009)	(0.008)
R^2	0.11	0.01	0.12
N	89	89	89

Robust standard errors are given in parentheses. Significance levels: $^*p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Constants are included in all regressions. Income per capita equals exporter value added per capita, where value added is calculated using our data and population is from the GTAP 7.1 database. Belgium, Luxembourg and Singapore are excluded from the data in part (a) and Botswana, Hong Kong, Paraguay and Peru are excluded from the data in part (b) as outliers.

Table 4.3: *Bilateral VAX ratio: bilateral HIY versus production sharing adjustment.*

	Variance decomposition	
Exporter	BHIY term (%)	PSA term (%)
USA	5	95
Germany	5	95
Japan	1	99
China	9	91
Argentina	1	99
France	8	92
Hungary	5	95
India	7	93
Portugal	9	91
Median country	3	97

See the text for details regarding the decomposition. The median country is the median statistic for all 93 countries in the data.

Table 4.4: *Decomposing trade: absorption, reflection and redirection.*

Japan exports to:				US exports to:			
China		USA		Mexico		Canada	
China	64.5	USA	92.7	Mexico	72.3	Canada	68.9
USA	11.1	Canada	1.4	USA	22.1	USA	24.1
Japan	4.3	Mexico	0.7	Canada	0.9	UK	0.7
Germany	2.5	Japan	0.6	Germany	0.4	Japan	0.7
Germany exports to:				**Korea exports to:**			
France		Czech Rep.		China		Japan	
France	74.8	Czech Rep.	57.7	China	61.3	Japan	83.1
Germany	3.6	Germany	11.7	USA	12.1	USA	4.7
UK	2.8	UK	3.0	Japan	4.7	China	2.3
USA	2.6	USA	2.6	Germany	2.7	Germany	1.0

All figures are given as percentages. See the text for details regarding the decomposition. The entries in the table describe the approximate share of bilateral exports to each destination that are ultimately consumed in that destination. Shares do not sum to 1 because we include only the top four destinations for each bilateral pair. Data is for 2004.

5

Estimating Domestic Content in Exports when Processing Trade Is Pervasive

ROBERT KOOPMAN, ZHI WANG AND SHANG-JIN WEI[1]

For many questions, it is crucial to know the extent of domestic value added (DVA) in a country's exports, but the computation is more complicated when processing trade is pervasive. We propose a method for computing domestic and foreign contents that allows for processing trade. By applying our framework to Chinese data, we estimate that the share of domestic content in its manufactured exports was about 50% before China's WTO membership, and has risen to nearly 60% since then. There are also variations across sectors. Those sectors that are likely to be labelled as relatively sophisticated, such as electronic devices, have particularly low domestic content (about 30% or less).

1 INTRODUCTION

This chapter proposes an accounting framework for estimating the domestic/foreign content share in a country's exports when processing trade is prevalent. We then apply the framework to the People's Republic of China (PRC), one of the world's best known processing exporters; however, the underlying methodology is relevant for all countries (*eg* Mexico and Vietnam) that use a processing trade scheme. Indeed, the World Trade Organization has identified more than 130 countries that use some form of processing exports (WTO and IDE-JETRO 2011). Processing trade can take on other names in some countries, such as a duty drawback scheme, which means a rebate of tariffs paid on imported inputs if they are used for exports.

Of course, the choice of China as an illustration of the general methodology is not random. 'Made in China' is one of the most common labels one encounters in a shopping mall in the USA and Europe. Increasingly, many products

[1]This chapter was originally published as Koopman *et al* (2012). It has been modified slightly to conform with the style of this book. We are grateful for the helpful comments by participants of numerous conferences and seminars, and to the editor of this book. The views expressed in this chapter are those of the authors alone. They do not necessarily reflect the views of the US International Trade Commission, or any of its individual Commissioners. We are solely responsible for any errors in the chapter.

that are supposed to be technically sophisticated and therefore likely to be associated with exports from high-income countries, such as digital cameras and computers, also carry that label. Since the most salient characteristic of the factor endowment in China is a vast supply of unskilled labour relative to either physical or human capital, is the country's actual export structure inconsistent with the predictions from the international trade theory based on its endowment? A possible resolution to the puzzle is that China is simply the last section of a long global production chain that ends up assembling components from various countries into a final product before it is exported to the USA and EU markets. Indeed, a MacBook computer carries a label on its reverse (in small type) that reads 'Designed by Apple in California; assembled in China'. This label is likely to be oversimplified already, as it reports only the head and the tail of a global production chain and skips many other countries that supply other components that go into the product.

China is the archetype of a national economy that is well integrated into a global production chain. It imports raw material, equipment and manufactured intermediate inputs, and then exports a big fraction of its output to the world market. The PRC is not the only country whose production and exports are a part of a global chain; Japan, Korea, Singapore and Malaysia, for example, participate actively in the international divisions of labour. However, the PRC is noteworthy due to its sheer size. In addition, its export/GDP ratio, at 35% or higher in recent years (compared with about 8% for the USA and 13% for India) is extraordinarily high for a large economy. With a reputation as a 'world factory', China is a top supplier of manufacturing outsourcing for many global companies.

For many policy issues, it is important to assess the extent of domestic content in exports. For example, what is the effect of a currency appreciation on a country's exports? The answer depends crucially on the share of domestic content in the exports. All other things being equal, the lower the share of domestic content in the exports, the smaller the effect a given exchange rate appreciation would have on trade volume. As another example, what is the effect of trading with the PRC on US income inequality? The answer depends in part on whether the PRC simply exports products that are intensive in low-skilled labour or whether its exports are more sophisticated. Rodrik (2006) notes that the per capita income typically associated with the kind of goods bundle that the PRC exports is much higher than the country's actual income. He interprets this as evidence that the skill content of its exports is likely to be much higher than its endowment may imply. Schott (2008) documents an apparent rapid increase in the similarity between the PRC's export structure and that of high-income countries, and interprets it as evidence of a rise in the level of sophistication embedded in the country's exports. Wang and Wei (2008) use disaggregated regional data to investigate the determinants of the rise in export sophistication. Indeed, many other observers have expressed fear that the PRC is increasingly producing and exporting sophisticated products and may be providing wage competition for mid- to high-skilled workers in the USA and Europe. However, Xu (2007) points out that the calculation of Rodrik (2006) and Schott (2008) did not take into account possible quality differences between Chinese varieties and those of other countries, and also did not take into account diverse production capabilities and income level in different Chinese regions. Our study further indicates that the calculations by Rodrik (2006) and Schott (2008) do not take into account the imported content in the country's exports. Therefore, Rodrik's and Schott's assessments on the sophistication of China's exports are very likely to be exaggerated. If the domestic content in exports from the PRC is low, especially in sectors that would have been considered sophisticated or high-skilled in the USA, then imports from the PRC may still generate a large downwards pressure on the wage of low-skilled Americans after all (as pointed out by Krugman 2008). These are important policy questions and have implications for both developing and developed countries. A good understanding of the nature and extent of global supply chains can provide important insights for economists and policymakers.

How would one assess foreign versus domestic content in a country's exports? Hummels *et al* (2001) (henceforth denoted HIY) propose a method to decompose a country's exports into domestic and foreign value-added share based on a country's input–output (IO) table. They make a key assumption that the intensity in the use of imported inputs is the same between production for exports and production for domestic sales. This assumption is violated in the presence of processing exports. Processing exports are characterized by imports for exports with favourable tariff treatment: firms import parts and other intermediate materials from abroad, with exemptions on the imported inputs and tax preferences from local or central governments and, after processing or assembling, the finished products. It is important to stress that processing exporters may also use different technologies from normal exporters; these call for different usages of imported inputs. They usually lead to a significant difference in the intensity of imported intermediate inputs in production of processing exports and that in other demand sources (for domestic final sales and normal exports). Since processing exports have accounted for more than 50% of China's exports every year since 1996, the HIY formula is likely to lead to a significant underestimation of the share of foreign value added in its exports.

Since processing exports are widespread,[2] ignoring processing exports is likely to lead to estimation errors, especially for economies that engage in a massive amount of processing trade.

In this chapter, we aim to make two contributions to the literature. First, we develop a formula for computing shares of foreign and domestic value added

[2] About 3500 export processing zones (EPZs) operated in 130 countries (WTO and IDE-JETRO 2011).

in a country's exports when processing exports are pervasive. The formula allows for potential differences in the use of imported inputs between normal and processing exports. We illustrate mathematically that the HIY formula is a special case of this general formula. The differences between the two types of exports could come from differences in the technology used, responses to different tariff or tax treatments, or some other reasons. This chapter does not formally investigate the sources of these differences, and our formula is invariant to the relative importance of the underlying factors. Second, we apply our methodology to China using data for 1997, 2002 and 2007. We estimate that the share of foreign value added in PRC's manufactured exports was about 50% in both 1997 and 2002, almost twice as high as that implied by the HIY formula, but fell to about 40% in 2007 after five years of its WTO membership. There also variations across sectors. Those sectors that are likely to be labelled as sophisticated, such as computers, telecommunications equipment and electronic devices, have particularly low domestic content (about 30% or less).

By design, this chapter presents an accounting framework and conducts an accounting exercise. As such, it does not examine determinants and consequences of changes in the domestic content share in China's gross exports. However, a solid methodology to estimate foreign value-added share in a country's exports is a necessary first step towards a better understanding of these issues.

In addition to the papers on vertical specialisation in the international trade literature, this chapter is also related to the IO literature. In particular, Chen *et al* (2004) and Lau *et al* (2007) were the first to develop a 'non-competitive'-type IO model for China (*ie* one in which imported and domestically produced inputs are accounted for separately) and to incorporate processing exports explicitly. However, these papers do not describe a systematic way to infer separate input–output coefficients for production of processing exports versus those for other final demands. It is therefore difficult for others to replicate their estimates or apply their methodology to other countries. They focus on estimating US–China bilateral trade balance and make no connection with vertical specialisation in the international trade literature. In addition, they use an aggregated version of China's 1995 and 2002 input–output tables, respectively, to perform their analysis, with only 21 goods-producing industries. We provide a more up-to-date and more disaggregated assessment of foreign and domestic value added in Chinese exports, with more than 80 goods-producing industries. Finally, they impose an assumption in estimating the import use matrix from the competitive type IO table published by China's National Statistical Bureau: within each industry, the mix of the imported and domestic inputs is the same in capital formation, intermediate inputs and final consumption. We relax this assumption by refining a method proposed in Dean *et al* (2007) that combines China's processing imports statistics with United Nations Broad Economic Categories (UNBEC) classification.

The rest of the chapter is organised as follows. Section 2 presents a conceptual framework for estimating shares of domestic and foreign value added in a country's exports when processing exports are pervasive. It also describes a mathematical programming procedure to systematically infer a set of IO coefficients called for by the new formula but not typically available from a conventional IO table. Section 3 presents the estimation results for Chinese exports. Section 5 concludes.

2 CONCEPTUAL FRAMEWORK AND ESTIMATION METHOD

2.1 When Special Features of Processing Exports Are Not Taken into Account

We first discuss how domestic and foreign contents in a country's exports can be computed when it does not engage in any processing trade. The discussion follows the input–output literature, and is the approach adopted (implicitly) by Hummels *et al* (2001) and Yi (2003). Along the way, we will point out a clear connection between the domestic content concept and the concept of vertical specialisation.[3]

When imported and domestically produced intermediate inputs are accounted separately, value-based input–output table can be specified as follows:[4]

$$A^{\mathrm{D}}X + Y^{\mathrm{D}} = X, \tag{5.1}$$

$$A^{\mathrm{M}}X + Y^{\mathrm{M}} = M, \tag{5.2}$$

$$uA^{\mathrm{D}} + uA^{\mathrm{M}} + A_v = u, \tag{5.3}$$

where $A^{\mathrm{D}} = [a_{ij}^{\mathrm{D}}]$ is an $n \times n$ matrix of direct input coefficients for domestic products, $A^{\mathrm{M}} = [a_{ij}^{\mathrm{M}}]$ is an $n \times n$ matrix of direct inputs of imported goods, Y^{D} is an $n \times 1$ vector of final demands for domestically produced products, including usage in gross capital formation, private and public final consumption and gross exports, Y^{M} is an $n \times 1$ vector of final demands for imported products, including usage in gross capital formation, private and public final consumption, X is an $n \times 1$ vector of gross output, M is an $n \times 1$ vector of

[3] We use the terms 'domestic value added' and 'domestic content' interchangeably. Similarly, we use the terms 'foreign value added', 'foreign content' and 'vertical specialisation' to mean the same thing.

[4] Such a model is called a 'non-competitive' model in the IO literature. HIY do not this system explicitly but go straight to the implied Leontief inverse, while Chen *et al* (2004) specify only the first two equations. A fully specified model facilitates better understanding of the connection between vertical specialisation and domestic content, and facilitates a comparison with the model in the next subsection that features processing exports.

imports, $A_v = [a_j^v]$ is a $1 \times n$ vector of each sector j's ratio of value added to gross output and u is a $1 \times n$ unity vector; i and j indicate sectors, and superscripts 'D' and 'M' represent domestically produced and imported products, respectively.

Equations (5.1) and (5.2) define horizontal balance conditions for domestically produced and imported products, respectively. A typical row k in Equation (5.1) specifies that total domestic production of product k should be equal to the sum of the sales of product k to all intermediate and final users in the economy (the final sales include domestic consumption and capital formation, plus exports of product k). A typical row h in Equation (5.2) specifies that the total imports of product h should be equal to the sum of the sales of product h to all users in the economy, including intermediate inputs for all sectors, plus final domestic consumption and capital formation. Equation (5.3) is both a vertical balance condition and an adding-up constraint for the input–output coefficient. It implies that the total output X in any sector k has to be equal to the sum of direct value added in sector k and the cost of intermediate inputs from all domestically produced and imported products.

From Equation (5.1) we have[5]

$$X = (I - A^{\mathrm{D}})^{-1} Y^{\mathrm{D}}. \tag{5.4}$$

$(I - A^{\mathrm{D}})^{-1}$ is the well-known 'Leontief inverse', a matrix of coefficients for total domestic intermediate product requirement. Define a vector of share of domestic content, or domestic value added, in a unit of domestically produced products, $\mathrm{DVS} = \{\mathrm{dvs}\}_j$, a $1 \times n$ vector, as the additional domestic added generated by one additional unit of final demand of domestic products ($\Delta Y^{\mathrm{D}} = u^{\mathrm{T}}$):

$$\mathrm{DVS} = \frac{\hat{A}_v \Delta X}{\Delta Y^{\mathrm{D}}} = \hat{A}_v (I - A^{\mathrm{D}})^{-1} = A_v (I - A^{\mathrm{D}})^{-1}, \tag{5.5}$$

where $\hat{A}_v$ is an $n \times n$ diagonal matrix with a_j^v as its diagonal elements. Equation (5.5) indicates that the domestic content for an IO industry is the corresponding column sum of the coefficient matrix for total domestic intermediate goods requirement, weighted by the direct value-added coefficient of each industry. Because the standard model assumes that exports and domestic sales are produced by the same technology, the share of domestic content in final demand and the share of domestic content in total exports are the same. So Equation (5.5) is also the formula for the share of domestic content in total exports for each industry.

Define a vector of share of foreign content (or foreign value added) in final demand for domestically produced products by $\mathrm{FVS} = u - \mathrm{DVS}$. By making use of Equation (5.3), it can be verified that

$$\mathrm{FVS} = u - A_v (I - A^{\mathrm{D}})^{-1} = u A^{\mathrm{M}} (I - A^{\mathrm{D}})^{-1}. \tag{5.6}$$

[5] $(I - A^{\mathrm{D}})$ has to be full rank.

<table>
<tr><td colspan="2"></td><td></td><td colspan="2">Intermediate use</td><td colspan="2"></td></tr>
<tr><td colspan="2" rowspan="2"></td><td></td><td>Production for domestic use & normal exports</td><td>Production of processing exports</td><td>Final use (C+I+G+E)</td><td>Gross output or imports</td></tr>
<tr><td>DIM</td><td>1, 2, …, N</td><td>1, 2, …, N</td><td>1</td><td>1</td></tr>
<tr><td rowspan="2">Domestic intermediate inputs</td><td>Production for domestic use & normal exports (D)</td><td>1 ⋮ N</td><td>Z^{DD}</td><td>Z^{DP}</td><td>$Y^D - E^P$</td><td>$X - E^P$</td></tr>
<tr><td>Processing exports (P)</td><td>1 ⋮ N</td><td>0</td><td>0</td><td>E^P</td><td>E^P</td></tr>
<tr><td colspan="2">Intermediate inputs from imports</td><td>1 ⋮ N</td><td>Z^{MD}</td><td>Z^{MP}</td><td>Y^M</td><td>M</td></tr>
<tr><td colspan="2">Value added</td><td>1</td><td>V^D</td><td>V^P</td><td colspan="2"></td></tr>
<tr><td colspan="2">Gross output</td><td>1</td><td>$X - E^P$</td><td>E^P</td><td colspan="2"></td></tr>
</table>

Figure 5.1: *Input–output table with separate production account for processing trade.*

For each industry, this is the column sum of the coefficient matrix for total intermediate import requirement. This turns out to be the same formula used to compute vertical specialisation by Hummels *et al* (2001). In other words, the concepts of vertical specialisation and of foreign content are identical.

2.2 Domestic Content in Exports when Processing Trade Is Prevalent

We now turn to the case in which processing exports are prevalent and, importantly, these exports could have a different intensity in the use of imported inputs than do domestic final sales (and normal exports). Conceptually, we wish to keep track separately of the IO coefficients of the processing exports and those of domestic final sales and normal exports. For now, we ignore the fact that these IO coefficients may not be directly available, and shall discuss a formal approach to estimate them in the next subsection. The IO table with a separate account for processing exports is represented by Figure 5.1.

We use superscript ‘P’ and ‘D’, respectively, to represent processing exports on the one hand, domestic sales and normal exports on the other. This expanded IO model can be formally described by the following system of equations:

$$\begin{bmatrix} I - A^{DD} & -A^{DP} \\ 0 & I \end{bmatrix} \begin{bmatrix} X - E^{P} \\ E^{P} \end{bmatrix} = \begin{bmatrix} Y^{D} - E^{P} \\ E^{P} \end{bmatrix}, \tag{5.7}$$

$$A^{MD}(X - E^{P}) + A^{MP}E^{P} + Y^{M} = M, \tag{5.8}$$

$$uA^{DD} + uA^{MD} + A_v^{D} = u, \tag{5.9}$$

$$uA^{DP} + uA^{MP} + A_v^{P} = u. \tag{5.10}$$

This is a generalisation of the model discussed in the previous subsection. Equations (5.7) and (5.8) are a generalisation of Equations (5.1) and (5.2), and Equations (5.9) and (5.10) are a generalisation of Equation (5.3), with a separate account for processing exports. Equations (5.9) and (5.10) are also the new adding-up constraint for the IO coefficients.

The analytical solution of the system is

$$\begin{bmatrix} X - E^{P} \\ E^{P} \end{bmatrix} = \begin{bmatrix} I - A^{DD} & -A^{DP} \\ 0 & I \end{bmatrix}^{-1} \begin{bmatrix} Y^{D} - E^{P} \\ E^{P} \end{bmatrix}. \tag{5.11}$$

The generalised Leontief inverse for this expanded model can be computed follows:

$$B = \begin{bmatrix} I - A^{DD} & -A^{DP} \\ 0 & I \end{bmatrix}^{-1} = \begin{bmatrix} B^{DD} & B^{DP} \\ B^{PD} & B^{PP} \end{bmatrix} = \begin{bmatrix} (I - A^{DD})^{-1} & (I - A^{DD})^{-1}A^{DP} \\ 0 & I \end{bmatrix}. \tag{5.12}$$

Substituting Equation (5.12) into Equation (5.11), we have

$$X - E^{P} = (I - A^{DD})^{-1}(Y^{D} - E^{P}) + (1 - A^{DD})^{-1}A^{DP}E^{P}. \tag{5.13}$$

Substituting Equation (5.13) into Equation (5.8), the total demand for imported intermediate inputs is

$$M - Y^{M} = A^{MD}(I - A^{DD})^{-1}(Y^{D} - E^{P}) + A^{MD}(1 - A^{DD})^{-1}A^{DP}E^{P} + A^{MP}E^{P}. \tag{5.14}$$

It has three components: the first is total imported content in domestic sale and normal exports, and the second and the third are indirect and direct imported content in processing exports, respectively.

We can compute vertical specialisation (VS) or foreign share processing and normal exports in each industry separately:

$$\begin{vmatrix} \mathrm{VSS}^{D} \\ \mathrm{VSS}^{P} \end{vmatrix}^{T} = \begin{vmatrix} uA^{MD}(I - A^{DD})^{-1} \\ uA^{MD}(1 - A^{DD})^{-1}A^{DP} + uA^{MP} \end{vmatrix}^{T}. \tag{5.15}$$

The total foreign content share in a particular industry is the sum of the two weighted by the share of processing and non-processing exports s^{P} and $u^{T}s^{P}$, where both s and u are $1 \times n$ vectors:

$$\overline{\mathrm{VSS}} = (u - s^{P}, s^{P}) \begin{vmatrix} \mathrm{VSS}^{D} \\ \mathrm{VSS}^{P} \end{vmatrix}. \tag{5.16}$$

The foreign (or foreign value added) share in country's total exports is:

$$\mathrm{TVSS} = uA^{\mathrm{MD}}(I - A^{\mathrm{DD}})^{-1}\frac{E - E^{\mathrm{P}}}{\mathrm{te}} + u(A^{\mathrm{MD}}(1 - A^{\mathrm{DD}})^{-1}A^{\mathrm{DP}} + A^{\mathrm{MP}})\frac{E^{\mathrm{P}}}{\mathrm{te}}, \quad (5.17)$$

where te is a scalar, the country's total exports. Equation (5.16) is a generalisation of Equation (5.7), the formula to compute industry-level share of vertical specialisation. Equation (5.17) is a generalisation of the formula for country-level share of vertical specialisation proposed by Hummels *et al* (2001, p. 80). In particular, either when $A^{\mathrm{DD}} = A^{\mathrm{DP}}$ and $A^{\mathrm{MD}} = A^{\mathrm{MP}}$, or when $E^{\mathrm{P}}/\,\mathrm{te} = 0$, Equation (5.18) reduces to the HIY formula for VS.

Similarly, the domestic content share for processing and normal exports at the industry level can be computed separately:

$$\begin{vmatrix} \mathrm{DVS}^{\mathrm{D}} \\ \mathrm{DVS}^{\mathrm{P}} \end{vmatrix}^{\mathrm{T}} = \bar{A}_v B = \begin{pmatrix} A_v^{\mathrm{D}} & A_v^{\mathrm{P}} \end{pmatrix} \begin{bmatrix} (I - A^{\mathrm{DD}})^{-1} & (I - A^{\mathrm{DD}})^{-1}A^{\mathrm{DP}} \\ 0 & I \end{bmatrix}$$
$$= \begin{vmatrix} A_v^{\mathrm{D}}(I - A^{\mathrm{DD}})^{-1} \\ A_v^{\mathrm{D}}(I - A^{\mathrm{DD}})^{-1}A^{\mathrm{DP}} + A_v^{\mathrm{P}} \end{vmatrix}^{\mathrm{T}}. \quad (5.18)$$

The total domestic content share in a particular industry is weighted sum of the two:

$$\overline{\mathrm{DVS}} = (u - s^{\mathrm{P}}, s^{\mathrm{P}}) \begin{vmatrix} \mathrm{DVS}^{\mathrm{D}} \\ \mathrm{DVS}^{\mathrm{P}} \end{vmatrix}. \quad (5.19)$$

The domestic content share in a country's total exports is:

$$\mathrm{TDVS} = A_V^{\mathrm{D}}(I - A^{\mathrm{DD}})^{-1}\frac{E - E^{\mathrm{P}}}{\mathrm{te}} + (A_V^{\mathrm{D}}(1 - A^{\mathrm{DD}})^{-1}A^{\mathrm{DP}} + A_V^{\mathrm{P}})\frac{E^{\mathrm{P}}}{\mathrm{te}}. \quad (5.20)$$

When either $A^{\mathrm{DD}} = A^{\mathrm{DP}}$ and $A_v^{\mathrm{D}} = A_v^{\mathrm{P}}$ or $E^{\mathrm{P}}/\,\mathrm{te} = 0$, Equation (5.20) reduces to the HIY formula in Equation (5.5). Note we can easily verify that for both processing and normal exports the sum of domestic and foreign content shares is unity.

2.3 Estimation Issues

Equations (5.18)–(5.20) allow us to compute the shares of domestic content in processing and normal exports for each industry as well as in a country's total exports. However, statistical agencies typically only report a traditional IO matrix, A, and sometimes A^{M}, but not A^{DP}, A^{DD}, A^{MP} and A^{MD} separately. Therefore, a method to estimate these matrices, based on available information, has to be developed. In this subsection, we propose to do this via a quadratic programming model by combining information from trade statistics and conventional IO tables.

The basic idea is to use information from the standard IO table to determine sector-level total imports/exports, and information from trade statistics to determine the relative proportion of processing and normal exports within each sector, and thus use all available data to split the national economy into processing and non-processing blocks, each with its own IO structure. The first step (using the data from the IO table to determine sector-level total imports/exports) helps to ensure that the balance conditions in the official IO account are always satisfied, and that the IO table with separate processing and non-processing accounts are consistent with the published official table. The second step (using data from trade statistics to determine the relative proportion of processing and normal exports within each sector) helps to ensure that the estimated new IO table is consistent with the trade structures implied by official trade statistics.

The following data are observable from a standard IO table and enter the model as constants.

x_i: gross output of sector i.
z_{ij}: goods i used as intermediate inputs in sector j.
v_j: value added in sector j.
m_i: total imports of sector i goods.
y_i: total final demand except for exports of goods i.

We combine those observed data from the IO table and processing trade shares[6] observed from trade statistics to determine the values for the following.

m_i^p: imports of sector i good used as intermediate inputs to produce processing exports.
m_i^d: imports of sector i goods used as intermediate inputs for domestic production and normal exports.
e_i^n: normal exports of sector i.
e_i^p: processing exports of sector i.

The partition of imports into intermediate and final use is based on a combination of China Customs import statistics and UN BEC classification, as described in Dean *et al* (2007). The results of such partition and the actual numbers used in our empirical estimation are reported and discussed in Section 3.1 on the data source. Parameters on domestic and imported final demand can be inferred from the observed data discussed above.

y_i^m: final demand of goods i from imports (residuals of $m_i - m_i^p - m_i^d$).
y_i^d: final demand of goods i provided by domestic production (residual of $y_i - y_i^m$).

[6]China Customs officially report processing and normal exports at the HS eight-digit-level. Processing trades include trade regime 'Process & assembling' (14) and 'Process with imported materials' (15) in China Customs statistics. These statistics are relatively accurate because they involve duty exemption and value-added tax rebates, which come under intensive Customs monitoring.

Define the following.

z_{ij}^{dd}: domestically produced intermediate good i used by sector j for domestic sales and normal exports.

z_{ij}^{dp}: domestically produced intermediate good i used by sector j for processing exports.

z_{ij}^{md}: imported intermediate good i used by sector j for domestic sales and normal exports.

z_{ij}^{mp}: imported intermediate good i used by sector j for processing exports.

v_j^d: direct value added by domestic and normal export production in industry j.

v_j^p: direct value added by processing export production in industry j.

Then the IO coefficients for the expanded IO model can be written as:

$$A^{\mathrm{DD}} = [a_{ij}^{dd}] = \left[\frac{z_{ij}^{dd}}{x_j - e_j^p}\right], \qquad A^{\mathrm{MD}} = [a_{ij}^{md}] = \left[\frac{z_{ij}^{md}}{x_j - e_j^p}\right],$$

$$A_v^{\mathrm{D}} = [a_j^{vd}] = \left[\frac{v_j^d}{x_j - e_j^p}\right], \qquad A^{\mathrm{DP}} = [a_{ij}^{dp}] = \left[\frac{z_{ij}^{dp}}{e_j^p}\right],$$

$$A^{\mathrm{MP}} = [a_{ij}^{mp}] = \left[\frac{z_{ij}^{mp}}{e_j^p}\right], \qquad A_v^{\mathrm{P}} = [a_j^{vp}] = \left[\frac{v_j^p}{e_j^p}\right].$$

To obtain unobservable IO coefficients, we need to estimate with-industry transactions $[z_{ij}^{dd}]$, $[z_{ij}^{dp}]$, $[z_{ij}^{md}]$ and $[z_{ij}^{mp}]$, as well as sector-level value added $[v_j^d]$ and $[v_j^p]$, subject to the flowing IO accounting identities and adding-up constraints:

$$\sum_{j=1}^{K} (z_{ij}^{dd} + z_{ij}^{dp}) = x_i - e_i^p - e_i^n - y_i^d, \tag{5.21}$$

$$\sum_{j=1}^{K} (z_{ij}^{md} + z_{ij}^{mp}) = m_i - y_i^m, \tag{5.22}$$

$$\sum_{j=1}^{K} (z_{ij}^{dd} + z_{ij}^{md}) + v_j^d = x_j - e_j^p, \tag{5.23}$$

$$\sum_{i=1}^{K} (z_{ij}^{dp} + z_{ij}^{mp}) + v_j^p = e_j^p, \tag{5.24}$$

$$\sum_{j=1}^{K} z_{ij}^{md} = m_i^d, \tag{5.25}$$

$$\sum_{j=1}^{K} z_{ij}^{mp} = m_i^p, \tag{5.26}$$

$$\sum_{j=1}^{K}(z_{ij}^{dd}+z_{ij}^{dp})=\sum_{j=1}^{K}z_{ij}-(m_i^d+m_i^p), \tag{5.27}$$

$$z_{ij}^{dd}+z_{ij}^{dp}+z_{ij}^{md}+z_{ij}^{mp}=z_{ij}, \tag{5.28}$$

$$v_j^d+v_j^p=v_j. \tag{5.29}$$

The economic meanings of the nine groups of constraints are straightforward. Equations (5.21) and (5.22) are row sum identities for the expanded IO account. They state that total gross output of sector i has to equal the sum of domestic intermediaries, final demand and exports (both processing and normal exports) in that sector. Similarly, total imports have to equal imported intermediate inputs plus imports delivered to final users. Equations (5.23) and (5.24) are column sum identities for the expanded IO account. They define the value of processing exports in sector j as the sum of domestic and imported intermediate inputs as well as primary factors used in producing processing exports; these four groups of constraints correspond to Equations (5.7)–(5.10) in the extended IO model, respectively. Equations (5.25) to (5.29) are a set of adding-up constraints to ensure that the solution from the model is consistent with official statistics on sector-level trade and within-industry transactions.

We can make initial guesses about the values of the unobserved within-industry transactions and sector-level value added using a combination of official statistics and some proportional assumptions (to be made precise later). These initial values may not satisfy all the adding-up constraints and need to be modified. We cast the estimation problem as a constrained optimisation procedure to minimise following objective functions:

$$\begin{aligned}\min S=&\sum_{i=1}^{K}\sum_{j=1}^{K}\frac{(z_{ij}^{dd}-z_{0ij}^{dd})^2}{z_{0ij}^{dd}}+\sum_{i=1}^{K}\sum_{j=1}^{K}\frac{(z_{ij}^{dp}-z_{0ij}^{dp})^2}{z_{0ij}^{dp}}+\sum_{i=1}^{K}\sum_{j=1}^{K}\frac{(z_{ij}^{md}-z_{0ij}^{md})^2}{z_{ij}^{md}}\\&+\sum_{i=1}^{K}\sum_{i=1}^{K}\frac{(z_{ij}^{mp}-z_{0ij}^{mp})^2}{z_{0ij}^{mp}}+\sum_{j=1}^{K}\frac{(v_j^d-v_{0j}^d)^2}{v_{0j}^d}+\sum_{j=1}^{K}\frac{(v_j^p-v_{0j}^p)^2}{v_{0j}^p}.\end{aligned} \tag{5.30}$$

Here z and v are variables to be estimated, and those variables with a 0 in the suffix denote initial values. Because all parameters in the nine groups of linear constraints (the right-hand sides of Equations (5.21)–(5.29)) were directly or indirectly obtained from observable official statistical sources, model solutions are thus restricted into a convex set and will be relatively stable with respect to variations in these initial values as long as all the parameters in these linear constraints are kept as constants.

The initial values of z_{ij}^{md} and z_{ij}^{md} are generated by allocating m_i^d and m_i^p in proportion to input i's usage in sector j as in Equation (5.31):

$$z_{0ij}^{mp}=\frac{z_{ij}(e_j^p/x_j)}{\sum_k^N z_{ik}(e_k^p/x_k)}m_i^p,\qquad z_{0ij}^{md}=\frac{z_{ij}(x_j-e_j^p)/x_j}{\sum_k^N z_{ik}(x_k-e_k^p)/x_k}m_i^d. \tag{5.31}$$

The split of total inter-sector intermediate inputs flowing from sector i to sector j between normal and processing use are based on their proportion in gross output. The residuals of the total intermediate inputs and the imported intermediate inputs estimated from Equation (5.31) are taken as the initial values for domestically produced intermediate inputs as in Equations (5.32) and (5.33):

$$z_{0ij}^{dd} = z_{ij}\frac{(x_j - e_j^p)}{x_j} - z_{0ij}^{md}, \tag{5.32}$$

$$z_{0ij}^{dp} = z_{ij}\frac{e_j^p}{x_j} - z_{0ij}^{mp}. \tag{5.33}$$

The initial values for direct value added in the production for processing exports in sector j (v_{0j}^p), are generally set to be the residuals implied by Equation (5.24). However, we set a minimum value at the sum of labour compensation depreciation in a sector multiplied by the share of processing exports in that sector's total output. In other words, the initial value v_{0j}^p is set equal to the greater of the residuals from Equation (5.24) or the minimum value. The initial value for direct value added in the production for domestic sales and normal exports (v_{0j}^d) is set as the difference between v_j (from the IO table) and v_{0j}^p.

We conduct some sensitivity checks using alternative initial values. It turns out that they do not materially alter our basic conclusions. We implement this programming model in GAMS (Brooke *et al* 2005); related computer programs and data files are available at the authors' and the USITC websites for downloading.

3 ESTIMATION RESULTS

After describing the data sources, we report and discuss the estimation results for shares of domestic and foreign content in Chinese exports at the aggregate level, and by sector, firm ownership and major destination countries.

3.1 Data

Inter-industry transaction and (direct) value-added data are from China's 1997, 2002 and 2007 benchmark IO tables published by the National Bureau of Statistics of China (NBS), while detailed export and import data of 1997, 2002 and 2007 are from the General Customs Administration of China. The trade statistics are first aggregated from the eight-digit HS level to China's IO industry, and then used to compute the share of processing exports in each IO industry. Modifying a method from Dean *et al* (2007), we partition all imports in a given commodity classification into three parts, based on the distinction

Table 5.1: *Major trade share parameters used in estimation, 1997–2008.*

	Imported intermediates (%)		Imported capital goods (%)			
	for processing exports	for normal use	for processing exports	for normal use	Imported final consumption (%)	Processing exports as % of total exports
Year	1	2	3	4	5	6
1996	46.2	26.8	16.7	8.1	2.2	56.0
1997	51.2	28.2	12.1	7.3	1.3	55.1
1998	50.7	28.2	9.7	10.0	1.4	57.4
1999	43.6	35.0	8.2	11.2	2.0	57.3
2000	39.4	41.2	8.5	9.1	1.8	55.7
2001	36.6	41.2	8.7	11.6	1.9	55.9
2002	38.0	39.1	10.2	11.0	1.8	55.9
2003	35.0	41.8	10.7	10.8	1.6	56.0
2004	34.7	43.0	11.8	8.9	1.5	56.3
2005	36.1	43.6	10.6	8.1	1.5	55.6
2006	35.3	44.2	9.8	8.9	1.7	53.6
2007	32.7	47.3	9.0	7.6	3.3	50.1
2008	27.5	53.5	8.1	7.2	3.7	48.1

Source: authors' calculations based on official China Customs trade statistics and the United Nations Broad Economic Categories (UNBEC) classification scheme.
'Normal use' refers to 'normal exports and domestic sales'. The UNBEC scheme classifies each HS six-digit product into one of three categories: 'intermediate inputs', 'capital goods' and 'final consumption'. For the first two categories, we further decompose the imports into two subcategories: 'processing imports' by customs declaration are classified as used for producing processing exports and cannot be sold to any domestic users by regulation, and the remaining imports are classified as for normal use. Capital goods are part of the final demand in a conventional IO model (columns 1–5 sum to 100%). However, this classification may underestimate the import content of exports. We therefore also experiment with classifying a fraction of the capital goods as inputs used in current year of production. This is discussed in Section 3.2.

between processing and normal imports in the trade statistics, and on the UN BEC classification scheme:

(i) intermediate inputs in producing processing exports;
(ii) intermediate inputs for normal exports and other domestic final sales; and
(iii) those used in gross capital formation and final consumption.

A summary of these trade statistics as a percentage of China's total imports along with share of processing exports during the period 1996–2008 is reported in Table 5.1, which shows a downwards trend for the use of imported inputs in producing processing exports and an upwards trend in their use in producing normal trade and domestic final sales.[7]

[7] Sector level counterparts of the data in Table 5.1 are used to determine the parameters in Equations (5.21)–(5.26). Additional parameters in Equations (5.27)–(5.29) are obtained directly from China's official benchmark IO tables.

We report detailed trade share parameters for each IO industry in the three benchmark year (1997, 2002 and 2007) in the online appendix. These data computed directly from detailed Chinese official trade statistics (at eight-digit HS) are important to understand our estimates of domestic and imported content in Chinese gross exports, especially cross-sector heterogeneity and their changes over time. Our estimation results reflect these parameters.

3.2 Domestic and Foreign Content in Total Exports

Table 5.2 presents the results for the decomposition of aggregate foreign and domestic value-added shares in 1997, 2002 and 2007. For comparison, the results the HIY method that ignores processing trade are also reported. The estimated aggregate domestic value-added share in China's merchandise exports was 54% in 1997 and 60.6% in 2007. For manufacturing products, these estimated shares are slightly lower but trend upwards more significantly from 50.0% in 1997 to 59.7% in 2007. In general, the estimated direct domestic value-added shares are less than half of the total domestic value-added shares. However, the estimated indirect foreign value-added share is relatively small; most of the foreign content comes from directly imported foreign inputs, particularly in 1997 and 2002. The indirect foreign value added increases over time, and reaches about a quarter of China's directly imported foreign inputs in 2007, indicating that the share of simple processing and assembling of foreign parts is declining, while more imported intermediates are being used in the production of other intermediate inputs that are then used in the production process of exported goods.

Relative to the estimates from the HIY method, our procedure produces estimates of a much higher share of foreign value added in Chinese gross exports and with a different trend over time. To be more precise, estimates from the HIY method show that the foreign content share (total VS share) increased from 17.6% in 1997 to 28.7% in 2007 for all merchandise exports, and from 19.0% to 27.1% for manufacturing only during the same period. In contrast, our estimates suggest a trend in the opposite direction, with the share of foreign value added in all merchandise exports falling from 46% in 1997 to 39.4% in 2007, and a somewhat more dramatic decline for the share in manufacturing exports from 50% in 1997 to 40.3% in 2007. The decline occurred mainly during the period 2002–7, which corresponds to the first five years of China's inclusion in the WTO. Our estimates indicate that the HIY method appears to incorrectly estimate both the level and the trend in domestic versus foreign content in the PRC's exports. These striking differences indicate the importance of taking account of differences between processing and normal exports.

What accounts for the difference between our approach and the HIY approach? There are at least three factors that drive the change of foreign content share in the country's gross exports, including:

Table 5.2: *Shares of domestic and foreign value added in total exports (%).*

	The HIY method			The KWW method		
	1997	2002	2007	1997	2002	2007
All merchandise						
Total foreign value added	17.6	25.1	28.7	46.0	46.1	39.4
Direct foreign value added	8.9	14.7	13.7	44.4	42.5	31.6
Total domestic value added	82.4	74.9	71.3	54.0	53.9	60.6
Direct domestic value added	29.4	26.0	20.3	22.2	19.7	17.1
Manufacturing goods only						
Total foreign value added	19.0	26.4	27.1	50.0	48.7	40.3
Direct foreign value added	9.7	15.6	16.3	48.3	45.1	32.4
Total domestic value added	81.1	73.6	72.9	50.0	51.3	59.7
Direct domestic value added	27.5	24.6	24.6	19.6	18.1	16.5

Source: authors' estimates based on China's 1997, 2002 and 2007 Benchmark Input–Output Table published by the Bureau of National Statistics, and official China trade statistics from China Customs. The HIY method refers to estimates from using the approach in Hummels *et al* (2001). The KWW method refers to estimates from using the approach developed in this chapter that takes into account special features of processing exports.

1. the relative proportions of imported intermediate inputs in producing processing exports and normal exports and domestic sales;
2. the share of processing exports in its total exports; and
3. the sector composition of its exports.

Because processing exports tend to use substantially more imported inputs, and processing exports account for a major share of China's total exports, the HIY indicator substantially underestimates the true degree of foreign content in China's exports. This explains why the level of domestic content by our measure is much lower than that of the HIY indicator. On the other hand, as exporting firms (both those producing for normal exports and those producing for processing exports) gradually increase their intermediate inputs sourcing from firms within China, including multinationals that have moved their upstream production to China, the extent of domestic content in exports rises over time. This process is likely to be aided by China's accession to the WTO. However, because exports from industries with relatively lower domestic content often grow faster, the composition of a country's total exports may play as an offsetting role to slow down the increase of domestic value-added share in the country's total exports. As the Chinese government started to narrow the gap in policy treatments for both foreign-invested firms relative to domestic firms and processing exports relative to normal exports since the end of 2006, the domestic content share of Chinese exports could continue its rise in the future.

Our interpretation is confirmed by DVA shares for processing and normal exports estimated separately (Table 5.3). There is an increase by more than

Table 5.3: *Domestic and foreign value added: processing versus normal exports (as percentage of total exports).*

	Normal exports			Processing exports		
	1997	2002	2007	1997	2002	2007
All merchandise						
Total foreign value added	5.2	10.4	16.0	79.0	74.6	62.7
Direct foreign value added	2.0	4.2	5.0	78.6	73.0	58.0
Total domestic value added	94.8	89.6	84.0	21.0	25.4	37.3
Direct domestic value added	35.1	31.9	23.4	11.7	10.1	10.9
Manufacturing goods only						
Total foreign value added	5.5	11.0	16.4	79.4	75.2	63.0
Direct foreign value added	2.1	4.5	5.2	79.0	73.6	58.3
Total domestic Value added	94.5	89.0	83.6	20.7	24.8	37.0
Direct domestic value added	31.5	29.5	22.4	11.7	10.0	10.9

Source: authors' estimates based on China's 1997, 2002 and 2007 Benchmark Input–Output Table published by the Bureau of National Statistics and official China trade statistics from China Customs.

10 percentage points in the total foreign value-added share for domestic sales and normal exports between 1997 and 2007. However, in processing exports, we see that as more domestically produced inputs were used, the domestic value-added share increased from 20.7% in 1997 to 37.0% in 2007, up by more than 16 percentage points. Because processing exports still constitute more than 50% of China's total exports in 2007, the domestic value-added share in total exports climbed up during the decades. Because the gap in the domestic content shares is large between the two types of exports, it is unlikely to disappear any time soon.

We perform a number of robustness checks on the sensitivity of our main results to alternative ways set the initial values of variables and the share parameters of import use. First, we initialise v_{0j}^{p} and v_{0j}^{d} by apportioning the observed direct value added in a sector to processing exports and other final demands based on their respective portions in the sector's total output. Second, we initialise v_{0j}^{p} either at the residuals implied by Equation (5.24) if the residuals are positive, or by following the previous alternative if the residuals are non-positive. Third, when we partition imports into different users, we use the average of a three-year period (previous, current and following years) rather than just one year's statistics. Fourth, we experiment with 0% versus 10% annual depreciation rate for capital goods. These variations produce relatively little change in the main results. In particular, the pattern of a trend increase in the domestic content share in total exports is robust to these variations.

Table 5.4: *Shares of domestic value added in exports by firm ownership (%), 2002 and 2007.*

	SPET	Non-processing Direct DVA	Non-processing Total DVA	Processing Direct DVA	Processing Total DVA	Weighted sum Direct DVA	Weighted sum Total DVA	SFT
2002								
Wholly foreign owned	87.5	34.9	90.1	9.8	25.3	13.0	33.4	*28.9*
Joint venture firms	70.5	31.2	89.4	9.9	24.5	16.2	43.6	*22.9*
State-owned firms	32.2	32.1	89.6	10.7	26.4	25.2	69.3	*38.1*
Collectively owned firms	27.4	29.9	89.6	10.8	28.2	24.7	72.8	*5.8*
Private firms	9.0	30.7	89.6	10.7	26.3	28.9	83.9	*4.3*
All firms	55.7	31.8	89.3	10.1	26.1	19.7	53.9	*100.0*
2007								
Wholly foreign owned	83.0	23.8	83.8	11.4	36.0	13.5	44.1	38.1
Joint venture firms	59.5	23.0	83.6	10.4	38.7	15.5	56.9	17.7
State-owned firms	25.8	23.4	83.4	10.0	39.5	20.0	72.1	18.9
Collectively owned firms	24.0	22.4	83.1	8.9	42.0	19.1	73.3	4.0
Private firms	9.6	23.5	84.9	9.8	42.0	22.2	80.8	21.3
All firms	50.0	23.5	83.9	10.5	38.7	17.1	60.6	100.0

Source: authors' estimates based on China's 2002 and 2007 Benchmark Input–Output Table published by Bureau of National Statistics and official China trade statistics from China Customs. SPET, share of processing exports in total exports; SFT, share of exports by firm ownership in China's total exports. The IO structure is assumed to be the same for a given export regime within a sector across all type firms. The variation of domestic value added by firm types is due solely to variation in sector composition and the relative reliance on processing exports.

3.3 Domestic Content in Exports by Firm Ownership

Since foreign-invested firms account for over half of China's exports, one may be interested in the domestic content share in their exports. However, since there is no information on separate input–output coefficients by firm ownership, we cannot meaningfully distinguish foreign firms from local firms within a sector and trade regime (processing or normal exports). Instead, we provide an estimate of the domestic content share of aggregate exports by foreign-invested firms. By construction, the differences across firms of different ownership are driven entirely by different degrees of their reliance on processing exports within a sector and differences in the sector composition of their total exports (both are observed directly from the customs trade statistics).

Estimates of the domestic content shares by firm ownership are in Table 5.4. The results show that exports by wholly foreign-owned enterprises exhibit the lowest share of domestic value added, but rose relatively quickly (from 33.4% in 2002 to 44.1% in 2007), followed by Sino-foreign joint venture companies (at about 44% in both 2002 and 2007). Exports from Chinese private enterprises embodied the highest domestic content shares (83.9% and 80.8% in 2002 and 2007, respectively), while those from state-owned firms were in the middle (about 70% in both years). Note that these estimates represent the best guesses based on currently available information; better estimates can be derived once information on IO coefficients by firm ownership becomes available.

The most noticeable feature of this table is the rising domestic content shares in exports produced by foreign-invested firms by more than 10 percentage points from 2002 to 2007. This suggests that the increase in the domestic content share is mainly due to foreign-invested processing exporters sourcing more of their intermediate inputs from within China. This is presumably also linked to more multinationals moving their upstream production to China.

3.4 Domestic Content by Sector

To see if there are interesting patterns at the sector level, Tables 5.5 and 5.6 report, in ascending order of the domestic content share, the value-added decomposition in Chinese exports by industry in 2002 and 2007, respectively, together with the shares of processing trade and foreign-invested firms in each sector's exports and the sector's share in China's merchandise exports. Because the sector classifications are consistent between 2002 and 2007 (but less so between 1997 and 2002), we choose to report the sector-level results for 2002 and 2007.

Among the 57 manufacturing industries in the table, 15 have a share of domestic value added in their exports less than 50% in 2002; they account for nearly 35% of China's merchandise exports that year. It is interesting to note that many low-DVA industries are likely to be labelled as sophisticated, such as telecommunication equipment, electronic computers, measuring instruments or electronic devices. A common feature of these industries is that processing exports account for over two-thirds of their exports (and foreign-invested enterprises played an overwhelming role). In 2007, the number of industries with less than 50% domestic contents in their exports declined to 10, and their collective share in China's total exports also declined to 32%.

The next 18 industries in Table 5.6 have their shares of domestic value added in the range 51–65%; they collectively accounted for 28% of China's total merchandise exports in 2002. Several labour-intensive sectors are in this group, as furniture, toys and sports products, leather, fur, down and related products.

The remaining 24 industries have high shares of domestic value added. They as a group produced slightly less than 30% of China's total merchandise exports in 2002. Apparel, the country's largest labour-intensive exporting industry, which by itself was responsible for 7% of the country's total merchandise exports in 2002, is at the top of this group, with a share of domestic content of 66%. The 12 industries at the bottom of Table 5.6 with DVA share more than 75% collectively produced only 10% of China's total merchandise exports in 2002.

Table 5.5: *Domestic value added share in manufacturing exports by sector, 2002.*

IO industry description	VA decomposition (%) Non-processing	Processing	Weighted sum	% of process. exports	% of FIE exports	% of merch. exports
Telecommunication equipment	87.5	5.3	12.5	91.2	88.4	3.2
Shipbuilding	82.3	14.7	17.5	95.8	21.0	0.6
Electronic computer equipment	83.6	18.7	19.3	99.1	89.7	7.0
Cultural and office equipment	79.7	19.3	23.3	93.4	71.6	4.3
Household electric appliances	88.2	6.8	23.9	79.1	56.9	1.9
Household audiovisual apparatus	82.5	21.3	27.0	90.6	62.3	5.2
Printing, reproduction or recording media	91.1	19.7	31.9	83.0	62.7	0.3
Plastic	84.4	10.3	36.6	64.5	51.2	2.4
Electronic components	84.6	32.8	38.1	89.7	87.5	3.4
Steelmaking	89.0	12.8	44.3	58.8	86.1	0.0
Generators	85.2	32.0	44.3	76.8	55.8	0.9
Other electronic and communication equipment	97.8	36.0	45.3	84.9	84.9	1.8
Rubber	90.6	12.2	48.9	53.1	44.4	1.6
Non-ferrous metal pressing	86.2	7.5	49.3	46.9	48.7	0.4
Measuring instruments	85.8	32.9	49.5	68.6	51.8	1.8
Paper and paper products	90.8	12.4	51.1	50.7	57	0.5
Furniture	88.3	12.5	52.5	47.2	56.8	1.7
Articles for culture, education and sports activities	87.5	38.2	52.7	70.6	56.3	3.3
Non-ferrous metal smelting	88.9	10.6	53.6	45.0	17.4	0.8
Smelting of ferroalloy	83.6	13.0	54.8	40.8	13.1	0.2

Source: authors' estimates. China 2002 and 2007 Benchmark Input–Output Tables have 84 and 90 goods-producing sectors, respectively. They both concord to China's four-digit classification of economic activities (GB/T 4754-2002). This concordance enables us to aggregate both year's estimates to 77 consistent goods-producing industries reported in this table.

The high-DVA industries saw their weights in the country's total exports to rise significantly from 2002 to 2007. The number of industries with DVA share of more than 75% increased from 12 in 2002 to 25 in 2007 (comparing the bottoms of Tables 5.5 and 5.6), and their exports as a share of the country's total exports also rose from 10% in 2002 to more than 30% in 2007. Among these high-DVA industries, besides the traditional labour-intensive

Table 5.5: *Continued.*

IO industry description	VA decomposition (%) Non-processing	Processing	Weighted sum	% of process. exports	% of FIE exports	% of merch. exports
Synthetic materials	80.5	37.1	55.2	58.3	65.4	0.3
Petroleum refining and nuclear fuel	79.4	5.5	55.7	32.1	24.9	0.8
Metal products	90.3	10.2	55.7	43.2	45.6	4.4
Other transport equipment	86.0	12.7	55.8	41.2	50.5	1.2
Other electric machinery and equipment	88.4	40.1	56.2	66.8	60.1	5.6
Special chemical products	82.9	31.4	58.7	46.9	48.4	0.8
Other manufacturing products	89.2	31.3	59.0	52.2	37.6	1.7
Woollen textiles	91.1	8.8	60.1	37.8	42.6	0.3
Paints, printing inks, pigments and similar products	83.5	8.3	61.6	29.1	44.4	0.4
Motor vehicles	89.6	10.0	61.6	35.2	48.2	0.8
Glass and its products	86.8	16.5	63.6	33.0	48.8	0.5
Leather, fur, down and related products	91.9	40.4	63.9	54.3	50.3	4.5
Chemical products for daily use	85.3	26.8	64.1	36.3	43.6	0.4
Wearing apparel	91.3	34.3	65.6	45.1	39.2	7.0
Chemical fibre	80.2	9.2	65.7	20.5	29.2	0.0
Other special industrial equipment	89.3	32.0	66.4	39.9	44.0	1.3
Boiler, engines and turbine	85.9	13.1	66.5	26.7	28.4	0.4
Other industrial machinery	90.1	38.6	67.6	43.7	43.7	3.5
Iron-smelting	86.8	11.0	68.8	23.7	3.0	0.1

Source: authors' estimates. China 2002 and 2007 Benchmark Input–Output Tables have 84 and 90 goods-producing sectors, respectively. They both concord to China's four-digit classification of economic activities (GB/T 4754-2002). This concordance enables us to aggregate both year's estimates to 77 consistent goods-producing industries reported in this table.

industries such as furniture, textiles and apparel, we start to see capital- and skill-intensive industries such as automobile, industrial machinery and rolling steel (accounting for nearly one third of these high-DVA sector's exports). This is likely to reflect industrial upgrading in the Chinese economy.

Table 5.5: *Continued.*

IO industry description	VA decomposition (%) Non-processing	Processing	Weighted sum	% of process. exports	% of FIE exports	% of merch. exports
Railroad transport equipment	83.9	14.6	70.1	19.9	5.9	0.1
Wood, bamboo, rattan, palm and straw products	87.8	11.3	72.8	19.6	45.6	1.0
Knitted and crocheted fabrics and articles	90.6	34.7	72.9	31.6	34.2	5.8
Agriculture, forestry, animal husbandry and fishing machinery	85.7	13.9	72.9	17.8	20.8	0.1
Pesticides	77.0	11.5	72.9	6.3	14.4	0.2
Hemp textiles	89.5	11.7	74.3	19.5	19.5	0.3
Textiles productions	90.1	28.9	75.5	24.0	31.8	1.4
Cotton textiles	91.8	35.6	75.7	28.7	28.8	3.3
Fire-resistant materials	90.5	15.4	76.2	19.1	49.8	0.1
Metalworking machinery	87.2	18.8	78.1	13.3	27.0	0.2
Medicines	90.2	24.3	79.1	16.9	28.7	0.7
Pottery and porcelain	88.2	14.8	79.8	11.4	33.1	0.7
Other non-metallic mineral products	90.4	16.7	80.1	14.0	35.7	0.4
Fertilisers	84.4	9.7	81.1	4.5	21.7	0.1
Basic chemical raw materials	87.1	43.7	82.0	11.7	18.8	2.0
Rolling of steel	90.2	40.5	82.3	16.0	16.8	0.3
Cement, lime and plaster	91.0	20.3	86.0	7.0	77.7	0.1
Coking	91.4	13.2	89.4	2.6	5.3	0.3
Total merchandise	89.6	25.4	53.9	55.7	51.8	92.5

Source: authors' estimates. China 2002 and 2007 Benchmark Input–Output Tables have 84 and 90 goods-producing sectors, respectively. They both concord to China's four-digit classification of economic activities (GB/T 4754-2002). This concordance enables us to aggregate both year's estimates to 77 consistent goods-producing industries reported in this table.

4 DVA SHARES IN CHINESE EXPORTS BY TRADING PARTNERS

By assuming that domestic value-added shares within a given sector and export regime are the same for all destination countries, we can further estimate the domestic value-added share in China's exports to each of its major trading partners. Note, however, that the variation by destination in

Table 5.6: *Domestic value-added share in manufacturing exports by sector, 2007.*

IO industry description	VA decomposition (%) Non-processing	Processing	Weighted sum	% of process. exports	% of FIE exports	% of merch. exports
Household audiovisual apparatus	75.9	29.6	32.6	93.4	79.1	2.5
Electronic computer equipment	75.7	33.0	33.9	97.9	93.3	11.3
Cultural and office equipment	74.1	33.1	36.5	91.7	86.4	1.6
Other electronic and communication equipment	68.0	34.7	39.7	84.8	81.6	1.4
Telecommunication equipment	75.2	35.3	43.6	79.3	83.6	5.9
Ship building	83.9	39.1	43.8	89.4	16.5	1.1
Petroleum refining and nuclear fuel	68.7	20.1	44.4	50.1	27.3	0.7
Measuring instruments	80.0	37.8	45.8	81.2	73.3	2.5
Synthetic materials	76.4	34.0	47.7	67.7	66.1	0.6
Household electric appliances	82.0	35.6	51.8	65.1	61.7	2.7
Other electric machinery and equipment	80.3	33.7	52.1	60.5	65.9	4.9
Rubber	81.8	27.0	53.4	51.8	41.9	1.7
Plastic	80.8	31.1	55.1	51.7	54.7	1.7
Articles for culture, education and sports activities	83.0	45.6	58.4	66.0	64.9	2.1
Special chemical products	76.7	34.0	61.6	35.3	51.2	0.8

Source: authors' estimates. China 2002 and 2007 Benchmark Input–Output Tables have 84 and 90 goods-producing sectors, respectively. They both concord to China's four-digit classification of economic activities (GB/T 4754-2002). This concordance enable us to aggregate both year's estimates to 77 consistent goods-producing industries reported in this table.

this method is driven solely by China's export structure (sector composition) to each of its trading partners. The decomposition results for China's total merchandise exports to each of its major trading partners are reported in Table 5.7 in increasing order of the estimated domestic value-added share in 2002.

Hong Kong, the USA, Singapore, Taiwan (Chinese Taipei) and Malaysia are at the top of the table in both 2002 and 2007, with less than or about 60% of China's domestic value added embodied in their exports. The noteworthy pattern is that China's exports to developing countries tend to embody

Table 5.6: *Continued.*

IO industry description	VA decomposition (%) Non-processing	Processing	Weighted sum	% of process. exports	% of FIE exports	% of merch. exports
Chemical fibre	76.4	51.9	62.6	56.2	48.7	0.3
Other special industrial equipment	82.5	43.0	65.2	43.8	54.7	2.7
Generators	80.3	51.2	66.6	47.2	50.3	0.7
Railroad transport equipment	77.7	54.1	69.0	37.0	12.2	0.1
Leather, fur, down and related products	90.4	40.4	69.2	42.5	46.0	2.4
Paper and paper products	85.5	57.6	69.2	58.4	62.8	0.4
Metal products	85.1	39.7	70.1	32.9	49.5	4.4
Boiler, engines and turbines	81.6	38.7	70.6	25.6	37.8	0.5
Non-ferrous metal pressing	78.6	56.1	71.2	32.7	41.4	1.0
Other manufacturing products	86.5	48.1	72.3	36.8	41.5	1.6
Paints, printing inks, pigments and similar products	76.5	56.8	72.6	20.1	47.3	0.3
Pesticides	73.9	53.6	72.9	4.8	19.5	0.1
Chemical products for daily use	80.8	58.4	73.3	33.5	55.5	0.3
Non-ferrous metal smelting	76.2	56.4	73.3	14.6	19.6	0.8
Other transport equipment	81.0	54.9	73.8	27.8	46.5	0.9
Basic chemical raw materials	80.8	42.5	74.9	15.6	26.4	1.9
Motor vehicles	84.0	47.4	75.3	23.7	42.0	2.0

Source: authors' estimates. China 2002 and 2007 Benchmark Input–Output Tables have 84 and 90 goods-producing sectors, respectively. They both concord to China's four-digit classification of economic activities (GB/T 4754-2002). This concordance enable us to aggregate both year's estimates to 77 consistent goods-producing industries reported in this table.

much higher domestic value added than its exports to OECD countries. While this pattern appears to mirror the finding by Manova and Zhang (2012) that China's export prices tend to be lower in lower income countries, our data and method do not allow us to estimate destination-specific domestic value share of a product.

Interestingly, the domestic value-added share in China's exports to high-income countries increased between 2002 and 2007, while it declined for

Table 5.6: *Continued.*

IO industry description	VA decomposition (%) Non-processing	Processing	Weighted sum	% of process. exports	% of FIE exports	% of merch. exports
Agriculture, forestry, animal husbandry and fishing machinery	80.6	57.7	75.6	21.9	32.7	0.1
Other industrial machinery	83.6	56.2	75.6	29.0	49.9	3.4
Iron-smelting	75.9	50.6	75.6	1.1	24.3	0.1
Smelting of ferroalloy	75.7	53.3	75.6	0.4	8.8	0.4
Furniture	86.7	56.1	76.2	34.2	56.0	2.0
Printing, reproduction or recording media	86.4	61.0	76.5	39.0	44.4	0.2
Glass and its products	83.3	59.0	76.7	27.2	46.4	0.6
Woollen textiles	89.4	57.9	76.9	39.8	46.8	0.2
Metalworking machinery	81.2	56.8	77.3	16.0	36.4	0.3
Rolling of steel	80.0	52.9	77.8	8.3	22.6	3.8
Fertilisers	81.0	57.3	77.9	13.2	9.5	0.3
Cotton textiles	88.0	45.8	78.9	21.5	26.1	2.1
Wearing apparel	89.5	53.9	79.0	29.7	36.9	4.6
Medicines	87.6	37.5	80.3	14.5	32.3	0.8
Wood, bamboo, rattan, palm and straw products	84.6	58.4	80.4	16.1	33.1	1.0
Steelmaking	80.8	51.7	80.8	0.2	7.1	0.3
Pottery and porcelain	83.4	58.2	82	5.2	29.9	0.5
Textiles productions	88.4	54.9	82.4	18.1	35.1	1.8
Knitted and crocheted fabrics and articles	88.2	51.6	82.5	15.6	25.7	5.7
Other non-metallic mineral products	86	56.6	83	10.1	25.1	0.5
Hemp textiles	86.6	56.8	83.9	9.0	14.7	0.2
Fire-resistant materials	86.6	55.1	84.7	5.8	51.6	0.1
Cement, lime and plaster	89.0	52.9	88.4	1.7	29.6	0.1
Coking	89.6	—	89.6	0.0	11.4	0.3
Total merchandise	84.0	37.3	60.6	50.1	55.7	96.0

Source: authors' estimates. China 2002 and 2007 Benchmark Input–Output Tables have 84 and 90 goods-producing sectors, respectively. They both concord to China's four-digit classification of economic activities (GB/T 4754-2002). This concordance enable us to aggregate both year's estimates to 77 consistent goods-producing industries reported in this table.

exports to developing countries. This suggests that progressively more locally supplied inputs were used in making exports to high-income countries, while the opposite may be true for exports to developing countries.

Table 5.7: *Total domestic value-added share in Chinese gross merchandise exports to its major trading partners (%), 2002 and 2007.*

Region description	Share of processing exports in total exports		Non-processing		Processing		Weighted sum		Share in total exports to the world	
	2002	2007	2002	2007	2002	2007	2002	2007	2002	2007
Hong Kong	74.0	77.4	89.8	83.0	26.3	35.3	42.8	46.0	17.5	14.3
USA	67.2	61.7	89.2	84.6	24.3	38.2	45.5	56.0	21.6	19.1
Singapore	62.7	59.7	88.7	83.4	24.3	33.0	48.3	53.3	2.1	2.4
Taiwan province (Chinese Taipei)	59.6	50.7	89.3	81.9	27.1	34.9	52.2	58.0	2.0	1.9
Malaysia	57.6	52.0	90.4	84.0	25.5	33.5	53.0	57.7	1.5	1.5
Japan	59.2	56.4	90.7	85.4	27.6	40.5	53.3	60.1	15.0	8.4
EU15	54.8	50.9	89.4	84.0	23.6	37.2	53.4	60.2	14.9	18.3
Thailand	48.1	38.8	88.3	82.0	22.9	38.7	56.8	65.2	0.9	1.0
Rest of OECD	46.9	38.5	89.7	85.4	25.4	40.3	59.5	68.0	1.7	2.1
Rep. of Korea	45.4	43.2	90.4	83.5	27.1	37.0	61.6	63.4	4.8	4.7
Australia/NZ	41.6	42.8	89.3	84.4	23.0	38.6	61.7	64.8	1.6	1.7
Mexico	42.1	49.1	89.6	84.2	26.6	35.8	63.1	60.4	0.9	0.9
Philippines	37.6	38.2	89.1	83.5	25.2	33.8	65.1	64.5	0.6	0.6
EU12	36.5	50.8	90.2	83.4	22.9	35.8	65.7	59.2	1.5	1.9
Brazil	35.0	36.7	89.4	83.2	27.1	37.7	67.6	66.5	0.5	0.9
India	24.0	27.0	89.3	81.7	21.5	38.6	73.1	70.1	0.8	2.0
Rest of Latin America/ Caribbean	20.3	24.2	89.2	83.4	23.1	38.1	75.8	72.5	1.6	2.4
Indonesia	20.7	23.4	89.4	83.3	25.8	36.1	76.2	72.2	1.1	1.1
Middle East/ N. Africa	19.4	18.2	89.3	83.9	21.9	38.8	76.3	75.6	3.6	4.8
Eastern Europe/ Central Asia	18.9	16.6	89.4	85.0	26.3	39.2	77.5	77.4	0.9	2.8
Rest of Asia	17.2	18.9	88.6	83.5	27.0	41.6	77.9	75.6	2.2	2.6
Sub-Saharan Africa	15.5	16.1	89.6	83.9	22.1	38.8	79.2	76.6	1.4	2.1
Russia	15.5	16.9	90.9	85.6	30.4	39.3	81.5	77.8	1.1	2.4
World	55.7	50.0	89.6	84.0	25.4	37.3	53.9	60.6	100.0	99.9

Source: authors' estimates based on China's 2002 and 2007 Benchmark Input–Output Table published by Bureau of National Statistics and Official China trade statistics from China Customs. IO structure is assumed to be the same for a given export regime within a sector across all trading partners. The variation of domestic value added by destination is due solely to variations in sector composition and the relative reliance on processing exports.

5 CONCLUDING REMARKS

Segmentation of production across countries allows for reductions in production costs and more efficient allocation of resources, but also creates a wedge between the gross export value and the domestic value added that is embedded in the exports. Because processing exports may have a different tendency to use imported inputs from normal exports, it is important to account for such differences in estimating the share of domestic value added in a country's exports.

In this chapter, we present a general framework in assessing the shares of domestic and foreign value added in a country's exports when processing exports are explicitly accounted for. This formula nests the existing best known approach (Hummels *et al* 2001) as a special case. If separate input–output coefficients for processing and normal exports are available, our formula can be applied in a straightforward way.

Because some of the IO coefficients called for by the new formula are not readily available from conventional IO tables, we propose an easy-to-replicate mathematical programming procedure to estimate these coefficients by combining information from detailed trade statistics (which records processing and normal exports/imports separately) with conventional input–output tables. This methodology should be applicable to Vietnam, Mexico and many other developing countries that engage in a significant amount of processing exports.

By applying our methodology to the Chinese data, we find several interesting patterns. First, the share of foreign content in China's manufacturing exports was close to 50% during 1997–2002, almost twice as high as that calculated using the HIY formula. Second, the share of domestic content increased from 51% to 60% during 2002–7, which corresponds to the first five years of China's membership of the WTO. We also report interesting heterogeneity across sectors: sectors that are likely to be labelled as sophisticated or high-skilled, such as computers, electronic devices and telecommunication equipment, tend to have notably lower shares of domestic content. Conversely, many sectors that are relatively intensive in low-skilled labour, such as apparel, are likely to exhibit a high share of domestic content in the country's exports. Finally, we find that foreign-invested firms (including both wholly owned foreign firms and Sino-foreign joint venture firms) tend to have a relatively low share of domestic content in their exports, as they tend to use more processing exports and take large shares in sectors that have a relatively low domestic value-added share.

There are several areas in which future research can improve upon the estimation in this chapter. First, we assign initial values of the direct domestic value added for processing exports at industry level based on information in conventional IO table and proportion assumptions. If firm-level survey data becomes available that track separately the direct value added for processing and normal exports, and that provide information on how the imported intermediate inputs are allocated across sector users, we can improve the accuracy of our estimates. Second, as an inherent limitation of an IO table, the input–output coefficients are assumed to be fixed (which is the nature of the assumed Leontief technology) rather than be allowed to respond to price changes. If the relevant IO tables are available every year, then the variations in the IO coefficients would be recorded. If IO tables are available only sparsely (*eg* once every five years), which tends to be the case for developing countries, then estimating domestic value shares in exports based on past IO tables could be problematic, especially in years when large shocks could induce large (but unobserved) changes in the IO coefficients.

This chapter does not directly investigate causes and consequences of changes in the domestic content share in exports. These can be fruitful areas for future research.

REFERENCES

Banister, J. (2005). Manufacturing Employment in China. *BLS Monthly Labor Review* (July), 11–29.

Brooke, A., D. Kendrick, A. Meeraus and R. Raman (2005). GAMS: User's Guide. GAMS Development Cooperation, Washington, DC.

Chen, X., L. Cheng, K. C. Fung and L. J. Lau (2004). The Estimation of Domestic Value-Added and Employment Induced by Exports: An Application to Chinese Exports to the United States. Working Paper. Stanford University.

Chinn, M. D. (2005). Supply Capacity, Vertical Specialization and Tariff Rates: The Implications for Aggregate US Trade Flow Equations. NBER Working Paper 11719.

Dean, J. M., K. C. Fung and Z. Wang (2007). Measuring the Vertical Specialization in Chinese Trade. Office of Economics Working Paper 2007-01-A. US International Trade Commission.

Goh, A.-T., and J. Olivier (2004). International Vertical Specialization, Imperfect Competition and Welfare. Working Paper, HEC School of Management (France).

Hummels, D., J. Ishii and K. Yi (2001). The Nature and Growth of Vertical Specialization in World Trade. *Journal of International Economics* **54**, 75–96.

Koopman, R., Z. Wang and S.-J. Wei (2008). How Much Chinese Exports Is Really Made in China: Assessing Foreign and Domestic Value Added in Gross Exports. NBER Working Paper 14109.

Koopman, R., Z. Wang and S.-J. Wei (2012). Estimating Domestic Content in Exports when Processing Trade Is Pervasive. *Journal of Development Economics* **99**(1), 178–189.

Krugman, P. (2008). Trade and Wages, Reconsidered. *Brookings Papers on Economic Activity*. URL: http://www.brookings.edu/.

Lau, L. J., X. Chen, L. K. Cheng, K. C. Fung, Y. Sung, C. Yang, K. Zhu, J. Pei and Z. Tang. (2007). Non-Competitive Input–Output Model and Its Application: An Examination of the China–US Trade Surplus. *Social Sciences in China* **2007**(5), 91–103 (in Chinese).

Lawrence, R. (2008). *Blue Collar Blues: Is Trade to Blame for Rising US Income Inequality?*, Policy Analyses in International Economics, Volume 85. Peter G. Peterson Institute for International Economics, Washington, DC.

Linden, G., K. L, Kraemer and J. Dedrick (2007). What Captures Value in a Global Innovation System? The Paul Merage School of Business, UC Irvine, Working Paper.

Manova, K., and Z. Zhang (2012). Export Prices across Firms and Destinations. *Quarterly Journal of Economics* **127**(1), 376–436.

National Research Council (2006). *Analyzing the US Content of Imports and the Foreign Content of Exports*. Committee on Analyzing the US Content of Imports and the Foreign Content of Exports. Center for Economics, Governance, and International Studies, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

Rodrik, D. (2006). What's So Special about China's Exports?' *China & World Economy* **14**(5), 1–19.

Schott, P. (2008). The Relative Sophistication of Chinese Exports. *Economic Policy* **53**, 5–49.

Varian, H. R. (2007). An iPod Has Global Value. Ask the (Many) Countries That Make It. *New York Times*, 28 June.

Wang, Z., and S.-J. Wei. (2008). What Accounts for the Rising Sophistication of China's Exports? NBER Working Paper 13771, February.

WTO and IDE-JETRO (2011). Trade Patterns and Global Value Chains in East Asia: From Trade in Goods to Trade in Tasks. Report. World Trade Organization, Geneva.

Xu, B. (2007). Measuring China's Export Sophistication. Working Paper, China Europe International Business School.

Yi, K.-M. (2003). Can Vertical Specialization Explain the Growth of World Trade? *Journal of Political Economy* **111**(1), 52–102.

6

Foreign and Domestic Content in Mexico's Manufacturing Exports

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This chapter provides estimates of foreign and domestic content in Mexico's manufacturing exports that take into account the import content in production under the maquiladora and Programa de Importación Temporal para Producir Artículos de Exportación (PITEX) programmes. We applied a modified version of the methodology developed in Koopman *et al* (2011) by using a recently available input–output table for the maquiladora industry. We also applied the original method suggested in Koopman *et al* (2011) and compare the results obtained under both methodologies. This is the first study for Mexico that measures vertical specialisation using a recently available input–output table for the maquiladora industry in addition to trade data from both export promotion programmes. On average, Mexico's manufacturing exports have a foreign content share of approximately 66%. Those industries that have a foreign content share of 50% or more account for 80% of the country's manufacturing exports. These include computer and peripheral equipment, audio and video equipment, communications equipment, semiconductor and other electronic components and electrical equipment.

1 INTRODUCTION

Mexico's international trade (exports plus imports of goods) grew from US$82.3 billion in 1990 to US$700.5 billion in 2011, an increase of 751.2%. The North American Free Trade Agreement (NAFTA), which took effect on 1 January 1994, played an instrumental role. Total bilateral trade between the USA and Mexico increased by 435.4% from US$78.9 billion in 1993, the year

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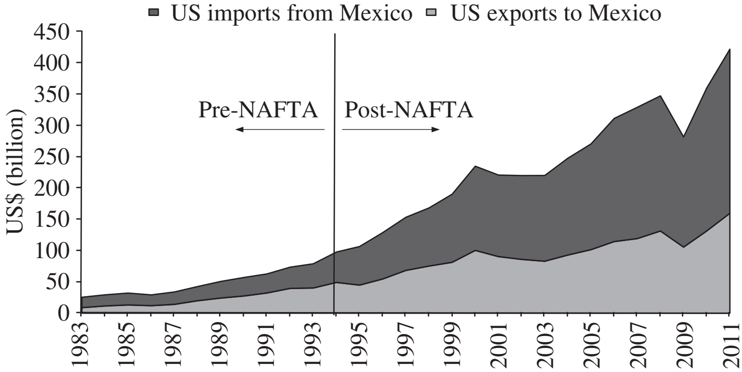

Figure 6.1: *US–Mexico goods trade.*

Source: US Department of Commerce.

prior to NAFTA entering into force, to US$422.6 billion in 2011 (Figure 6.1). In relative terms, Mexico's share of US imports has also increased from 6.7% in 1993 to 12.0 in 2011. Mexico together with Canada accounted for 26.5% of US imports of goods in 2011. The USA is Mexico's largest trading partner, and Mexico is the third largest trade partner the USA after Canada and China. In 2011, the USA accounted for 49.7% of Mexico's total imports, and 78.6% of its total exports. While the trade volume has exploded, the relative dominance of the USA in Mexico's trade has not changed much; these ratios were 69.3% and 82.7%, respectively, in 1993.

1.1 Production Fragmentation and Its Economic Effects

Cross-border production sharing or vertical specialisation has increased its relative importance in world trade and is thought to be responsible for the faster rate of growth in the trade share of GDP (Yi 2003). As a measure of foreign value added or foreign content in exports, vertical specialisation distorts trade data in terms of export content to GDP, as noted by Feenstra (1998), Feenstra and Hanson (2004) and Johnson and Noguera (2012). Recent literature in international economics shows that vertical specialisation may have important economic effects on wage inequality, employment and business cycles, and on the pass-through effects of changes in tariffs and exchange rates. In addition, it may also have policy implications for the relationships between trade, trade facilitation, investment and intellectual property policy, and the relationship between trade and competition policy (Nordås 2005).

Regarding wage inequality, Feenstra (1998, 2008), Feenstra and Hanson (1999, 2004), Krugman (2008) and Ebenstein *et al* (2009) note that global production sharing, outsourcing or trade in intermediate inputs are potentially important in explaining wage differentials between skilled and unskilled

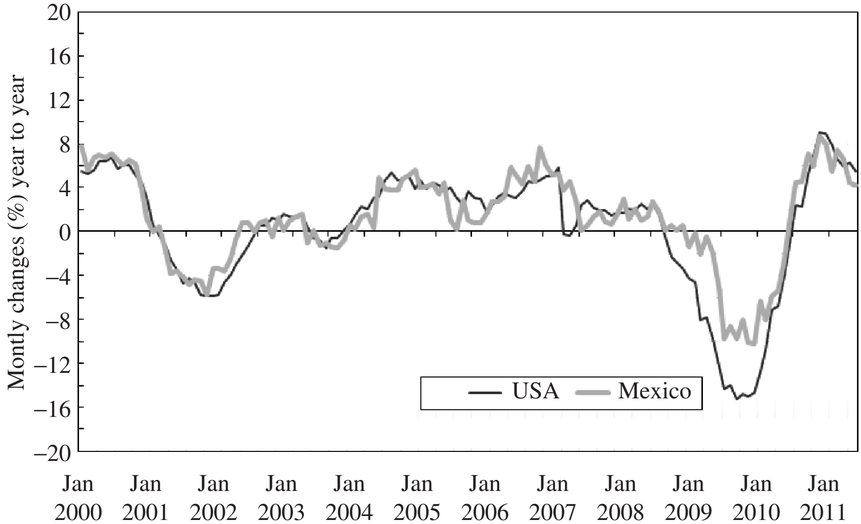

Figure 6.2: *US and Mexico manufacturing production, 2000–10.*

Source: Board of Govenors of the Federal Reserve System and Banco de México. The correlation coefficient between these indexes is 0.92.

workers in the USA and elsewhere. Specifically, Feenstra and Hanson (1999) found that outsourcing explains 15% of the increase in the US relative wage of nonproduction workers during the period 1979 to 1990. Trade in inputs or vertical specialisation depresses the demand for less-skilled workers while raising the relative demand and wages of the higher skilled. Evidence on Mexico also suggests that outsourcing by multinationals has contributed to the increase in the relative wage of skilled workers in the country (Feenstra and Hanson 1997).[2]

Production sharing has the potential to synchronise business cycles as well as to increase the volatility and severity of economic fluctuations. Burstein *et al* (2008) (in a multi-country setting) and López (2007) (for a small open economy) show that production sharing can generate business cycle synchronisation. The Lopéz model of business cycle, in which the transmission mechanism is production sharing, successfully replicated real business statistics of the Mexican maquiladora, or production sharing manufacturing sector. Empirically, Herrera-Hernandez (2004) and Chiquiar and Ramos-Francia (2005) show that the US and Mexican manufacturing sectors became synchronised after NAFTA was enacted. This also seems to be the case during the period from 2000 to 2011 (Figure 6.2). Furthermore, Bergin *et al*

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[2]Rising wage inequality in Mexico may also be explained by trade and quality upgrading noted by Verhoogen (2008), and by trade liberalisation, as suggested by Hanson and Harrison (1999) and Chiquiar (2008).

(2009a,b) provide theoretical and empirical evidence suggesting that the Mexican maquiladora industry associated with US production sharing experiences fluctuations in employment that are twice as volatile as those of their counterpart industries in the USA. Feenstra (2008, p. 87) adds:

> That fact that the maquiladora industries are more volatile means that the US is essentially exporting some of its business cycle, or more precisely, exporting the cyclical fluctuations due to demand shocks.

Regarding vertical specialisation and the severity of business cycles, Yi (2009) analysed the recent collapse of global trade, suggests that vertical specialisation can amplify trade effects so that the collapse in global trade in the fourth quarter of 2008 was sudden, severe and synchronised. Yi's explanation is based on the linkage between US exports and US imports, *ie* when US imports decline so do US exports of intermediate goods used in the manufacturing of US imports of final goods. In this instance, we have a multiplicative effect as vertical specialisation links a country's imports to its exports.

With respect to tariffs, in an earlier paper, Yi (2003) theorised that, because of vertical specialisation, tariff reductions can have magnifying effects on imports prices. Empirically, Feenstra (2008) confirmed this with evidence from the Information Technology Agreement (ITA) of the WTO, under which tariffs on high-tech goods were eliminated from 1997 to 1999. Feenstra estimated a tariff pass-through coefficient of 22.6, suggesting that the multilateral tariff reductions under ITA had magnified effects on decreasing US import prices, as prices declined many times more than the tariff decreases. In contrast, the pass-through effect of exchange rates under production sharing seems to be relatively small both empirically and theoretically, which has contributed to keeping prices low.[3] Bergin and Feenstra (2008) estimated that the pass-through effect of exchange rates would fall by about one-fifth of its size as a result of the growing share of US trade with China, a major source of offshoring. Additionally, Ghosh (2008) presents a theoretical model in which the exchange rate pass-through is lower with production sharing trade compared with the situation of standard trade. The pass-through symmetry of tariffs and exchange rates was tested by Feenstra (1989), but not under production sharing.

1.2 The Maquiladora Programme

The maquiladora programme started in the mid-1960s with plants and a few employees manufacturing televisions and plastics (INEGI 2007; Truett and Truett 1984). However, this industry did not grow substantially until the Mexican government relaxed its restrictions on foreign direct investment (FDI)

[3] Without accounting for the presence of vertical specialisation, most of the current literature asserts that the pass-through effect of exchange rates has been declining from 0.5 to 0.2 (Campa and Goldberg 2006).

in the 1980s (Bergin *et al* 2009a; OECD 1996; Truett and Truett 1984, 1993, 2007). Now, the maquiladora industry appears to be highly integrated with the US manufacturing sector, and most maquiladoras are US owned, but companies based in Japan, South Korea and Germany are also important participants. Maquiladoras received preferential treatment under both the US and Mexican laws by which US firms paid duties on foreign value added only, while Mexico allowed for duty-free imports as long as the maquiladora output was exported back to the USA. However, with the implementation of NAFTA, the preferential tariff treatment afforded to maquiladoras ended.

Given the importance of the maquiladora regime as a generator of jobs, exports and foreign exchange in Mexico for more than 35 years, in 2002 the Mexican government established sectoral development programmes (Programas de Promoción Sectorial, or PROSECs) to maintain competitiveness of the manufacturing sector in Mexico, irrespective of whether or not products were exported (WTO 2008). The PROSECs allowed participating companies to import eligible non-NAFTA inputs and capital equipment at a rate of either 0% or 5% (Gantz 2004). The maquiladoras' finished products were not contingent to subsequent exportation and were permitted to be sold in Mexico or exported. In addition, maquiladoras' exports were exempted from the value-added tax and, upon complying with certain rules, income tax and asset tax were done away with (Baker & McKenzie 2006). Thus, in spite of NAFTA's Article 303, growth in the maquiladora industry accelerated, and by 2006 there were 2810 maquiladora plants, with 1.2 million employees. In addition, Bergin *et al* (2009a) point out that the industry's real value added approximately tripled between 1994 and 2005.

1.3 PITEX, IMMEX and Other Programmes

Mexico's second major export promotion programme, the 'Program of Temporary Imports to Produce Export Goods' (Programa de Importación Temporal para Producir Artículos de Exportación, or PITEX) was established in 1990. This programme, designed for firms already established in Mexico and producing for the domestic and export markets, also granted fiscal and administrative benefits, *eg* importing intermediates and machinery free of duty as long as the final product was exported (USITC 1998b). One benefit of PITEX was to allow foreign investors to register as a national supplier to the automotive industry (USITC 1998b). Also, the programme included duty drawback for firms that had a significant share of imported inputs in their exports, in addition to special administrative, fiscal and financial benefits (OECD 1996). However, firms under PITEX were subject to taxes for which maquiladora firms were exempt (USITC 1998b). In 2006, PITEX firms numbered 3620 and included all motor vehicle assembly plants and most of their parts suppliers. They tended to locate in the interior of Mexico because a significant portion of their sales was destined to the domestic market, while maquiladora firms tended to locate in the border states. PITEX and maquiladora firms together employed approximately 60% of Mexico's total manufacturing employment in 2006.

On 23 November 2006, the Mexican government merged the maquiladora and PITEX programmes into a new regime to promote exports, named the 'Manufacturing Industry, Maquiladora and Export Services Program' (Industria Manufacturera, Maquiladora y de Servicios de Exportación, or IMMEX), administered by the Secretariat of Economy. The new programme simplified procedures and requirements for firms' import inputs, raw materials, parts and components, and machinery and equipment free of duty as long as the finished product was exported. Firms under the IMMEX programme also enjoyed certain tax exemptions.

In addition to the programme, Mexico has other programmes to promote export through tariff and tax concessions and administrative facilities. These include the 'High-Volume Exporting Companies' (Empresas Altamente Exportadoras, ALTEX) programme and the 'Foreign Trade Companies' (Empresas de Comercio Exterior, ECEX) programme. At the end of 2006, there were 2644 firms in the ALTEX programme and 340 firms in the ECEX programme. Between 2002 and 2006, the government approved 46,989 Mexican exporters under the duty-drawback programme (WTO 2008).

Mexico's processing exports through its maquiladora, PITEX, and other programmes underscore the importance of estimating the true domestic and foreign value added in its exports. We estimate these value-added measures by applying a variation of the methodology developed by Koopman *et al* (2011), which takes into account an actual input–output (IO) table for the maquiladora industry. In contrast, in estimating the domestic value added in China's exports, Koopman *et al* (2011) use an optimising algorithm to estimate the structure of processing export sectors. For comparison purposes, we also perform the calculations with their original methodology. In both instances, we assume that other export-promoting programmes, including PITEX, have the same IO coefficients as those of the maquiladora industry. This chapter, to the best of our knowledge, is the first study for Mexico that measures vertical specialisation using a recently available input–output table for the maquiladora industry in addition to using trade data from both export promotion programmes, the maquiladora and PITEX; to date most studies on processing exports for Mexico have used trade data only from the maquiladora industry. Our results suggest that Mexico's industrial strategy has resulted, although modestly and only in some industries, in its insertion into the global supply chains as the domestic value added share in Mexico's manufacturing exports increased in recent years.

The estimated measures indicate that on average Mexico's domestic value added in its manufacturing exports is about 34%. Accounting for 80% of the country's manufacturing exports, 41 industries (out of a total 75 three-digit NAICS), have a domestic content of less than 50%. These industries include computer and peripheral equipment, audio and video equipment, communications equipment, semiconductor and other electronic components, and electrical equipment among others. The remainder of this chapter explains the data and the methodology in Section 2, the estimation results in Section 3 and the conclusion in Section 4.

2 DATA AND ESTIMATION METHOD

2.1 Mexico's Input–Output Table for 2003 and Trade Data

The most up to date input–output table for Mexico was the one for 2003 developed by Mexico's statistical agency, the Instituto Nacional de Estadística, Geografía e Informática (INEGI), which has 255 four-digit North American Industry Classification System (NAICS) sectors. A notable feature is a specific IO table for the maquiladora industry.[4] This table includes national production of goods and services classified under Mexico's NAICS for 2002, inputs purchased in the domestic economy and imports from the rest of the world.

Mexico's trade data at the Harmonized System (HS) eight-digit level for 1996–2006 were obtained from the World Trade Atlas. The data were available for both the maquiladora and PITEX firms' imports and exports by country source and destination. INEGI reports trade data for the maquiladora industry but not PITEX. This is important because excluding PITEX data from an analysis of the processing industry in Mexico would omit important information. Moreover, US data on production sharing or US imports under HS Chapter 98 are likely to be underestimated as a result of the implementation of NAFTA and other preferential agreements (Burstein *et al* 2008). The World Trade Atlas trade data are from the Mexican government but the values are greater than those reported by the US Department of Commerce by about 10–12% (US Department of Commerce 2000, 2001).

2.2 Trade Statistics

Exports of manufactured goods under the maquiladora and PITEX programmes accounted for 85.4% of the total manufactured exports of US$195.6 billion in 2006, but in previous years this share was larger; for instance, in 2000 it was 93.5% (Table 6.1). Maquiladora and PITEX firms' imports accounted for 69.8% of their exports in 2006, *ie* out of one US dollar of exports from these firms, 69.8 cents consisted of imported parts and components. In 2006, the leading suppliers of these imports were the USA (51%), China (12.2%) and Japan (8.2%) (Table 6.2). Historically, the USA was the predominate supplier, but China, Japan, South Korea, Taiwan (Chinese Taipei), Malaysia and Singapore have gained market shares in recent years. The main

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[4]We are grateful to INEGI for providing us with the input–output table.

Table 6.1: *Mexico's processing manufacturing exports, 1996–2006.*

Year	A	B	C	D
1996	86.7	61.9	71.6	28.4
1997	89.0	58.9	69.2	30.8
1998	91.3	58.9	69.6	30.4
1999	93.0	59.6	68.6	31.4
2000	93.5	59.9	70.3	29.7
2001	92.7	57.1	68.0	32.0
2002	91.5	56.3	67.8	32.2
2003	89.9	55.1	68.0	32.0
2004	87.9	54.7	70.3	29.7
2005	85.7	53.2	70.8	29.2
2006	85.4	52.7	69.8	30.2

Source: World Trade Atlas. A: share of processing exports (PE) in total exports (TE) (100 × (PE/TE)). B: share of processing imports (PM) in total imports (TM) (100 × (PM/TM)). C: ratio of processing imports to processing exports (100 × (PM/PE)). D: processing trade surplus as a share of processing exports (100 × (PE − PM)/PE). Processing manufacturing refers to exports and imports under the maquiladora and PITEX programmes. Data include HS Chapters 28–97 only.

Table 6.2: *Mexico's total imports for processing exports, by leading markets, 2000–6.*

Market	2000	2001	2002	2003	2004	2005	2006
USA	80.8	74.5	69.6	68.7	60.3	55.7	51.0
China	1.1	2.0	3.7	6.6	9.3	10.0	12.2
Japan	3.7	5.9	6.9	5.4	6.6	7.8	8.2
Germany	2.8	2.6	2.2	2.3	2.3	2.7	2.8
Canada	1.4	1.6	1.5	1.3	1.6	1.7	1.8
Sum	89.8	86.6	83.9	84.3	80.1	77.9	76.0
Rest	10.2	13.4	16.1	15.7	19.9	22.1	24.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: World Trade Atlas. Imports for processing exports refer to imports under the maquiladora and PITEX programmes. Data include HS Chapters 1–99.

destination of Mexico's processing exports is the USA, to which Mexico exports about 90%, followed by Canada, with about 2% (Table 6.3).

Mexico's maquiladora processing exports amounted to US$111.9 billion in 2006, including, at the HS two-digit level, electrical machinery (49.0%), machinery (18.4%), automobiles and automobile parts (6.2%), medical instruments (6.1%), furniture and bedding (4.2%), knitted and non-knitted apparel (4.2%) and plastics (1.8%). These products combined represent about 90.0% of the total. Similarly, in the same year, Mexican firms under the PITEX programme exported US$62.3 billion, including automobiles and automobile parts (48.7%), machinery (12.3%), electrical machinery (6.4%), iron and steel (3.2%), beverages (3.1%), iron and steel products (3.0%), vegetables (2.9%) and medical instruments (2.1%); combined, these represent about 82.0% of the total.

Table 6.3: *Mexico's total processing exports, by leading markets, 2000–6.*

Market	2000	2001	2002	2003	2004	2005	2006
USA	92.4	92.3	92.4	92.8	92.8	90.2	89.1
Canada	2.1	2.0	1.9	1.8	1.4	1.9	2.1
Germany	1.0	1.0	0.7	1.0	0.9	1.3	1.4
Colombia	0.1	0.2	0.2	0.2	0.2	0.6	0.8
Netherlands	0.3	0.3	0.4	0.4	0.3	0.4	0.5
Sum	95.8	95.7	95.6	96.2	95.7	94.5	93.9
Rest	4.2	4.3	4.4	3.8	4.3	5.5	6.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: World Trade Atlas. Processing exports refer to exports under the maquiladora and PITEX programmes. Data include HS Chapters 1–99.

2.3 Estimation Methods

Hummels *et al* (2001) (henceforth denoted HIY) proposed the concept of vertical specialisation (VS) or foreign content or foreign value added in a country's trade as 'the imported input content of exports, or equivalently, foreign value added embodied in exports'. They provided a formula to compute shares based exclusively on a country's IO table. A key assumption needed for the HIY formula to work is that the intensity in the use of imported inputs is the same between production for exports and production for domestic sales.

However, Koopman *et al* (2011) noted that such an assumption is violated in the presence of processing exports and indicated that the HIY formula is likely to lead to a significant underestimation of the share of foreign value added in a country's exports. This is particularly important when policy preferences for processing trade lead to a significant difference in the intensity of import intermediate inputs in production for processing exports and the production for domestic final sales and normal exports. They developed a formula that can be used to estimate domestic and foreign content for economies that engage in a massive amount of tariff or tax-favoured processing trade, such as that of China, Mexico and Vietnam. They also demonstrated that there is a clear connection between the domestic content concept and the concept of vertical specialisation proposed by HIY.

The methodology, applied here, that uses an IO table for the maquiladora industry is discussed in De La Cruz *et al* (2011). That methodology is based on Koopman *et al* (2011) (henceforth denoted KWW). It implies that with a one-year single-country IO table and detailed bilateral export data for different years and with different trading partners, one is able to compute the domestic and foreign value-added shares at the aggregate level for different years and trading partners separately. The variation in such a computation will come only from the variations in export composition changes over time and across

Table 6.4: *Domestic and foreign value added in Mexico's manufacturing exports: three-digit NAICS versus four-digit NAICS (in percent of total manufacturing exports).*

	The HIY formula			The KWW formula					
				Lower bound[a]			Upper bound[b]		
	2000*	2003	2006*	2000*	2003	2006*	2000*	2003	2006*
Based on three-digit NAICS IO table									
Total foreign VA	47.1	48.9	48.2	54.2	55.0	55.1	72.1	70.5	68.1
Direct foreign VA	42.1	44.0	43.3	51.0	51.8	51.9	70.5	68.9	66.3
Total domestic VA	52.9	51.1	51.8	45.8	45.0	44.9	27.9	29.5	31.9
Direct domestic VA	28.7	28.0	28.0	24.3	24.1	23.5	15.6	16.7	17.6
Based on four-digit NAICS IO table									
Total foreign VA	46.9	46.6	46.3	54.5	52.4	52.5	70	66.2	63.8
Direct foreign VA	41.9	42.4	42.1	51.5	49.9	49.9	68.4	64.5	61.9
Total domestic VA	53.1	53.4	53.7	45.5	47.6	47.5	30.0	33.8	36.2
Direct domestic VA	28.4	32.4	32.1	23.7	28.8	28.2	17.2	20.3	21.1

Source: authors' estimates. [a]Only exports under Maquila are counted as processing exports, while exports under PITEX are counted as normal exports. [b]Both Maquila and PITEX are counted as processing trade.
The HIY method refers to estimates from using the approach in Hummels *et al* (2001). The KWW method refers to estimates using the method in Koopman *et al* (2008). *The estimates for 2000 and 2006 are preliminary as they use 2000 and 2006 exports as weights but sector domestic/foreign value added computed from the 2003 IO table, which is the latest available.

different trading partners, since the domestic and foreign content shares are the same at sector level.

3 ESTIMATION RESULTS

Decomposition results for foreign and domestic value-added shares in 2000, 2003 and 2006 for Mexico's manufacturing exports, with the exception of food, aggregated from both the three-digit and four-digit Mexican NAICS IO tables are reported in Table 6.4. Because exports under the PITEX programme may have a different intensity in using imported intermediates from those of exports under the maquiladora programme, we report two estimates: one in which exports under the PITEX programme are treated as normal exports, and the other when they are treated as processing exports. For comparison, the results from the HIY formula that ignore processing trade are also reported.

The KWW estimates indicate that, aggregated from the three-digit NAICS IO table, the total domestic value-added share in Mexico's manufacturing exports was 45.8% in 2000, 45% in 2003 and 44.9% in 2006 when only exports under the maquiladora programme were counted as processing exports. When exports under the PITEX programme are also counted as processing exports, the share declines to 28%, 30% and 32% in the same years (Table 6.4). If aggregated from the four-digit NAICS IO table, the values are slightly higher: 30%, 34% and 36% when exports under both Marquiladora and PITEX are counted as processing exports; 45.5%, 47.6% and 47.5% when exports under the PITEX programme were treated as normal exports. In general, the direct domestic value-added shares are less than two-thirds of the total domestic value-added shares. However, the indirect foreign value-added share (equal to the total foreign value-added share minus the direct foreign value-added share) was relatively small, suggesting that most of the foreign content comes from directly imported foreign inputs that are used for further processing and assembling, which are then exported back to the world market (mostly to the USA) as final products. The share of indirect foreign value added under the upper-bound estimates is smaller than that in the lower-bound estimate when only Maquila counted as processing trade, suggesting that it is reasonable to classify both Maquila and PITEX as processing exports. Therefore, we will focus our discussion of the results on the upper bound KWW estimates, but we will refer to the lower-bound estimates when necessary.

Relative to the HIY's estimates, the KWW calculations resulted in much higher shares of foreign value added in Mexico's gross exports and showed a different trend over time. To be more precise, considering aggregation from the four-digit NAICS IO table, estimates of the HIY method show that there is almost no trend in foreign content share (total VS share) in the data (47%, 47% and 46% in 2000, 2003 and 2006, respectively). However, when both maquiladora and PITEX are counted as processing exports, KWW estimates reveal that the foreign content in Mexican manufacturing exports declined steadily from 70% in 2000 to 64% in 2006 (or from 72% to 68% if aggregated from the three-digit NAICS IO table). This indicates that the domestic value added in Mexico's manufacturing exports is relatively low, but increased over the period 2000–6.

Overall, the HIY method appears to incorrectly estimate both the level and the trend in domestic versus foreign content in Mexican manufacturing exports (Table 6.4). The results also reveal another interesting fact: the difference (or bias) from trade regime aggregation (whether differentiate processing and normal trade) is much larger than the difference from aggregation based on more detailed sector classifications. There is only about a 2 percentage point difference in domestic or foreign content share estimates between the three-digit and four-digit NAICS classification using the HIY formula, while such a difference doubled when the KWW formula was applied (comparing the upper and lower panels of Table 6.4). But that difference is still less than 4 percentage points smaller than the difference between such estimates based on the HIY formula and the KWW formula (comparing the first, second and third panels in Table 6.4). Treating PITEX as processing exports also makes a difference in the estimation results. This shows that it matters whether or not to take processing trade into account: a finding consistent with what Koopman *et al* (2011) found using Chinese data.

3.1 Estimates for Major Manufacturing Sectors

On average, domestic value added in Mexico's manufacturing exports is 29.5% at the NAICS three-digit level and 33.8% at the NAICS four-digit level (Tables 6.5 and 6.6). Among the 19 manufacturing industries in Table 6.5, 12 industries have domestic content of less than 50%, comprising 89.3% of Mexico's manufacturing exports in 2003.

Similarly, of the 75 industries reported in Table 6.6, 41 industries have domestic content of less than 50% and together represent 79.5% of the country's manufacturing exports. The industries with the lowest shares of domestic value added are: computer and peripheral equipment; audio and video equipment; communications equipment; semiconductor and other electronic components; commercial and service industry machinery component manufacturing; hardware and electrical equipment. The following 21 industries have their shares of domestic content or domestic value added higher than 50% but lower than 65% and account for 15.3% of total manufacturing exports. These medium domestic value-added industries include motor vehicle body and trailer, fiber, yarn and tread mills, railroad rolling stock manufacturing, nonferrous metal production, fabric mills, and metalworking machinery manufacturing. The remaining 13 industries have shares higher than 65% but account for only 5.1% of Mexico's total manufacturing exports. Leading these high domestic value-added group of industries are: petroleum and coal products, with a share of 90.0%; lime and gypsum products, with a share of 88.2%; and pesticide, fertilizer and other agricultural chemicals, with a share of 79.9%.

Counting Mexican manufacturing exports under the PITEX programme as processing trade makes a difference in our calculations across industries. This is particularly important for transportation equipment industries (NAICS 336), but it has relatively less impact on electronic sectors (NAICS 334 and 335). Given the dominance of production sharing arrangements with the USA in Mexico's automobile sector, this should not be a surprise (PITEX made up more than 60% of Mexico's exports of transportation equipment, while those under the Maquila programme were only about 34%). These top three NAICS industries with the lowest domestic value added together made up about 70% of Mexico's total manufacturing exports in 2003. This suggests that Mexican manufacturing trade is highly concentrated in a few industries with an extremely high proportion of processing exports: between 72% and 85% and low domestic content of less than 27% (Table 6.5).

Similarly, there are some marked differences within industries. For instance, in two sectors within the transportation industry, at the four-digit NAICS classification, exports of motor vehicles and motor vehicle body and trailer (with PITEX exports of 100% and 96%) show very different domestic content: domestic value added in motor vehicle body and trailer is 63%, while that of motor vehicle is 35% (Table 6.6). Also, within the computer and electronic product

Table 6.5: *Domestic value-added share in Mexico's manufacturing exports by three-digit NAICS, 2003 (sorted by total foreign value added (weighted sum 2) in descending order).*

Three-digit NCICS	Industry description	Total manuf. exports	A	Non-processing C	Non-processing D	Processing C	Processing D	Weighted sum 1[a] C	Weighted sum 1[a] D	B	Weighted sum 2[b] C	Weighted sum 2[b] D	E
334	Computer and electronic products	35,103	21.4	28.8	71.2	86.0	14.0	77.4	22.6	84.9	85.0	15.0	98.4
336	Transportation equipment	43,393	26.5	31.2	68.8	75.3	24.7	46.2	53.8	34.1	73.8	26.2	96.6
335	Electrical equipment, appliances and components	15,804	9.6	23.5	76.5	75.7	24.3	66.5	33.5	82.4	72.4	27.6	93.7
339	Misc. manufacturing	7,809	4.8	16.1	84.0	71.7	28.3	60.3	39.7	79.6	67.0	33.0	91.5
333	Machinery	5,068	3.1	23.1	76.9	76.7	23.4	44.6	55.4	40.1	65.6	34.4	79.4
315	Apparel	6,784	4.1	21.5	78.5	65.3	34.7	52.9	47.1	71.6	63.6	36.4	96.1
314	Textile product mills	676	0.4	24.9	75.1	72.5	27.5	44.3	55.7	40.9	61.9	38.1	77.7
332	Fabricated metal products	3,502	2.1	20.9	79.1	72.1	27.9	45.9	54.1	48.9	61.3	38.7	78.9
337	Furniture and related products	1,652	1.0	16.2	83.8	67.2	32.8	50.7	49.3	67.7	59.9	40.1	85.7
323	Printing and related activities	289	0.2	20.7	79.3	64.9	35.1	55.6	44.4	79.0	57.6	42.4	83.5
326	Plastics and rubber products	2,074	1.3	27.6	72.4	66.2	33.8	47.0	53.0	50.3	56.1	43.9	73.8
316	Leather and allied products	512	0.3	20.2	79.8	72.1	27.9	35.7	64.3	29.9	53.9	46.1	65.0
331	Primary metal	3,239	2.0	19.4	80.6	64.4	35.6	22.4	77.6	6.7	45.4	54.6	57.8
322	Paper	790	0.5	26.3	73.7	67.3	32.7	40.6	59.4	34.9	45.0	55.0	45.6
327	Non-metallic mineral products	1,929	1.2	9.7	90.3	64.3	35.7	21.1	78.9	20.8	43.2	56.8	61.3
313	Textile mills	729	0.4	29.9	70.1	54.8	45.2	39.2	60.8	37.5	43.0	57.0	52.8
321	Wood products	212	0.1	7.9	92.1	58.1	41.9	24.8	75.2	33.7	40.3	59.7	64.6
325	Chemical	6,891	4.2	15.6	84.4	66.4	33.6	17.8	82.2	4.4	33.8	66.2	35.8
324	Petroleum and coal products	855	0.5	8.1	91.9	79.1	20.9	8.8	91.2	1.0	10.1	89.9	2.9
TOT	Total manufacturing goods except food	137,312	83.7	19.9	80.1	76.8	23.2	55.0	45.0	56.0	70.5	29.5	89.0

Source: authors' estimates. A, percentage of Mexico's total merchandise exports; B, Maquila exports as a percentage of industry exports; C, total FVA; D, total DVA; E, Maquila and PTEX exports as a percentage of industry exports. [a]Only exports under Maquila counted as processing exports, while exports under PITEX counted as normal exports. [b]Both Maquila and PITEX counted as processing trade.

Table 6.6: *Domestic value-added share in Mexico's manufacturing exports by four-digit NAICS, 2003 (sorted by total foreign value added (weighted sum 2) in descending order).*

Four-digit NCICS	Industry description	Total manuf. exports	A	Non-processing C	Non-processing D	Processing C	Processing D	Weighted sum 1[a] C	Weighted sum 1[a] D	B	Weighted sum 2[b] C	Weighted sum 2[b] D	E
3341	Computer and peripheral equipment	11,261	6.9	36.1	63.9	91.5	8.5	77.0	23.0	73.9	90.9	9.1	98.9
3343	Audio and video equipment	8,962	5.5	31.0	69.0	86.9	13.2	84.3	15.7	95.4	86.5	13.5	99.3
3342	Communications equipment	4,460	2.7	20.7	79.3	85.1	14.9	83.2	16.8	97.1	84.0	16.0	98.3
3344	Semiconductor and other electronic component manufacturing	7,276	4.4	19.7	80.3	84.8	15.3	75.0	25.0	85.0	83.6	16.4	98.3
3333	Commercial and service industry machinery manufacturing	580	0.4	32.0	68.0	84.7	15.3	46.7	53.3	27.8	81.4	18.7	93.6
3325	Hardware	747	0.5	18.0	82.0	79.1	20.9	68.6	31.4	82.8	77.2	22.9	96.9
3353	Electrical equipment	5,820	3.5	15.9	84.1	76.9	23.1	66.9	33.1	83.6	75.3	24.7	97.4
3345	Navigational, measuring, electronic medical and control instruments	2,600	1.6	23.6	76.4	77.2	22.8	63.8	36.2	75.0	74.6	25.4	95.1
3359	Other electrical equipment and component manufacturing	6,278	3.8	25.9	74.1	78.0	22.0	68.7	31.3	82.2	74.1	25.9	92.5
3346	Magnetic and optical media	544	0.3	16.2	83.8	80.2	19.8	58.3	41.7	65.8	73.6	26.4	89.7
3363	Motor vehicle parts	21,708	13.2	26.8	73.2	76.1	23.9	57.5	42.5	62.3	73.4	26.7	94.5
3391	Medical equipment and supplies	3,561	2.2	18.0	82.0	74.4	25.6	69.1	31.0	90.5	73.0	27.0	97.5
3366	Ship and boat building	107	0.1	4.0	96.0	72.8	27.2	37.0	63.0	47.9	72.0	28.0	98.9
3379	Other furniture related products	515	0.3	25.9	74.1	73.0	27.0	66.1	33.9	85.4	71.3	28.8	96.3
3351	Electric lighting equipment	1,413	0.9	16.2	83.8	73.7	26.4	64.8	35.2	84.7	66.9	33.1	88.3
3313	Alumina and aluminum production and processing	82	0.0	20.1	79.9	73.3	26.7	41.2	58.8	39.6	66.6	33.4	87.5
3352	Household appliance	2,293	1.4	29.7	70.3	69.3	30.8	60.8	39.2	78.7	65.7	34.3	91.1
3151	Apparel knitting mills	32	0.0	18.3	81.7	71.5	28.5	52.9	47.1	65.0	65.1	34.9	88.0

Source: authors' estimates. A, percentage of Mexico's total merchandise exports; B, Maquila exports as a percentage of industry exports; C, total FVA; D, total DVA; E, Maquila and PTEX exports as a percentage of industry exports. [a]Only exports under Maquila are counted as processing exports, while exports under PITEX counted as normal exports.

Table 6.6: *Continued.*

Four-digit NCICS	Industry description	Total manuf. exports	A	Non-processing C	Non-processing D	Processing C	Processing D	Weighted sum 1[a] C	Weighted sum 1[a] D	B	Weighted sum 2[b] C	Weighted sum 2[b] D	E
3361	Motor vehicles	6,657	4.1	33.2	66.8	64.8	35.2	33.2	66.8	0.0	64.8	35.2	99.9
3152	Cut and sew apparel	6,633	4.0	22.4	77.6	64.6	35.4	52.7	47.3	71.9	63.1	36.9	96.5
3331	Agriculture, construction, and mining machinery	426	0.3	20.4	79.6	76.7	23.3	48.4	51.6	49.7	63.1	36.9	75.8
3339	Other general purpose machinery	1,685	1.0	21.1	78.9	72.2	27.8	48.7	51.3	54.0	63.1	36.9	82.2
3336	Engine, turbine, and power transmission equipment	1,308	0.8	25.7	74.3	72.1	27.9	37.0	63.0	24.4	62.7	37.3	79.7
3149	Other textile product mills	484	0.3	25.9	74.1	71.5	28.5	44.1	55.9	40.0	62.4	37.6	80.0
3364	Aerospace products and parts	1,176	0.7	9.6	90.4	74.2	25.8	33.1	66.9	36.3	62.4	37.6	81.8
3272	Glass and glass products	852	0.5	13.4	86.6	71.9	28.1	25.5	74.5	20.6	62.1	38.0	83.1
3329	Other fabricated metal products	1,485	0.9	22.3	77.8	74.5	25.5	51.9	48.1	56.7	62.1	37.9	76.4
3399	Other misc. manufacturing	4,248	2.6	15.7	84.3	68.6	31.4	52.9	47.1	70.4	61.4	38.6	86.5
3334	Ventilation, heating, air-conditioning and commercial refrigeration equipment	669	0.4	26.6	73.4	71.7	28.3	50.8	49.3	53.6	61.3	38.7	77.0
3322	Cutlery and hand tools	222	0.1	17.3	82.7	73.1	26.9	31.3	68.7	25.2	60.0	40.1	76.5
3141	Textile furnishings mills	192	0.1	24.2	75.9	73.1	26.9	45.2	54.8	43.0	59.4	40.6	71.9
3261	Plastics products	1,586	1.0	28.5	71.5	66.6	33.4	49.4	50.6	55.0	58.6	41.4	79.1
3231	Printing and related support activities	289	0.2	21.1	78.9	64.8	35.2	55.9	44.1	79.6	57.6	42.4	83.5
3372	Office furniture	923	0.6	19.6	80.4	62.1	37.9	46.0	54.0	62.2	54.9	45.1	83.2
3311	Iron and steel mills and ferroalloy	1,239	0.8	19.4	80.7	65.7	34.3	19.8	80.2	1.0	54.1	45.9	75.0
3159	Apparel accessories and other apparel	119	0.1	16.4	83.6	64.5	35.5	45.8	54.2	61.1	53.5	46.5	77.2
3161	Leather and hide tanning and finishing	109	0.1	16.4	83.6	77.0	23.0	20.2	79.8	6.4	53.3	46.7	60.8
3169	Other leather and allied products	140	0.1	19.9	80.1	60.6	39.4	38.8	61.2	46.5	53.3	46.7	82.1

Table 6.6: *Continued.*

Four-digit NCICS	Industry description	Total manuf. exports	A	Non-processing C	Non-processing D	Processing C	Processing D	Weighted sum 1[a] C	Weighted sum 1[a] D	B	Weighted sum 2[b] C	Weighted sum 2[b] D	E
3162	Footwear	263	0.2	20.7	79.3	76.4	23.6	37.7	62.3	30.7	52.7	47.3	57.5
3371	Household and institutional furniture and kitchen cabinets	214	0.1	14.6	85.4	65.9	34.1	39.6	60.5	48.7	51.1	48.9	71.3
3327	Machine shops, turned products and screws, nuts and bolts	61	0.0	16.4	83.6	63.6	36.4	40.9	59.1	51.9	50.9	49.1	73.1
3324	Boiler, tank and shipping container	126	0.1	23.6	76.4	66.5	33.5	34.2	65.8	24.7	49.9	50.1	61.2
3133	Textile and fabric finishing and fabric coating mills	100	0.1	26.3	73.7	71.7	28.4	47.1	52.9	45.9	49.3	50.7	50.8
3212	Veneer, plywood and engineered wood products	55	0.0	13.9	86.1	69.0	31.0	20.6	79.4	12.2	48.5	51.5	62.8
3259	Other chemical products and preparation	835	0.5	22.4	77.6	70.6	29.4	28.4	71.6	12.4	48.0	52.0	53.1
3326	Spring and wire product	509	0.3	21.0	79.0	54.6	45.4	23.5	76.5	7.4	47.9	52.1	80.3
3211	Sawmills and wood preservation	3	0.0	4.4	95.6	65.9	34.1	13.1	86.9	14.1	47.4	52.6	70.0
3262	Rubber products	487	0.3	26.9	73.1	62.8	37.2	38.8	61.2	33.1	47.1	52.9	56.4
3222	Converted paper products	695	0.4	25.2	74.8	67.2	32.8	41.7	58.3	39.2	46.4	53.7	50.3
3369	Other transportation equipment	31	0.0	32.8	67.2	56.2	43.8	38.8	61.3	25.5	45.8	54.2	55.7
3332	Industrial machinery	146	0.1	14.6	85.4	62.0	38.0	32.7	67.3	38.1	43.0	57.0	59.8
3312	Steel product using purchased steel	620	0.4	22.3	77.7	54.3	45.7	26.1	73.9	11.9	41.9	58.1	61.3
3219	Other wood product	154	0.1	13.7	86.3	56.8	43.2	31.7	68.3	41.9	41.7	58.3	65.1
3323	Architectural and structural metals	250	0.2	22.1	77.9	48.4	51.6	30.6	69.4	32.5	41.5	58.5	73.8
3335	Metalworking machinery manufacturing	255	0.2	18.2	81.8	63.2	36.8	21.2	78.8	6.6	40.6	59.4	49.8
3252	Resin, synthetic rubber, and artificial synthetic fibers and filaments	1,145	0.7	25.9	74.1	58.2	41.9	26.3	73.7	1.1	40.5	59.6	45.1
3315	Foundries	30	0.0	15.1	84.9	60.1	39.9	18.4	81.6	7.3	38.9	61.1	52.9
3132	Fabric mills	514	0.3	29.1	70.9	44.8	55.2	35.8	64.2	42.4	38.8	61.2	61.5
3314	Non-ferrous metal (except aluminum) production and processing	1,267	0.8	16.2	83.8	74.4	25.6	20.7	79.3	7.7	38.1	61.9	37.6

Table 6.6: *Continued.*

Four-digit NCICS	Industry description	Total manuf. exports	A	Non-processing		Processing		Weighted sum 1[a]		B	Weighted sum 2[b]		E
				C	D	C	D	C	D		C	D	
3365	Railroad rolling stock manufacturing	202	0.1	40.1	59.9	37.1	63.0	39.5	60.5	19.3	37.5	62.5	85.6
3131	Fiber, yarn, and thread mills	115	0.1	32.6	67.4	62.5	37.5	35.1	64.9	8.4	37.2	62.8	15.5
3362	Motor vehicle body and trailer	13,512	8.2	6.4	93.6	36.7	63.3	7.5	92.5	3.5	36.7	63.3	99.8
3251	Basic chemical	1,561	1.0	12.0	88.0	53.5	46.5	13.8	86.3	4.2	33.8	66.2	52.5
3221	Pulp, paper and paperboard mills	94	0.1	29.4	70.6	67.0	33.0	30.6	69.4	3.2	33.5	66.5	10.8
3273	Cement and concrete product	121	0.1	7.1	92.9	63.0	37.1	22.5	77.5	27.6	33.1	66.9	46.6
3279	Other non-metallic mineral product	313	0.2	16.7	83.3	60.1	39.9	28.8	71.2	28.0	32.3	67.7	36.1
3271	Clay product and refractory	609	0.4	9.1	91.0	52.7	47.3	16.6	83.5	17.2	30.9	69.1	50.2
3254	Pharmaceutical and medicine	1,510	0.9	11.8	88.3	60.7	39.3	13.4	86.6	3.3	28.7	71.4	34.5
3321	Forging and stamping	103	0.1	19.4	80.6	57.6	42.4	24.1	75.9	12.4	27.0	73.0	19.8
3255	Paint, coating and adhesive	902	0.6	24.4	75.6	60.6	39.4	25.5	74.5	3.3	25.7	74.3	3.8
3256	Soap, cleaning compound and toilet preparation	841	0.5	18.4	81.6	74.2	25.8	20.9	79.1	4.4	25.2	74.8	12.2
3328	Coating, engraving, heat treating and allied activities	0	0.0	20.4	79.6	57.1	42.9	—	—	0.0	21.1	78.9	2.0
3253	Pesticide, fertilizer and other agricultural chemical	95	0.1	21.2	78.8	17.6	82.4	21.1	78.9	3.7	20.2	79.9	29.6
3274	Lime and gypsum product	35	0.0	11.7	88.3	36.0	64.0	11.7	88.3	0.2	11.8	88.2	0.5
3241	Petroleum and coal products	855	0.5	8.0	92.0	79.1	20.9	8.7	91.3	1.0	10.0	90.0	2.9
TOT	Total manufacturing goods except food	137,312	83.7	19.9	80.1	72.0	28.0	52.4	47.6	55.7	66.2	33.8	89.0

industry (whose exports are mostly under the Maquila programme) exports of communications equipment, audio and video equipment, semiconductor and other electronic component manufacturing, and computer and peripheral equipment show an average domestic content of 14%. In contrast, also within the computer and electronic product industry navigational, measuring, electromedical and control instruments show a domestic value added of 25%. Differences in the electrical equipment, appliance, and component industry (also mostly maquiladora exports) are less prominent. For instance, exports of electrical equipment and other electrical equipment and component manufacturing average a domestic value added of 25%, while those of electric lighting equipment and household appliances average a value added of 34%. This indicates that exporting industries that tend to use the maquiladora programme the most, *eg* electronics, have low domestic value added, while those industries that export under PITEX, *eg* automobile and machinery industries, have relatively higher domestic content.

3.2 Exports to Major Markets

The USA is the leading market for Mexican manufacturing exports, to which Mexico exported 86.4% of its total in 2006 (De La Cruz *et al* 2011, Table 9). Although this share declined from 2003 to 2006, the USA continues to play a dominant role as a market for Mexico's manufacturing exports. Canada follows with approximately 2% of Mexico's total manufacturing exports. Most of Mexico's manufacturing exports to the USA and Canada are processing exports in excess of 87% of such exports. Although the share of domestic value added in Mexico's processing exports is increasing, it remained relatively low, at about 34.3% for the USA and 36.8% for Canada, in 2006. Mexico's trading partners and its manufacturing exports under both the maquiladora and PITEX programmes indicate that in 2006 both programmes were important for the USA and Canada, but PITEX was particularly important for Brazil, the European Union and Japan. The share of Maquila exports to the USA remained at 60%, while that of PITEX declined from 35% to 27% from 2000 to 2006.

3.3 Comparing Mexico and China

On average, Mexico's domestic value added in manufacturing exports is about 34% (Table 6.6), a share that is relatively lower than that of 51% for China (Koopman *et al* 2011, Table 2). Low domestic content industries in both countries include computers and accessories and telecommunications equipment. Some higher domestic value-added industries that are similar in both countries include motor vehicles and cement.

Mexico's domestic content in processing trade for computers (8.5%; see Table 6.6) is lower than that of China (18.7%; see Koopman *et al* (2011, Table 5)), suggesting some integration in Mexico's information and communications technology but not as much as in China. Mexico has promoted partnerships among domestic firms, foreign firms and the university system in the city of Guadalajara, to create the country's 'Silicon Valley'.[5] In addition, the country has also moved, although modestly, in the global supply chain in the areas of software development and information technology services. Mexico's domestic value added in communication equipment (14.9%) and electronic components (15.3%) are almost half of China's (36.0% and 32.8%, respectively). High domestic value-added processing industries in Mexico are railroad rolling stock manufacturing (63.0%) and pesticide, fertilizer, and other agricultural chemicals (82.4%), which are more than twice as high as those of China (14.6 and 16.5%, respectively).

Estimates of domestic value added in manufacturing exports by country or region of destination indicate that domestic content in both Mexico and China's exports to the USA is similar but less that 50–44.7% for Mexico (De La Cruz *et al* 2011, Table 9) and 45.5% for China (Koopman *et al* 2011, Table 7). Moreover, Mexico's domestic content in exports to Japan and Brazil is, on average, higher (68.9%) than for China (60.5%). Notably, both countries' domestic value added in manufacturing exports to the rest of Latin America and the Caribbean is relatively high: 77.7% for Mexico and 75.8% for China.

3.4 Comparing Content Shares Estimates

As described above, the estimation method in this chapter uses a 'true' IO account that separately traces processing exports and other production transactions in the Mexican economy but which rarely exists for other countries. Mexico's statistical agency, the Instituto Nacional de Estadística, Geografía e Informática (INEGI), compiled a 2003 benchmark IO table based on an economic census, which has separate accounts for Mexico's domestic and maquiladora industries. The IO table includes national production of goods and services classified under Mexico's 2002 three- and four-digit NAICS, inputs purchased in the domestic and maquiladora industries and imports from the rest of the world by both economies. The 'true' domestic and foreign content shares computed directly from this special Mexico IO table at the three-digit NAICS are summarised in Table 6.7 for convenience. It provides a reference benchmark to test the performance of the estimation method proposed in Koopman *et al* (2011). Thus, with exports and import data for the maquiladora industries from the World Trade Atlas and Mexico's aggregate 2003 IO table, we implemented the same quadratic programming model that generates estimates for domestic and foreign content of exports as described in Koopman *et al* (2011). The computed estimates of domestic and foreign value-added shares for Mexico manufacturing exports are reported in

[5]We thank Ted H. Moran for making this important remark linked to the formation of backward linkages and supplier networks for multinational investors.

Table 6.7: *Domestic and foreign content in Mexico's gross exports, 2003, computed directly from the Mexico IO table with a separate maquiladora economy account.*

		Normal exports				Maquiladora exports				Weighted sum			
NAICS code	NAICS description	Direct FVA	Direct DVA	Total FVA	Total DVA	Direct FVA	Direct DVA	Total FVA	Total DVA	Direct FVA	Direct DVA	Total FVA	Total DVA
311	Food manufacturing	7.6	38.5	13.3	86.7	48.9	23.3	52.0	48.0	16.7	35.1	21.8	78.2
312	Beverage and tobacco product manufacturing	7.2	42.4	13.0	87.0	8.8	19.2	19.6	80.4	7.3	41.2	13.4	86.6
313	Textile mills	25.0	34.6	29.9	70.1	50.5	19.0	54.8	45.2	40.5	25.1	45.0	55.0
314	Textile Product Mills	18.1	39.5	24.9	75.1	71.4	18.6	72.5	27.5	59.1	23.4	61.6	38.4
315	Apparel manufacturing	15.3	48.7	21.5	78.5	63.3	21.5	65.3	34.7	53.3	27.2	56.2	43.8
316	Leather and allied product manufacturing	12.8	37.3	20.2	79.8	70.7	17.5	72.1	27.9	48.0	25.3	51.8	48.2
321	Wood product manufacturing	5.1	43.8	7.9	92.1	55.8	24.1	58.1	41.9	33.0	32.9	35.6	64.4
322	Paper manufacturing	19.0	33.3	26.3	73.7	65.6	20.0	67.3	32.7	45.3	25.8	49.4	50.6
323	Printing and related support activities	14.2	40.3	20.7	79.3	63.4	19.6	64.9	35.1	48.6	25.8	51.6	48.4
324	Petroleum and coal products manufacturing	4.5	14.3	8.1	91.9	78.4	14.6	79.1	20.9	4.5	14.3	8.1	91.9
325	Chemical manufacturing	11.2	30.7	15.6	84.4	64.3	18.0	66.4	33.6	17.3	29.2	21.5	78.5
326	Plastics and rubber products manufacturing	22.7	34.7	27.6	72.4	64.1	19.0	66.2	33.8	52.8	23.3	55.7	44.3
327	Non-metallic mineral product manufacturing	5.9	54.5	9.7	90.3	62.2	20.3	64.3	35.7	27.8	41.2	31.0	69.0
331	Primary metal manufacturing	12.8	37.0	19.4	80.6	61.9	17.8	64.4	35.6	22.6	33.2	28.4	71.6
332	Fabricated metal product manufacturing	14.7	39.7	20.9	79.1	70.6	16.4	72.1	27.9	45.6	26.8	49.2	50.8
333	Machinery manufacturing	18.2	43.7	23.1	76.9	75.3	11.9	76.7	23.4	43.7	29.5	47.0	53.0
334	Computer and electronic product manufacturing	24.2	43.9	28.8	71.2	85.2	8.2	86.0	14.0	77.7	12.6	78.9	21.1
335	Electrical equipment and component manufacturing	17.8	41.0	23.5	76.5	74.2	13.7	75.7	24.3	63.5	18.9	65.8	34.2
336	Transportation equipment manufacturing	24.8	35.6	31.2	68.8	74.3	16.5	75.3	24.7	45.8	27.5	49.9	50.1
337	Furniture and related product manufacturing	11.5	49.2	16.2	83.8	65.3	18.4	67.2	32.8	52.3	25.9	54.8	45.2
339	Miscellaneous manufacturing	11.7	52.6	16.1	84.0	70.4	18.5	71.7	28.3	61.4	23.7	63.1	36.9
	Total	19.0	37.7	24.7	75.3	76.3	13.4	77.5	22.5	54.5	22.6	57.5	42.6

Source: authors' estimates.

Table 6.8: *Domestic and foreign content in Mexico's gross exports, 2003, estimated from aggregated Mexico IO table by our mathematical programming model.*

		Normal exports				Maquiladora exports				Weighted sum			
NAICS code	NAICS description	Direct FVA	Direct DVA	Total FVA	Total DVA	Direct FVA	Direct DVA	Total FVA	Total DVA	Direct FVA	Direct DVA	Total FVA	Total DVA
311	Food manufacturing	6.2	38.4	12.3	87.7	46.7	20.2	50.3	49.7	10.1	36.7	16.0	84.0
312	Beverage and tobacco product manufacturing	12.4	42.4	17.5	82.5	54.9	22.6	57.7	42.3	14.1	41.6	19.1	81.0
313	Textile mills	20.3	33.6	27.7	72.3	46.1	16.4	51.3	48.7	30.0	27.2	36.6	63.4
314	Textile product mills	24.9	35.4	32.4	67.6	66.2	16.4	67.5	32.5	41.8	27.7	46.7	53.3
315	Apparel manufacturing	17.8	49.2	23.7	76.3	67.5	18.6	68.5	31.5	54.1	26.8	56.4	43.6
316	Leather and allied product manufacturing	11.0	36.4	19.3	80.7	64.3	18.7	65.7	34.3	27.0	31.1	33.3	66.8
321	Wood product manufacturing	7.2	43.6	10.7	89.4	59.9	23.0	62.1	37.9	25.3	36.5	28.3	71.7
322	Paper manufacturing	11.8	33.1	19.9	80.1	57.6	17.0	59.6	40.4	27.8	27.5	33.7	66.3
323	Printing and related support activities	14.8	40.5	20.9	79.2	54.9	20.2	56.6	43.4	46.5	24.5	49.1	50.9
324	Petroleum and coal products manufacturing	4.9	14.3	10.0	90.0	56.3	8.1	60.8	39.2	5.2	14.3	10.4	89.7
325	Chemical manufacturing	12.0	30.6	17.1	82.9	48.6	15.8	50.7	49.3	13.6	29.9	18.7	81.4
326	Plastics and rubber products manufacturing	21.9	34.0	28.1	72.0	60.0	16.3	61.8	38.2	41.3	25.0	45.3	54.8
327	Non-metallic mineral product manufacturing	7.6	53.6	11.8	88.2	45.6	27.6	47.9	52.1	15.5	48.2	19.3	80.7
331	Primary metal manufacturing	10.5	36.6	17.5	82.5	74.6	18.9	75.4	24.6	15.0	35.3	21.7	78.4
332	Fabricated metal product manufacturing	18.4	38.6	24.5	75.5	57.2	18.2	59.6	40.5	37.3	28.7	41.6	58.4
333	Machinery manufacturing	18.4	40.9	25.1	74.9	60.1	19.0	61.8	38.2	35.1	32.1	39.9	60.2
334	Computer and electronic product manufacturing	30.6	39.0	38.0	62.0	82.4	8.8	83.1	16.9	74.6	13.4	76.3	23.7
335	Electrical equipment and component manufacturing	25.2	42.3	31.3	68.7	70.6	13.3	72.1	27.9	62.7	18.3	65.0	35.0
336	Transportation equipment manufacturing	24.8	34.6	31.6	68.4	83.8	16.1	83.8	16.2	45.1	28.2	49.6	50.4
337	Furniture and related product manufacturing	16.3	47.1	21.2	78.8	57.9	21.4	59.6	40.4	44.5	29.7	47.2	52.8
339	Miscellaneous manufacturing	19.9	50.5	24.9	75.1	65.7	18.5	67.1	32.9	56.2	25.2	58.2	41.8
	Total	20.4	36.7	26.9	73.2	75.8	13.2	76.8	23.2	51.2	23.6	54.6	45.4
B1	Error at manufacture aggregate compared to true data	1.4	−1.0	2.1	−2.1	−0.4	−0.3	−0.7	0.7	−3.3	1.0	−2.8	2.8
B2	Mean absolute percentage error from the true data	22.7	2.9	17.3	4.3	16.1	14.1	14.2	28.0	18.5	7.8	15.3	12.4
B3	Correlation with true data	0.829	0.985	0.862	0.862	0.462	0.666	0.474	0.474	0.936	0.972	0.944	0.944

Source: authors' estimates.

Table 6.8. The three panels in Table 6.8 list direct, total domestic and total foreign value-added shares for normal, processing and total exports, respectively. To compare both methodologies and to quantitatively assess how much each set of value-added share estimates differs from the 'true' share data (computed directly from the Mexico IO table with a separate processing trade account) we report three metrics in the three bottom rows of Table 6.8.

The row labelled B1 in Table 6.8 shows the difference between the estimated shares and the 'true' shares computed directly from Mexico IO table with a separate processing trade account for manufactures as a whole. The errors for the various share estimates appear to be less than 3.5 percentage points. A second metric that measures the proportionate errors is the 'mean absolute percentage error' (MAPE) with respect to the 'true' shares. It is calculated as follows:

$$\text{MAPE} = \frac{100 \sum_{i=1}^{n} |s_i - s_{0_i}|}{\sum_{i=1}^{n} s_{0_i}},$$

where s_i is the estimated share and s_{0_i} is the reference 'true' share for industry i. The MAPE index is reported in row labelled B2. The error ranges from 4% to 17% for normal exports, 14% to 28% for processing exports and 12% to 15% for total exports. The third metric, reported in the row labelled B3 (Table 6.8), is the correlation coefficients between the estimated shares and the reference or 'true' shares. These suggest that the estimates are highly correlated with the 'true' shares computed directly from the Mexico IO table with a separate processing trade account for normal and total exports, though the correlations are lower for processing exports. Overall, the estimates calculated with the quadratic programming model and those 'true' shares computed directly from the Mexico IO table with a separate processing trade account show close values at the aggregate or total value, but not for some industries, including beverages and tobacco, petroleum and coal products, chemical manufacturing, non-metallic mineral products and machinery manufacturing.

4 CONCLUSIONS

Vertical specialisation is pervasive in Mexico. In line with global trade, Mexico's trade has increased at impressive rates over the last fifteen years, and more than 85% of its manufacturing exports are production sharing operations.

In this chapter, we estimated domestic and foreign value-added shares that are present in Mexico's manufacturing exports for 2000, 2003 and 2006. The estimation was carried out by applying the methodology developed by Koopman *et al* (2011), but with a slight modification. Instead of estimating the structure of the processing export sector via an optimising algorithm, we used an input–output table compiled specifically for the production sharing sector, *ie* for the maquiladora industry for 2003. This is the first study of its kind in that, for Mexico, it provides measures of vertical specialisation using such an input–output table in addition to using trade data from both export promotion programmes, the maquiladora and PITEX programmes.

The estimation results suggest that on average Mexico's manufacturing exports have a domestic value-added share of about 34%. Industries that have a domestic content of less than 50% account for approximately 80% of the country's manufacturing exports. Low domestic value-added industries include computer and peripheral equipment, audio and video equipment, communications equipment, semiconductor and other electronic components, and electrical equipment. Industries that have domestic content shares higher than 65% account for only 5.1% of Mexico's total manufacturing exports. Some leading industries in this higher domestic value-added group are: petroleum and coal products, with a share of 90.0%; lime and gypsum products, with a share of 88.2%; pesticide, fertilizer and other agricultural chemicals, with a share of 79.9%.

Counting Mexican manufacturing exports under the PITEX programme as processing trade makes a difference in our calculations across industries. In particular, it made a significant difference in the transportation equipment industries, whose exports under PITEX made up more than 60% of Mexico's exports of that industry, while those under the Maquila programme were only about 34%. This reflects the dominance of production sharing arrangements with the USA in Mexico's automotive sector. Furthermore, the top three NAICS industries with the lowest domestic value added (transportation equipment and electronic sectors), together made up about 70% of Mexico's total manufacturing exports in 2003. This suggests that Mexican manufacturing trade is highly concentrated in a few industries with an extremely high proportion of processing exports: between 72% and 85% and low domestic content of less than 27%. Our results also indicate that exporting industries that tend to use the maquiladora programme the most, for instance electronics, have low domestic value added, while those industries that export under PITEX (automotive and machinery industries) have a relatively higher domestic content. Most of Mexico's manufacturing exports to the USA and Canada consist of processing exports, and the USA is by far the largest single-country export market, to which Mexico exported 86.4% of its total in 2006. Canada's share of Mexico's total manufacturing exports was only approximately 2% in the same year.

Although relatively low, the domestic value added in Mexico's exports has increased in recent years, suggesting that Mexico's industrial strategy has resulted, although modestly and in some industries only, in its insertion into the global supply chains.

REFERENCES

Baker & McKenzie (2006). Doing Business in Mexico. Report. URL: http://www.bakernet.com/.

Bergin, R. P., and R. C. Feenstra (2008). Pass-Through of Exchange Rates and Competition between Floaters and Fixers. *Journal of Money Credit and Banking* **41**(s1), 35–70.

Bergin, R. P., R. C. Feenstra, and G. H. Hanson (2009a). Offshoring and Volatility: Evidence from Mexico's Maquiladora Industry. *American Economic Review* **99**(4), doi:10.1257/aer.99.4.1664.

Bergin, R. P., R. C. Feenstra, and G. H. Hanson (2009b). Volatility Due to Offshoring: Theory and Evidence. University of California, Davis, Working Paper, January. URL: www.econ.ucdavis.edu/faculty/bergin/research/Offshoring_and_Volatility_theory_web.pdf (accessed 29 May 2009).

Burstein, A., C. Kurz and L. Tesar (2008). Trade, Production Sharing, and the International Transmission of Business Cycles. *Journal of Monetary Economics* **55**, 775–795.

Campa, J. M., and L. S. Goldberg (2006). Pass Through of Exchange Rates to Consumption Prices: What Has Changed and Why? NBER Working Paper 12547.

Chiquiar, D. (2008). Globalization, Regional Wage Differentials and the Stolper–Samuelson Theorem: Evidence from Mexico. *Journal of International Economics* **74**, 70–93.

Chiquiar, D., and M. Ramos-Francia (2005). Trade and Business-Cycle Synchronization: Evidence from Mexican and US Manufacturing Industries. *North American Journal of Economics and Finance* **16**, 187–216.

De La Cruz, J., R. B. Koopman, Z. Wang, and S.-J. Wei (2011). Estimating foreign-Value Added in Mexico's Manufacturing Exports. US International Trade Commission, Office of Economics Working Paper 2011-04A.

Ebenstein, A., A. Harrison, M. McMillan, and S. Phillips (2009). Estimating the Impact of Trade and Offshoring on American Workers Using the Current Population Surveys. NBER Working Paper 15107.

Feenstra, R. C. (1989). Symmetric Pass-Through of Tariffs and Exchange Rates under Imperfect Competition: An Empirical Test. *Journal of International Economics* **27**, 24–45.

Feenstra, R. C. (1998). Integration of Trade and Disintegration in the Global Economy. *Journal of Economic Perspectives* **12**, 31–50.

Feenstra, R. C. (2008). Offshoring in the Global Economy. The Ohlin Lectures, presented at the Stockholm School of Economics, 17–18 September. URL: www.econ.ucdavis.edu/faculty/fzfeens/pdf/Feenstra_Ohlin_Lecture_2008.pdf.

Feenstra, R. C., and G. H. Hanson (1997). Foreign Direct Investment and Relative Wages: Evidence from Mexico's Maquiladoras. *Journal of International Economics* **42**, 371–394.

Feenstra, R. C, and G. H. Hanson (1999). The Impact of Outsourcing and High-Technology Capital on Wages: Estimates for the USA, 1979–1990. *The Quarterly Journal of Economics* **114**, 907–940.

Feenstra, R. C. and G. H. Hanson (2004). Global Production Sharing and Rising Inequality: A Survey of Trade and Wages. In *Handbook of International Trade* (ed. By E. K. Choi and J. Harringan), Volume 1 (Oxford: Blackwell).

Feenstra, R. C., G. H. Hanson, and D. Swenson (2000). Offshore Assembly from the United States: Production Characteristics of the 9802 Program. In *The Impact of International Trade on Wages* (ed. R. C. Feenstra), pp. 85–128. University of Chicago Press and NBER.

Gantz, A. D. (2004). NAFTA, Article 303, PROCEC and the New Maquiladora Regime in Mexico. In *The Auto Pact: Investment, Labour and the WTO* (ed. M. Irish). New York: Kluwer Law International.

Ghosh, A. (2008). Implications of Production Sharing on Exchange Rate Pass-Through. *International Journal of Finance and Economics* **14**(4), 334–345.

Hanson, G. H., and A. Harrison (1999). Trade, Technology, and Wage Inequality. *Industrial and Labor Relations Review* **52**(2), 271–288.

Hanson, G. H., R. Mataloni, and M. Slaughter (2005). Vertical Production Networks in Multinational Firms. *Review of Economics and Statistics* **87**(4), 664–678.

Herrera-Hernandez, J. (2004). Business Cycles in Mexico and the United States: Do They Share Common Movements? *Journal of Applied Economics* **7**(2), 303–323.

Hummels, D., J. Ishii, and K.-M. Yi (2001). The Nature and Growth of Vertical Specialization in World Trade. *Journal of International Economics* **54**, 75–96.

INEGI (2007). Industria maquiladora de Exportación. *Estadísticas Económicas INEGI*, Febrero.

Koopman, B. R., Z. Wang, and S.-J. Wei (2011). Estimating Domestic Content in Exports when Processing Trade Is Pervasive. *Journal of Development Economics* **99**(1), 178–189.

Johnson, R. C., and G. Noguera (2012). Accounting for Intermediates: Production Sharing and Trade in Value Added. *Journal of International Economics* **86**(2), 224–236.

Kose, M. A., and K.-M. Yi (2001). International Trade and Business Cycles: Is Vertical Specialization the Missing Link? *American Economic Review* **91**(2), 371–375.

Kose, M. A., and K.-M. Yi. (2006). Can the Standard Real Business Cycle Model Explain the Relation between Trade and Comovement? *Journal of International Economics* **68**(2), 267–295.

Krugman, P. (2008). Trade and Wages, Reconsidered. *Brookings Papers on Economic Activity*. URL: http://www.brookings.edu/.

López, J. J. (2007). Production Sharing and Real Business Cycles in a Small Open Economy. Federal Reserve Bank of Dallas, Globalization and Monetary Policy Institute, Working Paper 5, December. URL: http://www.dallasfed.org/institute/wpapers/2007/0005.pdf (accessed 28 May 2009).

Nordås, K. H. (2005). International Production Sharing: A Case for a Coherent Policy Framework', WTO Discussion Papers 11. WTO Geneva, Switzerland.

OECD (1996). *Trade Liberalisation Policies in Mexico*. Paris: Organization for Economic Co-operation and Development.

Truett, B. D., and L. J. Truett (1984). The Maquiladoras: Prospects for Mexico. *Journal of Economic Development* **9**(2), 45–66.

Truett, B. D., and L. J. Truett (1993). Maquiladora Response to US and Asian Relative Wage Rate Changes. *Contemporary Economic Policy* **11**(1), 18–28.

Truett, B. D., and L. J. Truett (2007). NAFTA and the Maquiladoras: Boon or Bane. *Contemporary Economic Policy* **25**(3), 374–386.

United States International Trade Commission (1994). Production Sharing: US Imports under Harmonized Tariff Schedule Provisions 9802.00.60 and 9802.00.80, 1989–1992. USITC Publication 2729, February.

US Department of Commerce (2000). Merchandise Trade Reconciliation: United States–Mexico–Canada 1996–1997. Report. Bureau of the Census, Economics and Statistics Administration. URL: http://www.census.gov/foreign-trade/aip/recon9697.pdf (accessed 17 June 2009).

US Department of Commerce (2001). Merchandise Trade Reconciliation: United States–Mexico–Canada 1998–1999. Bureau of the Census, Economics and Statistics Administration. URL: http://www.census.gov/foreign-trade/aip/recon9899.pdf (accessed 17 June 2009).

USITC (1998a). The Use and Economic Impact of TSUS Items 806.30 and 807.00. United States International Trade Commission Publication 2053, January.

USITC (1998b). Production Sharing: Use of US Components and Materials in Foreign Assembly Operations, 1994–1997. United States International Trade Commission Publication 3146, December.

Verhoogen, E. A. (2008). Trade, Quality Upgrading, and Wage Inequality in the Mexican Manufacturing Sector. *Quarterly Journal of Economics* **123**(2), 489–530.

WTO (2008). Trade Policy Review: Mexico. Review ET/TPR/S/195/Rev. 1, World Trade Organization. 2 May. URL: http://www.wto.org/english/tratop_e/tpr_e/tpr_e.htm (accessed 16 June 2009).

Yi, K.-M. (2003). Can Vertical Specialization Explain the Growth of World Trade? *Journal of Political Economy* **111**(1), 52–102.

Yi, K.-M. (2009). The Collapse of Global Trade: the Role of Vertical Specialization. In *The Collapse of Global Trade, Murky Protectionism, and the Crisis: Recommendations for the G20* (ed. R. Baldwin and S. Evenett), pp. 45–48. London: VoxEU/CEPR.

7

Gravity Chains: Estimating Bilateral Trade Flows when Trade in Components and Parts Is Important

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Trade is measured on a gross sales basis, while GDP is measured on a net sales basis, *ie* value added. The rapid internationalisation of production in the last two decades has meant that gross trade flows are increasingly unrepresentative of the value added flows. This fact has important implications for the estimation of the gravity equation. We present empirical evidence that the standard gravity equation performs poorly by some measures when it is applied to bilateral flows where parts and components trade is important. We also provide a simple theoretical foundation for a modified gravity equation that is suited to explaining trade where international supply chains are important.

1 INTRODUCTION

Trade is measured on a gross sales basis, while GDP is measured on a value-added basis. For the first decades of the postwar period, this distinction was relatively unimportant. Trade in intermediates was always important, but it was quite proportional to trade in final goods. The rapid internationalisation of supply chains in the last two decades has changed this (Yi 2003). Indeed, such trade has in recent decades boomed between advanced nations and emerging economies as well as among emerging nations, especially in Asia, where the phenomenon is known as 'Factory Asia'. There are, however, similar supply chains in Europe and between the USA and Mexico (Kimura *et al* 2007). As a result, gross trade flows are increasingly unrepresentative of the value-added flows. This fact has important policy implications (Lamy 2010), but it also has important implications for one of trade economists' standard tools: the gravity equation.

The basic point is simple. The standard gravity equation is derived from a consumer expenditure equation with the relative price eliminated using a general equilibrium constraint (Anderson 1979; Bergstrand 1985, 1989, 1990). The corresponding econometrics widely used today is based on this theory

(Anderson and Van Wincoop 2003). As such the standard formulation—bilateral trade regressed on the two GDPs, bilateral distance and other controls—is best adapted to explaining trade in consumer goods. When consumer trade dominates, the GDP of the destination nation is a good proxy for the demand shifter in the consumer expenditure equation; the GDP of the origin nation is a good proxy of its total supply. By contrast, when international trade in intermediate goods dominates, the use of GDPs for the supply and demand proxies is less appropriate.

Consider, for instance, the determinants of Thai imports of automobile parts from the Philippines. The standard formulation would use Thai GDP to explain Thailand's import demand. However, the underlying demand for parts is generated by Thai gross production of automobiles, not its value added in automobiles. As long as the ratio of local to imported content does not change, value added is a reasonable proxy for gross output, so the standard regression is likely to give reasonable results. However, for regions where production networks are emerging, value added can be expected to be a poor proxy.

Why do incorrectly specified mass variables matter? A large number of gravity studies focus on variables that vary across country pairs, say, free-trade agreements, cultural ties or immigrant networks. The most recent of these studies employ estimators that control for the mass variables with fixed effects. Such studies do not suffer from mass-variable mis-specification and so are unaffected by our critique. There are, however, a number of recent studies, especially concerning the 'distance puzzle', that do proxy for the production and demand variables with GDP. It is these studies that our work addresses.

For example, Rauch (1999), Brun *et al* (2005), Berthelon and Freund (2008) and Jacks *et al* (2008) use GDP as the mass variable when they decompose the change in the trade flow into the effects of income changes and trade cost changes; Anderson and Van Wincoop (2003) also use GDP as the mass variable in one of their estimation techniques. Since most of these studies are concerned with a broad set of nations and commodities, the mis-specification of the mass variable probably has a minor impact on the results, as the findings of Bergstrand and Egger (2010) showed. More worrying, however, is GDP use by authors that focus on trade in parts and components, such as Athukorala and Yamashita (2006), Kimura *et al* (2007), Yokota (2008) and Ando and Kimura (2009). These papers all use the consumer good version of the gravity model to describe parts and components trade and thus have mis-specified the mass variable.

1.1 Literature Review

There is nothing new about trade in intermediates. Intermediates have long been important in the trade between the USA and Canada; the 1965 US–Canada Auto Pact, for example, explicitly targeted preferential tariff reductions on cars and cars parts. Intermediates have also long been important within Western Europe, as early studies of the European Economic Community demonstrated (see, for example, Dreze 1961; Verdoorn 1960; Balassa 1965, 1966). The famous book by Grubel and Lloyd (1975) made it clear that much of intra-industry trade was in intermediates, not final goods, and the importance of intermediates was reflected in early work by well-known theorists. For example, Vanek (1963) presented an extension of the Heckscher–Ohlin model that allows for intermediates trade, and Ethier (1982) cast his model of intra-industry trade in a world where all trade was in intermediates.

As better data and computing technology became available, the importance of intermediates in trade was rediscovered and documented more thoroughly. In the context of efforts to understand the impact of the EU's Single Market Programme, European scholars focused on the role of intermediates. For example, Greenaway and Milner (1987) list this as one of the 'unresolved issues', writing

> it is becoming increasingly obvious that a significant proportion of measured [intra-industry trade] is accounted for by trade in parts and components. [Nevertheless,] most of the models developed so far assume trade in final goods. The modelling of trade in intermediates needs to be explored further.

The issue attracted renewed interest following development of the new trade theory in the 1980s (Helpman and Krugman 1985)[1] and again in the 1990s with Jones and Kierzkowski (1990), and Hummels *et al* (1998),[2] and more recently Kimura *et al* (2007) and Grossman and Rossi-Hansberg (2008).

The traditional gravity model was developed in the 1960s to explain factory-to-consumer trade (Tinbergen 1962; Poyhonen 1963; Linnemann 1966). This concept is at the heart of the first clear microfoundations of the gravity equation: the seminal paper by Anderson (1979).[3] This proposed a theoretical explanation of the gravity equation based on constant elasticity of substitution (CES) preferences when nations make a single differentiated product. Anderson and Van Wincoop (2003) use the Anderson (1979) theory to develop appropriate econometric techniques. Subsequent theoretical refinements have focused on showing that the gravity equation can be derived from many different theoretical frameworks (including monopolistic competition, and Melitz-type trade models with heterogeneous firms).[4]

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[1] As illustrated by Grunwald and Flamm (1985).

[2] See Feenstra (1998) for a survey of the 1990s literature.

[3] Leamer and Stern (1970) informally discuss three economic mechanisms that might generate the gravity equations, but these were based on rather exotic economic logic; Anderson (1979) was the first to provide clear microfoundations that rely only on assumptions that would strike present-day readers as absolutely standard.

[4] On the monopolistic competition frameworks see Krugman (1980); Bergstrand (1985, 1989); Helpman and Krugman (1985); on the Heckscher–Ohlin model see Deardorff (1998);

Studies on the gravity equations applicability to intermediate goods trade are more limited. These include Egger and Egger (2004) and Baldone *et al* (2007). The study that is closest to ours is Bergstrand and Egger (2010). These authors developed a computable general equilibrium model that explains the bilateral flows of final goods, intermediate goods and foreign direct investment (FDI). Calibration and simulation of the model suggests a theoretical rationale for estimating a near-standard gravity model for the three types of bilateral flows. Using a large data set on bilateral flows of final and intermediate goods trade, and a data set on bilateral FDI flows, they estimate the three equations and find that the standard gravity variables all have the expected size and magnitude.

The value added of our paper is primarily empirical: showing that the standard gravity specification performs poorly when applied to flows where trade in intermediates is important. Moreover, the failures line up with the predictions of our simple theory model that suggests a gravity equation formulation that is appropriate to intermediates trade. Note that when we perform the estimates on data pooled across a wide range of nations, we find the same results, namely that the standard specification performs well. We believe the difference in our results from those of Bergstrand and Egger (2010) is due to the fact that for many trade flows, the pattern of trade in intermediates is quite proportional to trade in final goods. This is especially for trade among developed nations.

1.2 Plan of the Chapter

The chapter starts with simple theory that generates a number of testable hypotheses. We then confront these hypotheses with the data and find that the estimated coefficients deviate from standard results in the way that the simple theory says they should. The key results are that the standard economic mass variable, which reflects consumer demand, does not perform well when it comes to bilateral trade flows where intermediates are dominant. Finally, we consider new proxies for the economic mass variables and show that using the wrong mass variable may bias estimates of other coefficients.

2 THEORY

To introduce notation and fix ideas, we review the standard gravity derivation following Baldwin and Taglioni (2007).[5] Using the well-known CES preference

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on Ricardian models see Eaton and Kortum (2001); on Melitz (2003) model applications, see Chaney (2008) and Helpman *et al* (2008).

[5] Another well-known derivation is from Helpman and Krugman (1985); they start from (8.1) and make supply-side assumptions that turn p_o into a constant, but make n_{od} proportional to nation o's GDP, so the resulting gravity equation is similar, at least in the case of frictionless trade (the case they worked with in 1985).

structure for differentiated varieties, spending in nation d on a variety produced in origination nation o is

$$v_{od} \equiv \left(\frac{p_{od}}{P_d}\right)^{1-\sigma} E_d, \quad \sigma > 1, \tag{7.1}$$

where v_{od} is the expenditure in destination country d, p_{od} is the consumer price inside nation d of a variety made in nation o, P_d is the nation d CES price index of all varieties, σ is the elasticity of substitution among varieties, and E_d is the nation d consumer expenditure.

From the well-known profit maximisation exercise of producers based in nation o, $p_{od} = \mu_{od} m_o \tau_{od}$, where μ_{od} is the optimal price mark-up, m_o is the marginal costs, and τ_{od} is the bilateral trade cost factor, *ie* 1 plus the *ad valorem* tariff equivalent of all natural and manmade barriers. The mark-up is identical for all destinations if we assume perfect competition or Dixit–Stiglitz monopolistic competition; in these cases, the price variation is characterised by 'mill pricing', *ie* 100% pass-through of trade costs to consumers in the destination market.[6]

Here we work with Dixit–Stiglitz competition exclusively, so the mark-up is always $\sigma/(\sigma - 1)$. This means the local consumer price is

$$p_{oo} = \left(\frac{\sigma}{\sigma - 1}\right) m_o \tau_{oo},$$

where τ_{oo} is unity as we assume away internal trade barriers. Using this and summing over all varieties (assuming symmetry of varieties by origin nation for convenience), we have

$$V_{od} = n_o p_{oo}^{1-\sigma} \frac{\tau_{od}^{1-\sigma}}{P_d^{1-\sigma}} E_d \tag{7.2}$$

where V_{od} is the aggregate value of the bilateral flow (measured in terms of the numeraire) from nation o to nation d; n_o is the number (mass) of nation o varieties (all of which are sold in nation d as per the well-known results of the Dixit–Stiglitz–Krugman model).

To turn this expenditure function (with optimal prices) into a gravity equation, we impose the market-clearing condition. Supply and demand match when (7.2), summed across all destinations (including nation o's sales to itself), equals nation o's output. When there is no international sourcing of parts, the nation's output is its GDP, denoted here as Y_o. Thus, the market-clearing condition is

$$Y_o = n_o p_{oo}^{1-\sigma} \sum_d \tau_{od}^{1-\sigma} P_d^{\sigma-1} E_d.$$

[6]If one works with the Ottaviano *et al* (2002) monopolistic competition framework, the mark-up varies bilaterally and so mill pricing is not optimal.

Solving this, we obtain that $n_o p_{oo}^{1-\sigma} = Y_o/\Omega_o$, where Ω_o is the usual market-potential index (namely, the sum of partners' market sizes weighted by a distance-related weight that places lower weight on more remote destinations); specifically, it is

$$\Omega_o \equiv \sum_d \tau_{od}^{1-\sigma} P_d^{\sigma-1} E_d.$$

Plugging this into (7.2) yields the traditional gravity equation:

$$V_{od} = \tau_{od}^{1-\sigma} E_d Y_o \frac{1}{P_d^{1-\sigma}} \frac{1}{\Omega_o}. \tag{7.3}$$

Here P_d is the nation d CES price index, while Ω_o is the nation o market-potential index. It has become common to label the product $P_d^{1-\sigma}\Omega_o$ as the 'multilateral trade resistance' term. However, it is insightful to keep in mind the fact that 'multilateral trade resistance' is a combination of two well-known, well-understood and frequently measured components.

In the typical gravity estimation, E_d is proxied with nation d's GDP, Y_d is proxied with nation o's GDP and τ is proxied with bilateral distance.

2.1 Gravity when Trade in Components and Parts Is Important

To extend the gravity equation to allow for trade in parts and components among firms, we need a trade model where intermediate goods trade is explicitly addressed. It proves convenient to work with the Krugman and Venables (1996) 'vertical linkages' model, which focuses squarely on the role of intermediate goods. Here we present the basic assumptions and the manipulations that produce the modified gravity equation.

Krugman and Venables (1996) work with the standard new economic geography model, where each nation has two sectors (a Walrasian sector, A, and a Dixit–Stiglitz monopolistic competition sector M) and a single primary factor: labour, L. Production of A requires only L, but production of each variety of X requires L and a CES composite of all varieties as intermediate inputs (*ie* each variety is purchased both for final consumption and for use as an intermediate). Following Krugman and Venables (1996), the CES aggregate on the supply side is isomorphic to the standard CES consumption aggregate.

The indirect utility function for the typical consumer is

$$V = \frac{I}{P^{\mathrm{c}}}, \quad P^{\mathrm{c}} \equiv p_A^{1-\alpha}(P)^{\alpha}, \quad P \equiv \left(\int_{i\in G} p_i^{1-\sigma}\,\mathrm{d}i\right)^{1/(1-\sigma)}, \tag{7.4}$$

where I is consumer income, P^{c} is the ideal consumer price index, p_A is the price of A, the parameter α is the Cobb–Douglas expenditure share for M-sector goods, σ is the elasticity of substitution among varieties, P is the CES price index for M varieties, p_i is the consumer price of variety i and G is the set of varieties available.

The cost function of a typical firm in a typical country is:

$$C[w, P, x] = (F + a_X x) w^{1-\alpha} P^{\alpha}. \tag{7.5}$$

Here x is the output of a typical variety, F and a_X are cost parameters, w is the wage and α is the Cobb–Douglas cost share for intermediate inputs.[7]

As noted above, mill pricing is optimal under Dixit–Stiglitz monopolistic competition. This, combined with the identity of the elasticity of substitution, σ, for each good's use in consumption and production, tells us that the price of each variety will be identical across the two types of customers. Choosing units such that $a_X = 1 - 1/\sigma$, the landed price will be

$$p_{od} = \tau_{od} w_o^{1-\alpha} P_o^{\alpha} \quad \text{for all } o, d. \tag{7.6}$$

Using Shepard's and Hotelling's lemmas on (7.4) and (7.5), and adding the total demand for purchasers located in nation d, we have an expression that is isomorphic to (7.2) except the definition of E now includes purchases by customers using the goods as intermediates:

$$V_{od} = n_o p_{oo}^{1-\sigma} \frac{\tau_{od}^{1-\sigma}}{P_d^{1-\sigma}} E_d, \qquad E_d \equiv \alpha(I_d + n_d C_d), \tag{7.7}$$

where I_d is nation d's consumer income and C_d is the total cost of a typical nation d variety.

As before, we solve for the endogenous $n_o p_{oo}^{1-\sigma}$ using the market-clearing condition. In this case, the value that nation o must sell is the full value of its M-sector output (not just its value added). Under monopolistic competition's free entry assumption, the value of sales equals the value of full costs, so the market clearing equation becomes

$$n_o C_o = n_o p_{oo}^{1-\sigma} \Sigma_d \tau_{od}^{1-\sigma} P_d^{1-\sigma} E_d, \qquad C_o \equiv C[w_o, P_o, x_o], \tag{7.8}$$

where the cost function C is given in (7.5). Solving (7.8) and plugging the result into (7.7) yields a gravity equation modified to allow for intermediates goods trade, namely

$$V_{od} = \tau_{od}^{1-\sigma} E_d C_o \frac{1}{P_d^{1-\sigma}} \frac{1}{\Omega_o}, \tag{7.9}$$

where E_d is defined in (7.7) and C_o is defined in (7.8), and

$$\Omega_o \equiv \sum_d \tau_{od}^{1-\sigma} P_d^{\sigma-1} E_d.$$

---

[7]The assumption that the Cobb–Douglas parameter is identical in the consumer and producer CES price index is one of the strategic implications in the Krugman–Venables model; see their book for a careful examination of what happens when this is relaxed (Fujita *et al* 2001). The standard conclusion is that it does not qualitatively change results but it does significantly complicate the analysis in a way that requires numerical simulation.

Expression (7.9) is the gravity equation modified to allow for trade intermediates. The key differences show up in the definition of the economic 'mass' variables, since purchases are now driven by both consumer demand (for which income is the demand shifter) and intermediate demand (for which total production cost is the demand shifter).

3 BREAKDOWN OF THE STANDARD GRAVITY MODEL

This theory exercise suggests a key difference that should arise between gravity estimates on nations and time periods where most imports are consumer goods versus those where intermediates trade is important. Specifically, the standard practice of using the GDP of origin and destination countries as the 'mass' variables in the gravity equations is inappropriate for bilateral flows, where parts and components are important. Of course, if the consumer demand and producer demand move in synch, as they may in a steady-state situation, then GDP may be a reasonable proxy for both consumer and producer demand shifters. But if the role of vertical specialisation trade is changing over time, GDP should be less good at proxying for the underlying demand shifters. For this reason, we expect that origin country's GDP and destination country's GDP will have diminished explanatory power for those countries where value-chain trade is important.

These observations generate a number of testable hypotheses.

- The estimated coefficient on the GDPs should be lower for nations where parts trade is important, and should fall as the importance of parts trade rises.
- As vertical specialisation trade has become more important over time, the GDP point estimates should be lower for more recent years.
- In those cases where the GDPs of the trade partners lose explanatory power, bilateral trade should be increasingly well explained by demand in third countries.

For example, China's imports should shift from being explained by China's GDP to being explained by its exports to, say, the USA and the EU. There are two ways of phrasing this hypothesis. First, China's imports are a function of its exports rather than its own GDP. Second, China's imports are a function of US and EU GDP rather than its own, since US and EU GDP are critical determinants of their imports from China.

To check these conjectures, we estimate the standard gravity model for different sets of countries and sectors for a panel that spans the years 1967 to 2007. We run standard log-linear gravity equations using pooled cross-section time series data, namely

$$\ln(V_{odt}) = G + \alpha_1 \ln\left(\frac{Y_{ot}}{\Omega_{ot}} \frac{E_{dt}}{P_{dt}^{1-\sigma}}\right) + \alpha_2 \ln \tau_{odt} + \varepsilon_{odt}. \tag{7.10}$$

A key econometric problem is that the price index P_{dt} and the market potential index Ω_{ot} are unobservable and yet include factors that enter the regressions independently (*eg* E, Y and τ). Thus, ignoring them can lead to serious biases.

If the econometrician is only interested in estimating the impact of a pair-specific variable, such as distance or tariffs, the standard solution is to put in time-varying country-specific fixed effects. This eliminates all the terms multiplied by α_1 in Equation (7.10). Plainly, we cannot use this approach to investigate the impact of using GDPs as the economic mass proxies when trade in parts and components is important. We thus need other means of controlling for Ω_{ot} and P_{dt}.

Our baseline specification accounts for the terms Ω_{ot} and P_{dt} explicitly. As precise measures of Ω_{ot} and P_{dt} are hard to construct, we perform robustness checks using fixed effects specifications. To ensure comparability with the fixed effects specification, in the key specifications we enter the importer's and exporter's economic mass as a single product-term into the equation, with the shortcoming of forcing the coefficient of the importer and exporter mass variables to be the same. Specifically, the term accounting for the product of the trade partners' economic mass is the product of importer d's real GDP (so as to account for P_{dt}) and of exporter o's nominal GDP divided by a proxy for Ω_{ot}, constructed adapting a method first introduced by Baier and Bergstrand (2001), namely

$$\Omega_{ot} = \left(\sum_{d} \mathrm{GDP}_{dt} (\mathrm{Dist}_{od})^{1-\sigma} \right)^{1/(1-\sigma)}.$$

The elasticity value in the Ω_{ot} relationship has been set as $\sigma = 4$, which corresponds to estimates proposed in empirical literature (see, for example, Obstfeld and Rogoff (2001); Carrere 2006).

Turning to the trade cost variable, τ, we introduce standard trade frictions, including log of bilateral distance, dummies for contiguity and common language. Moreover, for robustness we also test for additional time-varying trade frictions measured by the ratio of cost, insurance and freight (CIF) prices to free on board (FOB) prices, as proposed by Bergstrand and Egger (2010).

The data used for the bilateral trade flows, and the CIF/FOB ratios are taken from the UN Comtrade database. GDPs are from the World Bank's World Development Indicators. Bilateral distances, contiguity and common language are from the CEPII database. Data for Taiwan (Chinese Taipei), which are missing from the UN databases, are from CHELEM (CEPII) and national accounts.

Estimation is by simple ordinary least squares with the standard errors clustered by bilateral pairs, since we work in direction-specific trade flows rather than the more traditional average of bilateral flows.

3.1 Empirical Results

In Table 7.1 we report the gravity equation estimates for all goods as well as for intermediate and final goods separately. Intermediate and final goods have

Table 7.1: *Bilateral flows of total, intermediate and final goods, 187 nations, 2000–7.*

	All goods		Intermediates only		Consumer goods only	
Variables	(1)	(2)	(3)	(4)	(5)	(6)
$\ln\left(\frac{GDP_{ot}GDP_{dt}}{\Omega_{ot}P_{dt}}\right)$	0.860***	0.865***	0.898***	0.905***	0.791***	0.796***
	(0.006)	(0.006)	(0.007)	(0.007)	(0.008)	(0.008)
ln(CIF/FOB)	−0.0833***	−0.0798***	−0.189***	−0.184***	−0.341***	−0.338***
	(0.013)	(0.013)	(0.015)	(0.015)	(0.017)	(0.017)
ln distance	−0.775***	−0.777***	−0.851***	−0.855***	−0.758***	−0.760***
	(0.019)	(0.019)	(0.022)	(0.022)	(0.025)	(0.025)
Contiguity	1.575***	1.565***	1.711***	1.697***	1.356***	1.347***
	(0.105)	(0.105)	(0.119)	(0.119)	(0.127)	(0.127)
Common language	0.966***	0.972***	0.997***	1.005***	1.186***	1.192***
	(0.046)	(0.046)	(0.052)	(0.052)	(0.059)	(0.059)
Constant	−28.61***	−28.74***	−30.84***	−31.03***	−26.87***	−27.02***
	(0.359)	(0.363)	(0.400)	(0.404)	(0.456)	(0.459)
Time dummies		Yes		Yes		Yes
Observations	62,875	62,875	62,875	62,875	58,468	58,468
R^2	0.627	0.628	0.585	0.587	0.479	0.480

Source: authors' calculations. Dependent variable: imports + reimports. Standard errors are clustered by bilateral pair. Robust standard errors are reported in parentheses: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 7.2: *Classification for intermediate and final goods.*

Goods	BEC categories
Intermediate goods:	111 Primary food and beverages, mainly for industry
	121 Processed food and beverages, mainly for industry
	21 Primary industrial supplies not elsewhere specified
	22 Processed industrial supplies not elsewhere specified
	32 Processed fuels and lubricants
	42 Parts and accessories of capital goods (except transport equipment)
	53 Parts and accessories of transport equipment
Consumption goods:	112 Primary food and beverages, mainly for household consumption
	122 Processed food and beverages, mainly for industry
	51 Passenger motor cars
	6 Consumer goods not elsewhere specified
Other:	31 Primary fuels and lubricants
	41 Capital goods, excluding parts and components
	51 Other transport equipment
	7 Other

Source: Comtrade's Broad Economic Categories. For details see http://unstats.un.org/unsd/tradekb/Knowledgebase/Intermediate-Goods-in-Trade-Statistics.

been identified according to the UN Broad Economic Categories Classification (see Table 7.2). The sample includes all the nations where data is available, namely 187 nations.

Coefficients have the expected signs and are statistically significant. For all six regressions (all goods, only intermediates and only consumer goods with and without time fixed effects) the estimates are broadly similar. The mass variables are all estimated to be close to unity. The bilateral distance variable is negative and falls in the expected range. The additional trade cost measure, the CIF/FOB ratio, is always negative, as expected for the subsamples, but positive for the aggregate sample. Continuity and language always have the expected sign and fall in the usual ranges.

These Table 7.1 results confirm the findings of Bergstrand and Egger (2010), namely that the size of the estimated coefficients does not vary for consumer and intermediate goods. As such, it would seem that our concern about mis-estimating the gravity equation is misplaced. However, as noted above, if the consumer and intermediate trade is roughly proportional over time, GDP will be a reasonable proxy for both consumer income and gross value added. The real test of the stability of the parameters would be on a sample where the importance of intermediates trade was rising significantly.

To check this, we turn to a subsample of nations where we *a priori* expect intermediate trade to be both very important and growing more rapidly than consumer trade. Specifically, we estimate a gravity model as in Table 7.1, but on bilateral trade between pairs of Factory Asia countries (*ie* Japan, Indonesia,

Table 7.3: *Bilateral flows of total goods among Factory Asia nations (1967–2008).*

Variables	No time interactions (1)	(2)	(3)	Variable mass coefficient (4)	(5)
$\ln(GDP_o GDP_d/\Omega_o P_d)$	0.725***	0.725***	0.764***	0.425***	0.504***
	(0.009)	(0.028)	(0.026)	(0.055)	(0.051)
*years 1967–1986				0.318***	0.278***
				(0.048)	(0.048)
*years 1987–1996				0.177***	0.164***
				(0.027)	(0.032)
*years 1998–2002				0.007	0.00274
				(0.015)	(0.017)
ln(distance)	−0.258***	−0.258		−0.0414	
	(0.0570)	(0.298)		(0.297)	
Contiguity	0.188***	0.188		0.167	
	(0.0682)	(0.386)		(0.367)	
Colony	−0.487***	−0.487		0.0695	
	(0.101)	(0.388)		(0.405)	
Common coloniser	−0.620***	−0.620*		−0.296	
	(0.116)	(0.325)		(0.324)	
Constant	−7.218***	−7.218***	−8.825***	−1.465	−2.632**
	(0.433)	(2.281)	(0.485)	(2.279)	(1.178)
Observations	1722	1722	1722	1722	1722
R^2	0.833	0.833	0.936	0.851	0.948
Time effects	Yes	Yes			
Exporter* time effects			Yes	Yes	Yes
Importer* time effects			Yes	Yes	Yes
Pair effects			Yes	Yes	Yes
Observations	820	820	820	820	820
R^2	0.932	0.932	0.978	0.934	0.978
Clustered standard errors		Yes	Yes	Yes	Yes

Source: authors' calculations; Note: Standard errors are clustered by bilateral pair. Robust standard errors in parentheses: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. Factory Asia countries: Japan, Indonesia, Republic of Korea, Malaysia, Thailand and Taiwan (Chinese Taipei).

Korea, Malaysia, Philippines, Thailand and Taiwan (Chinese Taipei)). To gauge the stability of parameters, we interact time dummies with the mass variable. The results, shown in Table 7.3, are quite different to those of Bergstrand and Egger (2010) and to those of Table 7.1.

The baseline regressions (without time interactions) show the fairly common result that the gravity model does not work well on Factory Asia nations. The estimated mass coefficient is fairly low at about 0.7. The distance estimate, however, at −0.26 is much lower than the commonly observed −0.7 to −1.0. When we include time interaction terms for the economic mass variable, we find that the coefficient is not stable over time. When the standard

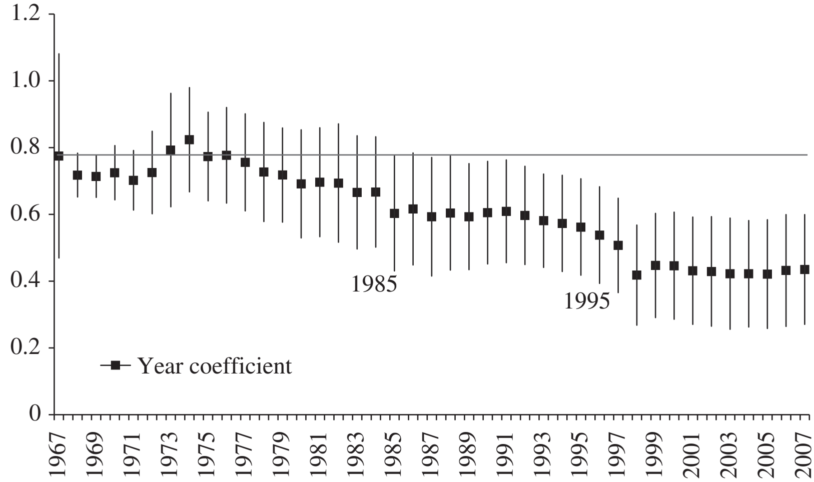

Figure 7.1: *GDP coefficients for Factory Asia countries, 1967–2008.*

Estimated coefficients of α_1 with year dummies. Base estimation is specified as in (7.9). Fixed effects estimation is specified as in (7.10). Factory Asia countries: Japan, Indonesia, Republic of Korea, Malaysia, Thailand, and Taiwan (Chinese Taipei).

controls are included (see column 4), the base case estimate is 0.4, to which must be added the period coefficients, which are 0.3 for the pre-Factory Asia period (Baldwin 2006), 0.2 for the 1987–96 period and essentially zero (and insignificant) for the post-1998 period.

To estimate the mass variable's instability over time more clearly, we re-do the same regression but allow yearly interaction terms. The results, displayed in Figure 7.1, show the evolution of the GDP coefficients. The mass elasticity fall over time, with two clear breaks in the estimated coefficients, 1985 and 1998.

The timing and direction of these structural changes are very much in line with the literature on the internationalisation of production. According to many studies, production unbundling started in the mid-1980s and accelerated in the 1990s (see, for example, Hummels *et al* 1998). The idea is that coordination costs fell with the information and communications technology (ICT) revolution and this permitted the spatial bundling of production stages (Baldwin 2006). The ICT revolution came in two phases. The Internet came online in a massive way in the mid-1980s, and then, in the 1990s, the price of telecommunications plummeted with various ITC-related technical innovations and widespread deregulation (Baldwin 2011). The upshot of all these changes was that it became increasingly economical to geographically separate manufacturing stages. Stages of production that previously were performed within walking distance to facilitate face-to-face coordination could be dispersed without an enormous drop in efficiency or timeliness.

Table 7.4: *Estimates for EU15, and USA, Canada, Australia and New Zealand, 1967–2008.*

	No time interactions			Variable mass coefficient	
Variables	(1)	(2)	(3)	(4)	(5)
$\ln(GDP_o GDP_d/\Omega_o P_d)$	0.659***	0.659***	0.632***	0.725***	0.703***
	(0.009)	(0.025)	(0.027)	(0.058)	(0.034)
*years 1967–1986				−0.0408	−0.0503
				(0.051)	(0.044)
*years 1987–1996				−0.0376	−0.0444
				(0.036)	(0.032)
*years 1998–2002				0.0132	0.005
				(0.017)	(0.014)
ln(distance)	−0.843***	−0.843***		−0.688**	
	(0.059)	(0.233)		(0.276)	
Constant	−1.630**	−1.630	−8.819***	−4.966	−10.72***
	(0.726)	(2.284)	(0.657)	(3.733)	(0.917)
Time effects	Yes	Yes			
Exporter* time effects			Yes	Yes	Yes
Importer* time effects			Yes	Yes	Yes
Pair effects			Yes	Yes	Yes
Observations	8020	8020	8020	8020	8020
R^2	0.932	0.932	0.978	0.934	0.978
Clustered standard errors		Yes	Yes	Yes	Yes

Source: authors' calculations. Standard errors are clustered by bilateral pair. Robust standard errors are reported in parentheses: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

As far as the Figure 7.1 results are concerned, the notion is that as trade became increasingly focused on intermediates, GDP became an increasingly poor determinant of trade flows, as suggested by our theory. The impacts of the mid-1980s and the mid-1990s changes are clear from the estimated GDP elasticities. More specifically, from 1967 to 1985 the elasticity of these countries' bilateral imports to GDP was stable, with a coefficient of about 0.77. Between 1985 and 1997, it steadily decreased, to reach a coefficient value of about 0.60, and after 1998 it further dropped, to close to 0.40. The coefficient estimates for the different periods in Factory Asia are summarised in Table 7.3, columns (4) and (5).

For comparison we also report results of time-year interactions with GDP for bilateral trade between countries where we *a priori* expect bilateral trade to be dominated by consumption goods and/or a stable ratio of intermediates to final goods trade. To this end, we re-run the Table 7.3 regressions for bilateral trade between each of the EU15 nations, the USA, Canada, Australia and New Zealand. Because most of the internationalisation of supply chains is regional rather than global (except for microelectronics), we expect these bilateral trade flows to be less influenced by the second unbundling that so marked Factory Asia trade. The results, shown in Table 7.4 tend to confirm our view that the gravity model breaks down only for bilateral flows where production sharing is especially important and growing quickly. That is, as predicted by our theory, we find no breaks over time in the trade coefficients, while distance coefficients have elasticity levels which are closer to unity. None of the time interaction terms in columns (4) and (5) are significant and the other point estimates fall in the expected ranges.

3.2 More Precise Estimates of the Impact of Components on the Mass Estimate

These two sets of results are highly suggestive. On data that is widely recognised as being dominated by parts and components trade, we find structural instability in the mass variable coefficient moving in the expected direction. However, on data where this sort of production fragmentation is not widely viewed as having been important, we find that mass point estimates are stable over time.

To explore this more systematically, we consider a less granular relationship between the importance of components trade and the point estimate on the mass variable on the full sample. Our basic assertion is that the composition of trade flows will influence the point estimates of the economic mass variables, since the standard gravity model is mis-specified when it comes to the mass variable. The most direct test of this hypothesis is to include the ratio of intermediates to total trade as a regressor, both on its own and, more importantly, as an interaction term with the economic mass variable. Of course a mis-specification of one part of the regression has implications for the point estimates of the other regressors, so we also consider the ratio's interaction with the other main regressors.

To this end, we re-estimate the basic equation on the full sample of 187 countries for the years 2000–8, allowing for interactions with a variable that accounts for the share of intermediate goods over total imports in each particular bilateral trade flow.

The idea here is that GDP as a measure for economic mass should work less well for those bilateral flows that are marked by relatively high shares of intermediates trade. By estimating the effect on the full sample, we avoid the problem of identifying the exact sources of the variation in the coefficients. We implement the idea in two ways.

First we estimate the standard regression but include the share of bilateral imports that is in intermediates (denoted as M_d^{interm}/M_d). This new variable is included on its own and interacted with the other right-hand side variables. Table 7.5 reports the estimated results for the coefficients of interest.

The regression results tend to confirm our hypothesis. The regression reported in column (1) includes the ratio on its own and interacted only with the mass variable. The coefficients for economic mass and distance are a

Table 7.5: *Interactions with share of intermediates in total imports, full sample.*

Variables	(1)	(2)	(3)	(4)
M_d^{interm}/M_d	6.536***	8.018***	6.954***	7.330***
	(0.858)	(1.015)	(0.835)	(1.004)
$\ln(\text{GDP}_o\text{GDP}_d/\Omega_o P_d)$	1.031***	1.027***	1.064***	1.058***
	(0.010)	(0.010)	(0.010)	(0.010)
$*M_d^{\text{interm}}/M_d$	−0.129***	−0.118***	−0.137***	−0.126***
	(0.017)	(0.017)	(0.017)	(0.016)
ln(distance)	−1.173***	−1.051***	−1.011***	−0.954***
	(0.018)	(0.037)	(0.0191	(0.037)
$*M_d^{\text{interm}}/M_d$		−0.232***		−0.110*
		(0.059)		(0.0601
Contig_{od}			1.350***	0.967***
			(0.101)	(0.246)
$*M_d^{\text{interm}}/M_d$				0.625*
				(0.369)
Common language			1.215***	1.126***
			(0.044)	(0.078)
$*M_d^{\text{interm}}/M_d$				0.178
				(0.119)
Constant	−27.58***	−28.40***	−30.85***	−31.07***
	(0.551)	(0.634)	(0.541)	(0.625)
Observations	121,737	121,737	121,737	121,737
R^2	0.604	0.604	0.621	0.621

$M_{dtinterm}/M_d$ is the share of intermediate imports by a country d over its total imports. Robust standard errors are reported in parentheses: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

very reasonable, at 1.031 and −1.173, respectively (both significant at the 1% level). The ratio on its own comes in positive as expected (bilateral trade links marked by a high share of intermediates tend to have ‘too much’ trade compared with the prediction of the standard gravity equation). The ratio interacted with economic mass also has a negative sign, −0.129, which conforms with our hypothesis (the higher the ratio of intermediates for the particular trade pair, the lower the estimate of the economic mass variable). All coefficients are significantly different to zero at the 1% level of confidence.

The other columns report robustness checks on the main regression. The qualitative results on the variables of interest (the mass coefficient, the ratio coefficient and the mass × ratio interaction coefficient) are robust to inclusion of interaction terms with any or all of the control variables. This confirms the more informal tests based on an *a priori* separation of the sample.

Interestingly, the interaction term is also highly significant and negative for distance in specification (2). That is, distance seems to matter more for components trade: a result that is not in line with our simple model, but is expected from the broader literature on offshoring. For example, transporta-

Table 7.6: *All countries, 2000–7, by share of intermediate imports.*

Variables	$\left(\frac{GDP_o GDP_d}{\Omega_o P_d}\right)$	ln(distance)	Constant
Base effect	0.985***	−1.105***	−26.29***
	(0.018)	(0.018)	(0.898)
Base effect* d2	−0.0308		
	(0.021)		
Base effect* d3	0.0108		
	(0.021)		
Base effect* d4	−0.0330		
	(0.020)		
Base effect* d5	−0.0803***		
	(0.020)		
Base effect* d6	−0.103***		
	(0.021)		
Base effect* d7	−0.0903***		
	(0.021)		
Base effect* d8	−0.0723***		
	(0.022)		
Base effect* d9	−0.118***		
	(0.024)		
Base effect* d10	−0.0748***		
	(0.022)		
Observations	121,712		
R^2	0.610		

Source: authors' estimations. Deciles categorise countries' bilateral imports by increasing shares of intermediate imports over total imports. Hence, d10 indicates the 10% bilateral import relationships where the share of intermediate imports in total imports is highest, and the base effect indicates the 10% bilateral import relationships where the share of intermediate imports in total imports is lowest. Common language and contiguity included by not reported. Standard errors are clustered by bilateral pair. Robust standard errors are reported in parentheses: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

tion costs become more important when trade costs are incurred between each stage of production, while the value added per stage is modest.

The second approach is to use decile-dummies to permit a more flexible relationship between the share of imports made up of components and the mass point estimate. The idea is that the inclusion of the intermediates-ratio imposes linearity on the relationship. The deciles approach allows the interaction terms to be nonlinear, for example, it allows for the possibility of a threshold effect whereby the interaction is significant but only for ratios that are sufficiently large. More specifically, the dummies categorise the share of intermediates in total imports, *ie* a dummy that selects bilateral flows where the proportion of intermediate imports is below 10%, between 10% and 20%, *etc*. The results are shown in Table 7.6. All results are robust to the addition of other trade determinants.

For the variable of greatest interest, the economic mass variable, the coefficient for the base-case decile is 0.985, which is very close to unity as expected,

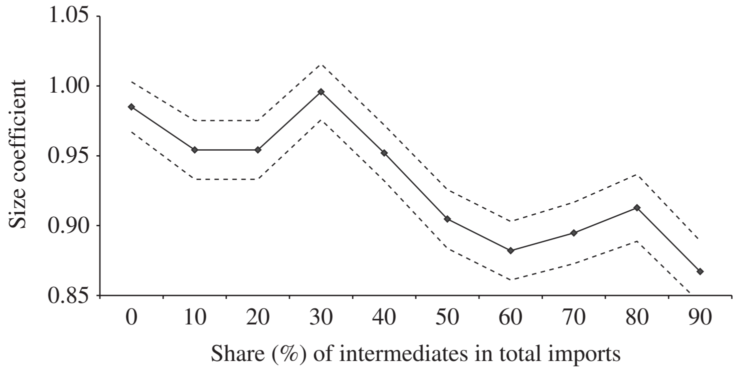

Figure 7.2: *Coefficient for the size variables measured as* $\ln((Y_{ot}/\Omega_{ot})(E_{dt}/P_{dt}^{1-\sigma}))$.
Source: authors' estimations.

and very precisely estimated. The subsequent rows show the additional effects for each decile. What we see is that the interaction terms are insignificant for shares of intermediates below 50% of total imports. However, for high concentrations of intermediates, the interaction terms are all negative and highly significant – at the 1% level. The additional effects lower the base case point estimate by around 0.10. The distance term is a very reasonable (-1.1) and highly significant.

The results in Table 7.6 suggest that there is something of a threshold effect in operation. What we see is that the standard gravity specification works rather well for bilateral trade flows where the ratio of intermediates is not too great. For trade flows where intermediates are more important, however, we get the by now familiar result that the mass coefficient is significantly lower. Since this share is indeed rather low for most bilateral trade flows in the world (since production fragmentation tends to be a regional phenomenon), this may help explain the Bergstrand and Egger (2010) result mentioned above.

To illustrate the point graphically, we plot, in Figure 7.2, the point estimates and standard errors using a candle chart. Here the point estimates of the mass coefficients are plotted as the horizontal bar; the associated standard errors are shown with the vertical bar.

4 A SEARCH FOR MASS PROXIES WHEN INTERMEDIATES ARE IMPORTANT

The previous section provides clear evidence that the standard gravity equation is 'broken' when it comes to bilateral flows where trade in intermediates is important. The theory suggests that the perfect solution would require data on total costs to construct the demand shifter for intermediates imports. If the economy is reasonably competitive, gross sales would be a good proxy for the total costs. Unfortunately, such data are not available for a large number of nations, especially the developing nations, where production fragmentation is so important. On the mass variable for the origin nation, theory suggests that we use gross output rather than value added. Again such data are not widely available.

This section presents the results of our search for a pragmatic 'repair' which relies only on data that is available for a wide range of nations. The basic thrust is to use the theory in Section 2 to develop some proxies for economic mass variables that better reflect the fact that the demand for intermediates depends upon gross output, not value added.

4.1 Fixes for Economic Mass Proxies

We start with the destination nation's mass variable. In Section 2 we showed that a bilateral flow of total goods is the sum of goods whose demand depends upon the importing nation's GDP (*ie* consumer goods) and goods whose demand depends upon the total costs of the sector buying the relevant intermediates. The theory says that our economic mass measure should be a linear combination of two mass measures, not a log-linear combination (see equations (7.9) and (7.7)).

This suggests a first measure that adds imports of intermediates to GDP. The idea here is to exploit the direct definition of total costs as the cost of primary inputs plus the value of intermediate inputs. For any given local firm, some of the intermediates it purchases will be from local suppliers, but on summing across all sectors and firms within a single nation, such intermediates will cancel out, leaving only payments to local factors of production and imports of intermediates. Our first pragmatic fix therefore is to measure the destination nation's demand shifter by using

$$E_d \equiv Y_d + \sum_{i \neq o} V_{d,i}^{\text{interm}}, \tag{7.11}$$

where V^{interm} is the value of bilateral imports of intermediates. If we summed across all partners, this measure would include part of the bilateral flow to be explained (namely, intermediates from nation o to nation d). To avoid putting the trade flow to be explained on both sides of the equation, we build the measure for each pair in a way that excludes the pair's bilateral trade.

For the economic mass variable size pertinent to the origin nation, we are trying to capture gross output that must be sold. The proposed measure is a straightforward application of the theory; it uses the origin nation's value added in manufacturing and its purchases of intermediate inputs from all sources except from itself (due to a lack of data):

$$C_o \equiv AV_o^{\text{manuf}} + \sum_{i \neq 0} V_{i,o}^{\text{interm}}. \tag{7.12}$$

Note that our specification of the gravity equation uses the exports from nation o to nation d, so the second term in this does not include the bilateral

Table 7.7: *New mass proxies with share of intermediate, all nations, 2000–7.*

Variables	(1)	(2)	(3)	(4)
M_d^{interm}/M_d	1.180	2.644**	2.044**	1.907*
	(1.020)	(1.142)	(0.988)	(1.143)
$\ln(E_d C_o/\Omega_o P_d)$	0.898***	0.889***	0.945***	0.932***
	(0.012)	(0.0116)	(0.012)	(0.012)
$*M_d^{\text{interm}}/M_d$	−0.0322	−0.0132	−0.0289	−0.0247
	(0.020)	(0.020)	(0.020)	(0.020)
ln(distance)	−1.080***	−0.929***	−0.908***	−0.838***
	(0.018)	(0.038)	(0.019)	(0.038)
$*M_d^{\text{interm}}/M_d$		−0.279***		−0.131*
		(0.065)		(0.067)
Contig_{od}			1.441***	1.211***
			(0.092)	(0.224)
$*M_d^{\text{interm}}/M_d$				0.356
				(0.354)
Common language			1.251***	1.047***
			(0.047)	(0.088)
$*M_d^{\text{interm}}/M_d$				0.385***
				(0.143)
Constant	−20.05***	−20.87***	−24.17***	−24.08***
	(0.623)	(0.687)	(0.610)	(0.685)
Observations	87,258	87,258	87,258	87,258
R^2	0.607	0.607	0.631	0.631

Note: Robust standard errors are reported in parentheses: $***p < 0.01$, $**p < 0.05$, $*p < 0.1$. Pair effects and standard errors are clustered by pair. $M_{d\text{interm}}/M_d$ is the share of intermediate imports by a country d over its total imports. New mass variables are defined in the text.

flow to be explained. The second term involves nation o's imports from all nations, not its exports to nations.

4.2 Empirical Results

To test whether these proposed proxies work better than GDP, we run regressions like those reported in Table 7.5 but with the new proxies for economic mass replacing the standard proxy (*ie* GDP). The results are shown in Table 7.7.

The results in Table 7.7 (compared with those in Table 7.5) suggest that our proxies work better than GDP. The key piece of evidence can be seen in column (1). This includes the ratio of intermediates in total bilateral trade both on its own and interacted with the mass variable. The lack of significant of the ratio in either role suggests that our new proxy is doing a better job than GDP did in picking up demand and supply of intermediates.

Interestingly, the column (2) regression, which allows an interaction between distances on the ratio of intermediates, suggests that the distance coefficient may also be mis-specified. When the interaction effect between the above mentioned ratio and the dummy for distance is computed, results show

Table 7.8: *New mass proxies with intermediate deciles, all nations, 2000–7.*

	$\ln(E_d C_o/\Omega_o P_d)$	ln(distance)	Constant
Base effect	0.877***	−1.051***	−19.29***
	(0.022)	(0.018)	(1.074)
Base effect* d2	0.0402		
	(0.024)		
Base effect* d3	0.0365***		
	(0.025)		
Base effect* d4	0.0294		
	(0.024)		
Base effect* d5	−0.0256		
	(0.024)		
Base effect* d6	−0.0531**		
	(0.025)		
Base effect* d7	−0.0390		
	(0.025)		
Base effect* d8	−0.0306		
	(0.026)		
Base effect* d9	−0.0652**		
	(0.028)		
Base effect* d10	0.0102		
	(0.027)		
Observations	87,251		
R^2	0.609		

See notes to Table 7.6.

that the distance estimate falls somewhat on average, but especially for trade flows where parts and components are especially important (*ie* the ratio is high).

This suggests that distance is more important, not less, for bilateral trade flows dominated by intermediates. The finding may reflect the well-known fact that most production fragmentation arrangements are regional rather than global (components trade is more regionalised that overall trade). This result, however intriguing, does not really stand up to minor changes in the specification. In regression (4), which includes the ratio's interaction with all variables, the distance result fades; indeed, only the common language effect seems to be magnified for trade flows marked by particularly high ratios of intermediates.

Importantly, we note that in all specifications, the ratio's interaction term on the economic mass is always insignificant. This suggests that our new mass proxies are doing a better job of picking up the true supply and demand variables including intermediates.

For symmetry, and to check for nonlinear interaction terms, we use our new mass proxies in a regression akin to Table 7.6. The idea is to use ratio decile dummies instead of the ratio itself in order to allow the interactions to vary nonlinearly for bilateral flows marked by different degrees of intermediates trade. The results are shown in Table 7.8.

To interpret our findings, recall that the significance of the upper-tier decile interaction terms was taken as evidence that GDP was not working well for trade flows marked by much trade in intermediates. Thus, the results in Table 7.8 suggest that our new proxy is working better than GDP.

Specifically, the base effect for our economic mass variable and the distance coefficients are estimated at very reasonable point estimates (0.88 and −1.1, respectively). Critically, only one of the decile interaction terms is significant, and it is positive, not negative as the theory would suggest. Two other interaction terms are borderline significant and negative: those for the sixth and tenth deciles.

5 WHY DO INCORRECTLY SPECIFIED MASS VARIABLES MATTER?

A large number of gravity studies focus on variables that vary across country pairs, say free-trade agreements, cultural ties or immigrant networks. The most recent of these studies employ estimators that control for the mass variables with fixed effects. Such studies do not suffer from mass-variable mis-specification and so are unaffected by our critique.

There are, however, as mentioned in Section 1, a number of recent studies, especially concerning the 'distance puzzle', that do proxy for the production and demand variables with GDP. It is these studies that our work addresses.[8]

However, since most of these studies are concerned with a broad set of nations and commodities, the mis-specification of the mass variable probably has a minor impact on the results, as the findings of Bergstrand and Egger (2010) showed and we confirmed with our Table 7.1 results. More worrying, however, is its use by authors who focus on trade in parts and components.[9] These papers use the consumer-good version of the gravity model and thus mis-specify the mass variable.

Once the equation is mis-specified—in particular, if the standard economic mass proxies do not correctly reflect the supply and demand constraints—we are in the realm of omitted variable biases. The first task is to explore the nature of the biases that would arise from this mis-specification. To simplify, we assume away GDPs and distance and focus on a pair-wise policy variable, say, nation d's tariffs on imports from nation o; we denote this by T_{od}. The estimated gravity equation will thus have the following structure:

$$\ln V_{odt} = \text{const.} + a_5 \ln T_{odt} + \varepsilon_{odt}, \tag{7.13}$$

[8]See Rauch (1999), Brun *et al* (2005), Berthelon and Freund (2008), Jacks *et al* (2008), and Anderson and Van Wincoop (2003).

[9]See Athukorala and Yamashita (2006), Kimura *et al* (2007), Yokota (2008) and Ando and Kimura (2009).

where the error is assumed to be independent and identically distributed (iid).

Because intermediates supply is measured by total costs rather than GDP, and the supply of intermediates that must be sold depends upon gross output rather than value added. This means that the true model includes an additional term. That is,

$$\ln V_{odt} = a_0 + a_5 \ln T_{odt} + a_6 \ln Z_{odt} + \varepsilon_{odt}, \tag{7.14}$$

where Z_{odt} is the difference between the GDP-based mass variables and the true mass variables as specified in (7.7). We can write Z_{odt} as a function of T_{odt} in an auxiliary regression:

$$\ln Z_{odt} = b_0 + b_1 \ln T_{odt} + u_{odt}, \tag{7.15}$$

where u is assumed to be iid. Using this notation for the coefficients of the auxiliary regression, we can see that in estimating (7.3), we are actually estimating

$$\ln V_{odt} = (a_0 + b_o a_6) + (a_5 + a_6 b_1) \ln T_{odt} + (\varepsilon_{odt} + a_6 u_{odt}). \tag{7.16}$$

What this tells us is that the coefficient on the policy variable of interest will almost surely be biased. The point is that the only way it is not biased is if there is no correlation between the mis-specification of the economic mass variables and the policy variable.

What sort of correlation should we expect? Recall that the mis-measurement of the economic mass variable goes back to the importance of trade in intermediate goods. Since almost all bilateral variables of interest are things that affect bilateral trade flows, it seems extremely likely that the variable of interest will also affect the flow of intermediates. As long as it does, then we know that the mis-specification of the mass variable will also lead to a bias in the pair-wise variables.[10]

For example, let us suppose that tariffs discourage trade overall, but they especially discourage intermediates trade (for the usual effective rate of protection reasons, *ie* the tariff is paid on the gross trade value but its incidence falls on the value added only). In this case, we should expect low tariffs to encourage two things: an overall increase in trade and an increase in the ratio of intermediates. In this case, the bias in the mis-specified gravity equation is likely to be negative, since the policy variable is negatively correlated with the omitted variable. Furthermore, the mis-specification also affects the standard errors, which would result in a biased inference (Wooldridge 2003, Chapter 4).

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[10] As noted above, the modern techniques for controlling for mass with time-varying country-specific dummies eliminates such biases, since they correctly control for the role of intermediates.

6 CONCLUDING REMARKS

In this chapter we present empirical evidence that the standard gravity model performs poorly by some measures when it is applied to bilateral flows where parts and components trade is important. The chapter also provides a simple theoretical foundation for a modified gravity equation that is suited to explaining trade where international supply chains are important. Finally, we suggest ways in which the theoretical model can be implemented empirically.

REFERENCES

Anderson, J. (1979). The theoretical foundation for the gravity equation. *American Economic Review* **69**, 106–116.

Anderson, J., and E. van Wincoop (2003). Gravity with gravitas: a solution to the border puzzle. *American Economic Review* **93**(1), 170–192,

Anderson, J., and Y. V. Yotov (2010). The changing incidence of geography. *American Economic Review* **100**(5), 2157–86.

Ando, M., and F. Kimura (2009). Fragmentation in East Asia: Further Evidence. ERIA Discussion Paper Series, DP-2009-20, October.

Athukorala, P., and N. Yamashita (2006). Production fragmentation and trade integration: east asia in a global context. *The North American Journal of Economics and Finance* **17**(3), 233–256.

Baier, S. L., and J. H. Bergstrand (2001). The Growth of World Trade: Tariffs, Transport Costs, and Income Similarity. *Journal of International Economics* **53**(1), 1–27.

Balassa, B. (1965). Economic Development and Integration Report. Centro de Estudios Monetarios Latinoamericanos.

Balassa, B. (1966). Tariff reductions and trade in manufacturers among the industrial countries. *American Economic Review* **56**(3), 466–473.

Baldone, S., F. Sdogati and L. Tajoli (2007). On some effects of international fragmentation of production on comparative advantages, trade flows and the income of countries. *The World Economy* **30**(11), 1726–1769.

Baldwin, R. (2006). Globalisation: The Great Unbundling(s). In *Globalisation Challenges For Europe*, Chapter 1, pp. 5–47. Secretariat of the Economic Council, Finnish Prime Minister's Office, Helsinki.

Baldwin, R. (2011). 21st Century Regionalism: Filling the Gap between 21st Century Trade and 20th Century Trade Governance. CEPR Policy Insight, No. 56.

Baldwin, R., and D. Taglioni (2007). Trade effects of the euro: a comparison of estimators. *Journal of Economic Integration* **22**(4), 780–818.

Bergstrand, J. (1985). The gravity equation in international trade: some microeconomic foundations and empirical evidence. *Review of Economics and Statistics* **67**(3), 474–481.

Bergstrand J. (1989). Generalized Gravity Equation, Monopolistic Competition, and the Factor-Proportions Theory in International Trade. *The Review of Economics and Statistics* **71**(1), 143–153.

Bergstrand J. (1990). The Heckscher–Ohlin–Samuelson Model, the Linder Hypothesis and the Determinants of Bilateral Intra-industry Trade. *Economic Journal* **100**(403), 1216–1229.

Bergstrand, J., and P. Egger (2010). A general equilibrium theory for estimating gravity equations of bilateral FDI, final goods trade and intermediate goods trade. In *The*

Gravity Model in International Trade: Advances and Applications (ed. S. Brakman and P. Van Bergeijk). New York: Cambridge University Press.

Berthelon, M., and C. Freund (2008). On the conservation of distance in international trade. *Journal of International Economics* **75**(2), 310–320.

Brun, J.-F., C. Carrère, P. Guillaumont and J. de Melo (2005). Has distance died? Evidence from a panel gravity model. *World Bank Economic Review* **19**(1), 99–120.

Carrere, C. (2006). Revisiting the Effects of Regional Trade Agreements on Trade Flows with Proper Specification of the Gravity Model. *European Economic Review* **50**(2), 223–247.

Chaney, T. (2008). Distorted Gravity: The Intensive and Extensive Margins of International Trade. *American Economic Review* **98**(4), 1707–1772.

Coe, D., A. Subramanian and N. Tamirisa (2007). The missing globalization puzzle: evidence of the declining importance of distance. *IMF Staff Papers* **1**(54), 34–58.

Deardorff, A. (1998). Determinants of Bilateral Trade: Does Gravity Work in a Neoclassical World?, In *The Regionalization of the World Economy*, pp. 7–32. National Bureau of Economic Research.

Dreze, J. (1961). Les exportations intra-CEE, en 1958 et la position Beige. *Recherches Economiques de Louvain* **27**, 717–738.

Eaton, J., and S. Kortum (2001). Technology, Trade, and Growth: A Unified Framework. *European Economic Review* **45**(7), 1195–1235.

Egger, H., and P. Egger (2004). Outsourcing and Trade in a Spatial World. CESifo Working Paper Series 1349.

Ethier, W. J. (1982). The General Role of Factor Intensity in the Theorems of International Trade. *Economics Letters* **10**, 337–342.

Evenett, S. J., and W. Keller (2002). On theories explaining the success of the gravity equation. *Journal of Political Economy* **110**(2), 281–316.

Feenstra, R. (1998). Integration of trade and disintegration of production in the global economy. *Journal of Economic Perspectives* **12**(4), 31–50.

Fujita, M., P. Krugman and A. J. Venables (2001). *The Spatial Economy: Cities, Regions, and International Trade*, Volume 1 (1st edition). The MIT Press.

Greenaway, D, and C. Milner (1987). Intra-Industry Trade: Current Perspectives and Unresolved Issues. *Weltwirtschaftliches Archiv* **123**(1), 39–57.

Grossman, G. M., and E. Rossi-Hansberg (2008). Trading tasks: a simple theory of offshoring. *American Economic Review* **98**(5), 1978–97.

Grubel, H. G., and E. J. Lloyd (1975). *Intra-industry Trade: The Theory and Measurement of International Trade in Differentiated Products.* London: Macmillan.

Grunwald, J., and K. Flamm (1985). *The Global Factory: Foreign Assembly in International Trade.* Washington, DC: Brookings Institution.

Haddad, M. (2007). Trade Integration in East Asia: The Role of China and Production Networks. World Bank Policy Research Working Paper 4160, March.

Harrigan, J. (1996). Openness to trade in manufactures in the OECD. *Journal of International Economics* **40**, 23–39.

Helpman, E., and P. Krugman (1985). *Market Structure and Foreign Trade.* Boston, MA: MIT Press.

Helpman, E., M. Melitz and Y. Rubinstein (2008). Estimating trade flows: trading partners and trading volumes. *The Quarterly Journal of Economics* **123**(2), 441–487.

Hummels, D., D. Rapoport and K.-M. Yi (1998). Vertical specialization and the changing nature of world trade. *Federal Reserve Bank of New York Economic Policy Review June*, 79–99.

Jacks, D., C. Meissner and D. Novy (2008). Trade costs, 1870–2000. *American Economic Review* **98**(2), 529–534.

Jones, R., and H. Kierzkowski (1990). The Role of Services in Production and International Trade: A Theoretical Framework, in *The Political Economy of International Trade Jones* (ed. R. Jones and A. Krueger), Chapter 3. Oxford: Blackwell.

Kimura, F., Y. Takahashi and K. Hayakawa (2007). Fragmentation and parts and components trade: comparison between East Asia and Europe. *The North American Journal of Economics and Finance* **18**(1), 23–40.

Krugman P. (1980). Scale Economies, Product Differentiation, and the Pattern of Trade. *The American Economic Review* **70**(5), 950–959.

Krugman, P., and A. Venables (1996). Integration, specialisation, and adjustment. *European Economic Review* **40**, 959–967.

Lamy, P. (2010). An urban legend about international trade. Speech, 5 June 2010, URL: http://other-news.info/index.php?p=3390.

Leamer, E. E., and R. M. Stern (1970). *Quantitative International Economics.* Boston, MA: Allyn and Bacon.

Linnemann, H. (1966). *An Econometric Study of International Trade Flows.* Amsterdam: North-Holland.

Melitz, M. J. (2003). The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity. *Econometrica* **71**(6), 1695–1725.

Novy, D. (2010). Trade costs in the first wave of globalization. *Explorations in Economic History* **47**(2), 127–141.

Obstfeld, M., and K. Rogoff (2001). The Six Major Puzzles in International Macroeconomics: Is There a Common Cause?, In *NBER Macroeconomics Annual 2000*, Volume 15, pages 339–412. National Bureau of Economic Research.

Ottaviano, G. I. P., T. Tabuchi and J.-F. Thisse (2002). Agglomeration and trade revisited. *International Economic Review* **43**, 409–436.

Poyhonen, P. (1963). A tentative model for the volume of trade between countries. *Weltwirtschaftliches Archiv* **90**, 93–99.

Rauch, J. (1999). Networks versus markets in international trade. *Journal of International Economics* **48**, 7–35.

Tinbergen, J. (1962). *Shaping the World Economy: Suggestions for an International Economics Policy.* New York: The Twentieth Century Fund.

Vanek, J. (1963). Variable factor proportions and interindustry flows in the theory of international trade. *Quarterly Journal of Economics* **77**(1), 129–142.

Verdoorn, R. (1960). The Intra-Block Trade of Benelux. In *Economic Consequence of the Size of Nations* (ed E. Robinson). London: Macmillan.

Woolridge J. (2002). *Econometric Analysis Cross Section Panel.* Boston, MA: MIT Press.

Yi, K.-M. (2003). Can vertical specialization explain the growth of world trade? *The Journal of Political Economy* **111**(1), 52–102.

Yokota, K. (2008). Parts and components trade and production networks in East Asia: a panel gravity approach. In *Vertical Specialization and Economic Integration in East Asia* (ed. D. Hiratsuka and Y. Uchida), Chapter 3. Chosakenkyu-Hokokusho: IDE-JETRO.

8

Using Trade Microdata to Improve Trade in Value-Added Measures: Proof of Concept Using Turkish Data

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1 INTRODUCTION

The dynamics of globalisation pose new challenges for economic and policy analysis. The liberalisation of trade policies and capital controls, coupled with reductions in transport, communication and information costs, has led to a significant reduction in trade costs and facilitated a reorientation of firms' production strategies in recent decades towards increasingly fragmented processes, with each production stage assigned to the most cost-effective location: a phenomenon which has became known as international fragmentation of production (Jones and Kierzkowski 2001).[2]

Vertical fragmentation of production can occur within the firm, as the firm internalises countries' and regions' comparative advantages and establishes subsidiaries abroad. Another option is for the firm to outsource certain parts of the production process to non-affiliated companies located overseas. Whether within the boundaries of the firm or at arm's length, the vertical fragmentation of production has changed trade patterns in a significant way. Firstly, intermediate goods and services cross borders several times as they incorporate subsequent stages of production. Miroudot *et al* (2009) estimate that in 2006 trade in intermediate inputs represented 56% and 73% of overall trade flows in goods and services, respectively, and Yi (2003) noted that

[1] The authors are grateful to TurkStat, Turkey's National Statistical Institute, for granting access to their micro databases which allowed testing the methodology outlined in this chapter.

[2] Several terms have been used to coin the international fragmentation of production: global value chains, international supply chains, internationally sliced up value-added chain, segmentation of production across national borders, vertical fragmentation, *etc*. This chapter uses these different terms interchangeably.

the increase in trade in intermediates is the single most important factor explaining why world trade has grown much faster than global GDP in the past three decades. Secondly, it gives rise to vertical specialisation, by which countries specialise in very specific stages of the production process. Indeed, as firms or production units located in different countries increasingly collectively contribute to the production of a single final product, the usefulness of the concept ‘country of origin’ has also become increasingly questionable.

This phenomenon has also led many to question the meaning that can be attributed to conventional estimates of trade statistics, which record the full value of a good or service each time it crosses a border as it passes along the production chain. In other words, this is a form of multiple counting that risks exaggerating the economic importance of trade to an economy. An often cited case study is that of the Apple iPod, undertaken by Linden *et al* (2009), which concludes that only 10% of the price of an assembled iPod at the Chinese factory-gate is Chinese value added. The bulk of the components (around 70% of the iPod’s value at the factory-gate) are imported from Japan, with much of the rest coming from the USA and Korea. Yet the export figures for China record the full value of the final good. This is not an isolated example and applies to a wide range of goods coming from many countries, as reported by Koopman *et al* (2008), who estimated that, on average, foreign countries contribute 80% or more of the value added embodied in recorded Chinese exports of information and communications technology equipment.[3]

It is clear that the multiple counting masks the contribution that exports make to domestic value added as well as the identification of the products a country truly has a comparative advantage in. These increasingly international production processes call for the development of measures of trade in the underlying value added embodied in a product.[4]

Indeed, there are a number of areas where measuring trade in value added can bring a new perspective and is likely to impact on policy choices.

Global imbalances. 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

[3]Similar studies include Apple’s iPhone (Xing and Detert 2010), the Boeing 787 Dreamliner (Newhouse 2007), Mattel’s Barbie doll (Tempest 1996) and Nokia’s N95 Smartphone (Ali-Yrkkö *et al* 2011).

[4]Using input–output tables for Sweden, Isakson and Wajnblom (2011) show that the share of national value-added exports in GDP is 18 percentage points lower than the share of gross exports in GDP, which includes the value of intermediate imports (31% versus 40%, respectively).

the value of foreign inputs.[5] The true imbalance is therefore also with the countries who have 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.

Market access and trade disputes. Measuring trade in value added sheds new light on today's trade reality, where competition is not between nations, but between firms. Competitiveness in a world of global value chains means access to competitive inputs and technology. Outsourcing and offshoring of elaborate parts and components can only take place in situations where the regulatory frameworks are non-discriminatory and intellectual property is respected. The optimum tariff structure in such a situation is flat (little or no escalation) and reliable (contractual arrangements within supply chains, especially between affiliated establishments, tend to be long term). WTO's World Trade Report 2011 on preferential trade agreements (PTA) reveals that more and more PTAs are going beyond preferential tariffs, with numerous non-tariff areas of a regulatory nature being included in the agreements. According to the report, global production networks may be prompting the emergence of these 'deep' PTAs, as good governance on a range of regulatory areas is far more important to these networks than further reductions in already low tariffs (WTO 2011).

Moreover, in the context of the fragmentation of production and global value chains, mercantilist-styled 'beggar thy neighbour' strategies can turn out to be 'beggar thyself' miscalculations. As mentioned earlier, domestic value added is found not only in exports but also in imports: some goods and services are intermediates, shipped abroad, whose value is returned to the domestic economy embodied in imports. As a consequence, tariffs, non-tariff barriers and trade measures, such as anti-dumping rights, are likely to impact domestic producers 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% and 80% of European Union value added. In 2006, anti-dumping rights were introduced by the European Commission on shoes imported from China and Vietnam. An analysis in value-added terms would have revealed that EU value added was in fact subject to the anti-dumping rights (National Board of Trade 2007).

The impact of macroeconomic shocks. The 2008–9 financial crisis was characterised by a synchronised trade collapse in all economies. Various 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

[5] See Maurer and Degain (2010). Koopman *et al* (2008) find that the domestic value added of Chinese exports is on average 60%.

particular, the literature has emphasised the 'bullwhip effect' of global value chains.[6] 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 recently demonstrated in the aftermath of the natural disaster that hit Japan in March 2011.[7]

Trade and employment. Several studies on the impact of trade liberalisation 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 Vietnam 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 job 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 embedded in the domestic content of exports reflects the relative development level of participating countries. Industrialised countries tend to specialise 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 specialises in low-skill types of jobs. Japan, on the contrary, has been focusing in 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 (WTO and IDE-JETRO 2011).

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

[6] See Escaith *et al* (2011) and Lee *et al* (1997).

[7] For an application of international IO in this case see Escaith *et al* (2011).

gas emissions and their 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 Organisation for Economic Co-operation and Development (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 and Wyckoff 2003; Nakano *et al* 2009).

Trade, growth and competitiveness. Likewise, indicators of competitiveness such as 'revealed comparative advantage' are affected by the measurement of trade in gross terms. Going back to the iPhone example, traditional trade statistics suggest that China has a comparative advantage in producing iPhones, but with value-added measures its comparative advantage is in assembly work. Having in mind growth strategies and the concerns of policymakers in identifying export sectors and promoting industrial policies, the analysis of the export competitiveness of industries cannot ignore the fragmentation of production and the role of trade in intermediates.

The use of input–output (IO) tables to determine the domestic content of exports in value-added terms at the industry level is now widespread and has the great advantage of providing comprehensive estimates, as both direct and indirect imports (embedded in domestic inputs) are included in the calculation of value added. However, IO tables have historically been and are typically constructed by national statistics offices as tools to determine interactions within industries of an economy, with the underlying assumption, when used as an analytical tool, that the production processes of firms within a given sector are homogeneous. However, the advent of global production processes raises questions about this assumption, especially in the context of studies that try to estimate the domestic value added embodied in exports, if the firms producing goods or services for export markets use different production processes from those firms producing the 'same' goods or services for domestic markets. Arguably, therefore, what is needed is an approach that motivates the development of more detailed input–output tables that adequately reflect, by design, this heterogeneity.

Motivating such a development will take some time, however, particularly at a time of stretched resources within statistical offices. But other approaches that capitalise on the availability of microdata could provide the basis for simpler solutions.

This chapter describes such an approach using Turkish firm-level microdata. It provides methodological guidelines on how to compute import coefficients at the level of the firm and shows how trade microdata, *ie* the matching of trade and business activity information at the level of the firm can refine the aggregate nature of the indicators in IO tables, by increasing their granularity.

Furthermore, the chapter critically assess the results of the implementation of the proposed methodology using Turkish firm-level data, kindly made available by TurkStat, the Turkish National Statistical Institute.

This chapter is structured as follows: Section 2 describes the concept of trade in value added (TVA) and how IO tables have been used to measure the contribution a country's exports make to overall domestic value added. Section 3 explains the limitations of existing aggregate IO tables and the bias which can be introduced when computing trade in value-added measures. Section 4 proposes a methodology to compile trade microdata indicators that can be produced by statistical offices as standard outputs in their own right but that are also able to be plugged into IO tables. It also presents the data used in the study to test the outlined methodology and documents the main limitations found which are directly related with the information available from trade microdata. Section 5 comments on the main findings stemming from the integration of firm-level indicators into Turkey's IO table, and Section 6 concludes, by proposing a research agenda.

2 TRADE IN VALUE ADDED: CONCEPT OVERVIEW

In a perfect world with perfect information it would be possible to decompose each product into a value-added chain that was able to identify where the value added originated by tracing it throughout the production chain.

Conceptually (ignoring taxes and subsidies for simplicity), it is possible to decompose any particular product with value V^p into the value added VA^p generated in country i for the production product p (directly and indirectly), such that the total value of

$$V^p = \sum_i \mathrm{VA}_i^p. \tag{8.1}$$

This is relatively clear and simple. However, complications can arise when aggregating up for a whole industry group or for a whole economy, as shown in the following example.

Consider an economy i that produces only two products a and b for export, with product a exported to country j for further processing before being reimported into country i for use in the production of b. Let us assume that 100 units of a, with value 200, are produced and exported and then used in the production of 100 units of product c, with value 300, that are in turn used in the production of 100 units of b with value 400. Let us further assume, for simplicity, that each unit of a is produced entirely in country i; in other words, no intermediate inputs are directly or indirectly sourced from abroad. We also assume that, apart from the intermediate imports referred to above, all the value added in b is also generated in country i only.

If we consider the global production chain, it is at least, in theory, possible to show that the 100 units of a generated 200 units of domestic value added, and the 100 units of b generated 300 units of domestic value added (100 directly after processing the 100 units of product c, but 200 indirectly, reflecting the fact that each unit of c reflects two units of value added generated in producing a, an intermediate input into c). We know that total gross exports in economy i were equal to 600, which overstates the contribution of overall trade to the economy, but simply summing the value-added contribution at the product level (the direct and indirect value added generated by a and the direct and indirect value added generated by b) will also overestimate the significance of trade in this context, as the overall value added generated in the economy through the sale of both a and b is only 300; reflecting the fact that of the 300 units of value added generated through the production of b, 200 units reflect the embodiment of product a, whose value added is separately shown under the production of a.

Input–output tables are designed to measure the interrelationships between the producers of goods and services (including imports) within an economy and the users of these same goods and services (including exports). In this context they can be used to estimate the contribution that imports make in the production of any good (or service) for export. For example, if a motor car manufacturer imports certain components (*eg* the chassis), the direct import contribution will be the ratio of the value of the chassis to the total value of the car. And if the car manufacturer purchases other components from domestic manufacturers, who in turn use imports in their production process, those imports must be included in the car's value. These indirect imports should be included in any statistic that attempts to measure the contribution of imports to the production of motor cars for export. The total direct and indirect imports are known as 'embodied imports'.

In an input–output framework the relationship between producers and consumers can be simply described as follows:

$$g = A \cdot g + y, \tag{8.2}$$

where g is an $n \times 1$ vector of the output of n industries within an economy. A is an $n \times n$ matrix describing the interrelationships between industries (known as the Leontief matrix), where a_{ij} is the ratio of inputs from domestic industry i used in the output of industry j. y is an $n \times 1$ vector of final demand for domestically produced goods and services, including exports.

Assuming that all goods produced by any particular industry are homogenous, total imports embodied directly and indirectly within exports and the additional domestic activity induced by this additional production can be calculated thus:

$$\text{embodied imports} = m(1 - A)^{-1} \times e, \tag{8.3}$$

where m is a $1 \times n$ vector with components m_j (the ratio of imports to output in industry j) and e is an $n \times 1$ vector of exports by industry.

In the same way, one can estimate the total indirect and direct contribution of exports to value added by replacing the import vector m above with an equivalent vector that shows the ratio of value added to output (v). So, the contribution of exports to total economy value added is equal to

$$v(I - A)^{-1} \times e. \tag{8.4}$$

At the whole-economy level this works fine, both for imports, if we accept the fact that they are measured gross, and, importantly, for value added. Returning to the example above, the approach would accurately record the 300 contribution exports made to value added. In addition, policymakers are equally interested in understanding the contribution that specific sectors make to the domestic content of exports, both directly and indirectly. In advanced industrialised economies, a large share of global GDP (and employment) accrues to services, while international trade remains largely dominated by goods. Yet, identifying backwards linkages from those export-oriented sectors producing tradeable goods (agriculture, manufacture) allows us to map where the domestic value added was created. The break-up of domestic content by direct and indirect sectoral value added reveals that a large chunk of the value originates indirectly from service sectors. This breakdown is particularly important when identifying the sources of national competitiveness, which may rest in up-stream sectors which are not considered as exporters by traditional statistics, or measuring the employment impact of export production.

An additional level of complexity arises because imports may often themselves embody some domestic value added (reimports). This amount may be significant when economies are closely inserted in global value chains. In order to trace this value, a global input–output table is needed: a table that in effect reallocates imports and exports to intermediate consumption or final domestic demand (such as household and government final consumption and capital formation).

Let G be a global input–output table with dimensions $(nc) \times (nc)$, where c is the number of countries and n is, as before, the number of industries. Furthermore, let the table be structured so that rows 1 to n reflect the industries of country 1, and rows $n + 1$ to $2n$ reflect the industries of country 2 and so on, and v_i^k is the direct value added produced by industry i in country k, as a share of its total output. It can be shown that the total direct and indirect domestic value added produced by industry j in country k is equal to

$$\sum v_i^k L_{(kn+i)(kn+j)}, \tag{8.5}$$

where L_{ij} is the ijth element of the global Leontief inverse $(I - G)^{-1}$.

Similarly,

$$\sum v_i^k L_{(hn+i)(hn+j)} \tag{8.6}$$

reflects the total value added generated in country k for unit output of industry j in country h, and

$$v_i^k L_{(hn+i)(hn+j)} \tag{8.7}$$

reflects value added generated by industry i in country k for unit output of industry j in h, providing a mechanism that shows the contributions made across different sectors of the economy.

Therefore, for any given export therefore by an industry, it should be possible to decompose the entire value into

(i) the domestic value added generated in its production, both directly from the main producing industry and indirectly via transactions between domestic industries and via transactions between domestic and foreign industries, and

(ii) the imported value added generated in producing the imports used in production (not including any part of the import value that reflects domestic value added).

A global input–output table will thus allow users and policymakers to decompose the entire value of any good in the following way:

- direct domestic value added from the final producer;
- indirect domestic value added by producing industry;
- indirect imported value added by produced country and industry.

The ability to generate output such as this is, in itself, beneficial to policymakers interested in the real contribution that industries make to economic growth, and indeed employment (as the flows above can be reformulated to show employment contributions), since they can be used to assess the domestic content of both imports and exports. Overall trade balances, however, will necessarily need to be estimated at a higher level (including all international economy linkages) to remove the double counting that occurs as goods and services criss-cross national boundaries during the production process. But the approach described above will allow more meaningful measures of overall bilateral trade balances, such as the one in a recent WTO report, according to which the US–China trade balance in 2008 would have been about 40% lower if calculated in value-added terms (Maurer and Degain 2010).

3 IMPROVING TRADE IN VALUE-ADDED MEASURES USING TRADE MICRODATA FOR EXPORTING FIRMS

A number of efforts have been undertaken in recent years to estimate the value added content of trade, including in the OECD, using linked IO tables.[8] However, improved estimates using microdata could be attained.

[8]There are four different recent initiatives to develop global or international IO tables: the Global Trade Analysis Project (GTAP), Asian International Input–Output Tables, OECD Input–Output Database and the World Input–Output Database (WIOD); see Ahmad *et al* (2011) for an overview. The first studies to estimate the value-added content of international trade under an explicit international input–output framework all rely on the GTAP database (Daudin *et al* 2011; Johnson and Noguera 2010; Koopman *et al* 2011).

In this context it is important to highlight some of the restrictive assumptions inherent in the use of IO tables when used to estimate trade in value added.

- **Domestic sales are assumed to have the same foreign value-added content as exports**. This limitation is also a direct consequence of aggregating information at the industry level, which can lead to biases in the estimation of the domestic value-added content of exports. If, for instance, the bulk of imported inputs are used in a sub-sector where most of the final production is destined to the domestic market and most of that industry's exports come from another sub-sector that uses mainly domestic inputs, the foreign content of (aggregate) exports is going to be higher than it is in reality.
- **Indigenous firms are assumed to source inputs in a similar way as foreign-owned enterprises**. As data for China show (Table 8.1), it is likely that foreign-owned firms' are more engaged in global value chains inputs produced abroad by other parts of the foreign business group of which they are part, which will in turn result in different intensity of imported inputs in intermediate consumption between indigenous and foreign-owned firms.

Against this background, it is clear that the use of IO tables that do not adequately differentiate between exporting firms and firms producing goods and services for domestic markets may provide an imperfect picture of the domestic value added embodied in a country's exports. Although it is impractical to estimate the domestic value-added content as outlined in Section 2 at a very detailed product level, identifying three simple statistics of exporting firms and those that produce goods for domestic markets only can, as shown below, provide not insignificant improvements to the overall results: value-added-to-output ratios; import-to-intermediate-consumption ratios and share of overall output of exporting firms.

4 DATA

The microdata used in this analysis are sourced from the Annual Industry and Service Statistics database (Structural Business Statistics, SBS), the Turkish trade register and the Annual Industrial Products Statistics database of TurkStat.

Since 2003 SBS has collected information on firm incomes, input costs, employment and investment activity, at the primary four-digit NACE (Rev 1.1) sector of activity and the region of location since 2003. The survey covers the whole population of firms with more than 20 employees operating in Turkey

Table 8.1: *Use of imported intermediates and output breakdown by firm type in China.*

		Imported intermediates		Export breakdown		
Year	Firm type	Share of intermediates for processing exports	Share of intermediates for normal use	Share of normal exports	Share of processing exports	Other
2002	Wholly foreign	66.0	10.4	11.9	87.9	0.3
2002	Joint venture	45.3	34.2	27.8	71.0	0.8
2002	State owned	18.2	57.5	64.7	31.8	2.6
2002	Collective	27.1	54.0	70.7	28.1	2.7
2002	Private	8.1	63.2	88.4	8.7	7.6
2002	All	38.3	38.5	42.2	55.9	1.7
2003	Wholly foreign	62.4	12.4	11.8	87.9	0.4
2003	Joint Venture	40.0	38.7	29.4	69.9	1.1
2003	State owned	14.0	62.9	67.2	28.8	2.2
2003	Collective	24.0	56.4	71.2	26.4	1.8
2003	Private	14.3	59.4	78.9	15.9	6.0
2003	All	35.4	41.2	41.9	56.0	1.6
2004	Wholly foreign	60.9	13.2	12.4	87.5	0.4
2004	Joint venture	39.5	37.1	30.1	69.1	1.2
2004	State owned	12.7	68.1	66.7	29.0	1.8
2004	Collective	22.7	61.2	71.8	25.1	2.1
2004	Private	14.9	61.3	81.1	13.8	5.6
2004	All	35.1	42.3	41.6	56.3	1.5
2005	Wholly foreign	63.3	13.3	13.4	86.5	0.7
2005	Joint venture	41.0	38.6	32.0	67.0	1.0
2005	State owned	11.7	70.8	66.5	28.1	1.7
2005	Collective	21.6	64.5	70.4	26.2	1.7
2005	Private	15.4	61.1	82.1	12.0	5.8
2005	All	36.6	42.9	41.9	55.6	1.5
2006	Wholly foreign	61.9	14.9	14.6	85.3	1.1
2006	Joint venture	38.8	40.8	35.2	63.1	1.1
2006	State owned	11.0	71.4	65.8	27.1	1.5
2006	Collective	20.3	67.5	71.8	24.7	1.6
2006	Private	13.8	61.6	84.1	10.3	5.8
2006	All	35.7	43.5	43.5	53.6	1.7

Source: China's Customs (cited in Wang (2008) and adapted by the authors).

and a representative sample of firms with less than 20 employees and whose activity lies in NACE Sections C–K and M–N.[9]

The second database used is the trade register which is sourced from

[9]The survey excludes firms operating in the following sectors: agriculture and related activities, hunting and forestry, public administration and defence and activities of households and of extra-territorial bodies.

customs declarations and contains information on merchandise trade only. Hence, exports do not cover services and imported intermediates cover goods only. Also excluded from imports and exports are border and coastal trade, transit, temporary trade and monetary gold transactions under US$100. Import and export flows are collected at 12-digit GTIP[10] classification. Information on the origin/destination countries of trade flows is also available.

The third database used is the Annual Industrial Products Statistics database which contains information on the type and number of produced goods, their volume and value of production together with the total quantity and value of total sales from products produced within the reference year or preceding years. Product data are collected at 10-digit PRODTR level.[11] Production data are available for firms with more than 20 persons employed and which primary or secondary activity lays either in the C (Mining & Quarrying) or D (Manufacturing) sections of NACE Rev 1.1.

This database, available for the period 2005–9, is used to identify the export flows of goods that the firm effectively produces (by matching the codes of the exported products to those of the products produced by the firm) and to exclude from import flows those goods which belong to its product scope (*ie*, the products that the firm import and that also correspond to products produced by the firm) on the assumption that these are imported goods that are sold without further processing. Merging foreign trade data and production data at the product level was achieved by establishing a correspondence between the GTIP and PROTR classifications provided by TurkStat.

The databases were matched using a single identifier of each enterprise created by TurkStat. The analysis used Turkish enterprise level data for the year of 2006.

The IO table for Turkey uses the latest table for 2002 sourced from the OECD's IO database (see Appendix A on page 204).

It is useful at this stage to say a few words on the computation of the indicators mentioned above.

- Export intensity: this is the value of the export to output ratio.
- Intermediate imports ratio: this is the value of intermediate imports divided by intermediate consumption
- Exporting firms' share of total output: share of sector or total economy production undertaken by exporting firms.

The value of output is proxied by firm turnover, available in enterprise surveys. It equals all activity incomes plus subsides, fiscal aids and other incomes but excludes other ordinary and extraordinary revenues and profits such as

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[10] Turkish Customs Tariff and Tariff Classification of Goods.

[11] This is national product classification with the first eight digits corresponding to Eurostat's Prodcom classification of 2006.

interest and dividends from affiliates and subsidiaries. Also included is the annual change in the stock value of semi-finished and finished products:

$$\begin{aligned} \text{output} = {} & \text{income from sales of goods and services} \\ & + \text{subsidies, fiscal aids and other incomes} \\ & + \Delta\text{stock value of semi-finished products} \\ & + \Delta\text{stock value of finished products.} \end{aligned} \tag{8.8}$$

Intermediate consumption comprises all types of expenditures necessary to undertake the economic activity of the enterprise. Hence, it excludes from financing charges (interest) and extraordinary expenses, including non-operating expenses and costs and previous years' expenditures.[12] From the obtained value of activity expenditures is deducted the annual variation of both changes in the stock value of raw and auxiliary materials, operating and packing goods and changes in the stock value of trading goods:[13]

$$\begin{aligned} & \text{intermediate consumption} \\ & \quad = \text{total value of equipment, raw and auxiliary materials, operating} \\ & \qquad \text{and packing good purchased to he used in production of goods and} \\ & \qquad \text{services in the reference period} \\ & \qquad + \text{value of goods to be sold without further processing} \\ & \qquad + \text{purchase of electricity} \\ & \qquad + \text{purchase of other fuels} \\ & \qquad + \text{payments made to employment agencies and similar organisations} \\ & \qquad + \text{expenditures on auxiliary activities provided by other enterprises} \\ & \qquad + \text{payments made for production subcontracted to third parties} \\ & \qquad + \text{rental expenses} \\ & \qquad - \Delta\text{stock value of raw, auxiliary materials, operating and} \\ & \qquad\ \ \text{packing goods} \\ & \qquad - \Delta\text{stock value of goods purchased to be sold without} \\ & \qquad\ \ \text{further processing.} \end{aligned} \tag{8.9}$$

Measuring imported intermediates at the firm level has some important caveats, which are worth discussing. Firstly, only direct imports can be captured in customs data. Imported inputs can embody themselves domestic value added which cannot be disentangled from the total import value. Secondly, a firm can buy locally (*ie* via a wholesaler in the domestic market) inputs

[12] Also excluded from the analysis here were advertising, accounting and marketing costs, although these should in theory be included.

[13] In theory these should also be adjusted for any stock revaluations (*ie* holding gains/ losses).

Table 8.2: *Merchandise trade by large economic sectors (as a percentage of total trade in 2009 or latest available year).*

	Total exports (%)					
	Agriculture	Industry	Trade	Services	Unspecified	Total
Canada	1.6	71.6	10.5	16.4	—	100.0
Turkey	0.1	59.9	34.5	5.5	—	100.0
USA	0.4	63.0	25.1	11.5	—	100.0
EU average	0.4	56.8	19.3	11.0	12.5	100.0
	Total imports (%)					
	Agriculture	Industry	Trade	Services	Unspecified	Total
Canada	0.5	48.5	40.8	10.3	—	100.0
Turkey	0.0	54.6	31.5	13.9	—	100.0
USA	0.1	47.0	41.6	11.3	—	100.0
EU average	0.2	37.5	38.3	12.8	11.1	100.0

Source: OECD-Eurostat Trade by Enterprise Characteristics (TEC) Database. Rounded figures, which may not sum exactly to 100.

that are produced abroad. According to the OECD-Eurostat TEC database, the percentage of wholesalers and retailers in many countries is not insignificant: they account, for example, for 19% of Germany's extra-EU exporters and 36% of exporting enterprises in the USA, where they are almost 50% of all importing enterprises as well. As shown in Table 8.2, wholesalers and retailers undertake a sizeable share of merchandise trade, which in the case of imports is above 30% of total imports, on average, for the countries covered by the database.[14]

Future plans, of both the Eurostat-OECD Trade by Enterprise Characteristics expert group and the OECD group working on the measurement of trade in value added, will focus on allocating these imports to using these goods as inputs by separately identifying and treating imports purchased by the wholesaling industry. Research will also focus on creating links between enterprises and any affiliate enterprises they set up as separate wholesale/retail arms.

In this study the microdata were based on 2006 results, whereas the IO coefficients and the export values were retrieved from the 2002 IO table, meaning that a full reconciliation of data was not possible. But there are other reasons why a complete reconciliation between the two sources would in any case be non-trivial. One of the reasons reflects the fact that the IO tables will, by design, include a number of corrections and adjustments to reflect reporting errors, such as incorrect reporting information from enterprises, and national accounts adjustments to reflect the non-observed (informal, grey, shadow) economy among others. But another equally important reason reflects the

[14]For a review of the literature on the role of wholesalers in international trade and its determinants see Crozet *et al* (2010) and Bernard *et al* (2011).

allocation of businesses to different industry sectors. The assumption used in the analysis here is that enterprises in the firm-level data are also the basis for constructing the IO tables. In theory, statistical offices are encouraged to construct IO tables using establishments. For most businesses the enterprise and the establishment is one and the same, but this is not always the case, particularly for larger enterprises. Further work will be needed to ensure a reconciliation of allocation methods used in the IO tables with those used in this additional analysis.

That said, these caveats are not expected to have a significant impact on the overall results. Firms engaged in the informal sector, for example, are typically small and unlikely to be involved in international trade. And, as noted, most establishments are also enterprises. In any case, to minimise the possibility of these differences having a major impact on the overall results, the approach used here is based on ratios.

In other words, in creating a split of any industrial sector into an exporting component and a non-exporting component, the approach has been to split total output in the sector in accordance with the split prevailing in the firm level data (assuming the ratios for 2006 are suitable for 2002). The next step is to create the estimates for each sector using information on the ratio of value added to output and the ratio of import to intermediate consumption for the population of exporting firms in every industry.

5 SUMMARY OF RESULTS

Table 8.3 presents the key results by two-digit ISIC industry. The table compares the share of imported inputs in total industrial output for exporting firms only (column 3) against the aggregate industry shares (across all firms in each sector) obtained via the aggregate two-digit IO tables (column 5). It shows that estimated imports embodied in exports were, on average, 125% higher combining IO information with firm level information about import shares from exporters compared with the results based on the aggregated IO coefficients. The table also shows that, in every industrial sector where some disaggregation was attempted, the amount of imports embodied in exports was higher and the difference was significant. The only exception was post and telecommunications (IO 64), where the difference was negligible. However, the latter result may be related to the low degree of tradability of that activity.

6 CONCLUSIONS AND RESEARCH AGENDA

The experimental results shown above demonstrate that more detailed IO tables which have a greater focus on the structure of exporting firms than

Table 8.3: *Comparison of results, 2002.*

		Import shares from exporting firms		Results based on aggregated IO table		
ISIC	Exports	A	B	A	B	C
1	2,244,050	0.13	299,932	0.06	145,611	106
2	10,896	0.06	662	0.03	311	113
5	65,569	0.14	9,440	0.07	4,585	106
10	1,655	0.26	438	0.12	200	118
11	1,708	0.14	240	0.08	133	81
13	114,967	0.36	40,909	0.16	18,845	117
14	251,485	0.26	64,926	0.13	32,242	101
15	2,457,225	0.29	700,829	0.12	287,108	144
16	122,341	0.56	68,994	0.23	27,552	150
17	7,018,726	0.61	4,260,200	0.27	1,872,164	128
18	8,242,291	0.54	4,447,960	0.24	1,992,294	123
19	287,732	0.63	182,681	0.37	105,676	73
20	146,946	0.70	102,729	0.28	41,604	147
21	344,823	0.63	217,567	0.30	101,801	114
22	46,795	0.44	20,644	0.23	10,562	95
23	606,703	1.11	676,060	0.57	343,648	97
24	1,545,378	0.68	1,045,659	0.28	438,663	138
25	1,327,502	0.82	1,085,012	0.33	444,134	144
26	1,819,875	0.40	729,259	0.18	325,196	124
27	3,700,493	0.79	2,932,985	0.37	1,354,991	116
28	1,116,763	0.64	718,554	0.30	333,180	116
29	2,299,397	0.59	1,348,560	0.28	636,981	112
30	10,242	0.49	5,049	0.27	2,803	80
31	1,239,762	0.73	903,317	0.31	388,618	132

'ISIC' denotes ISIC Rev. 3.1 industry. Export values are given in billion TL. A, direct and indirect imports as share of output. B, value of imports embodied in exports. C, difference in imported input contents, in percent.

has hitherto been the case should be pursued and developed by statistical offices. As noted above, this is unlikely to happen soon, but much can be done to motivate this development by exploiting existing microdata to produce indicators that can be integrated into existing IO tables. Moreover, as demonstrated in Appendix B on page 206, the development of these indicators is justifiable, as they provide stand-alone inputs for many other forms of analysis.

Certainly there remain a number of challenges, some of which have already been mentioned above, such as

- the alignment of enterprise and establishment based data,
- the inclusion of exporters of services in the exporting sector and imports of services in the calculation of total imports by the non-exporting and exporting sectors,

Table 8.3: *Continued.*

		Import shares from exporting firms		Results based on aggregated IO table		
ISIC	Exports	A	B	A	B	C
32	1,889,535	0.95	1,794,366	0.47	890,595	101
33	50,983	0.65	33,033	0.36	18,567	78
34	4,329,850	0.89	3,846,233	0.34	1,459,386	164
35	457,860	0.57	260,670	0.22	100,917	158
36	1,147,834	0.64	739,668	0.41	470,319	57
40	23,590	0.47	11,159	0.24	5,571	100
45	1,258,809	0.43	546,747	0.33	411,653	33
50	1,288,810	0.49	625,801	0.07	95,017	559
51	2,674,465	0.46	1,237,896	0.17	457,308	171
52	3,533,579	0.32	1,138,621	0.15	521,427	118
60	3,949,926	0.22	879,132	0.10	404,293	117
61	1,581,180	0.18	276,993	0.09	138,304	100
62	860,967	0.19	159,600	0.09	75,480	111
63	1,675,591	0.23	393,472	0.11	175,954	124
64	155,113	0.15	23,933	0.15	22,725	5
65	1,481,153	0.30	439,548	0.14	209,600	110
66	225,731	0.18	40,885	0.09	19,296	112
72	23,033	0.28	6,424	0.10	2,263	184
74	153,218	0.15	23,163	0.05	7,854	195
75	226,844	0.11	25,500	0.05	11,942	114
90	90	0.18	16	0.09	8	87
92	97,915	0.12	11,556	0.05	5,193	123
93	102	0.35	36	0.09	10	277
Total	62,109,502	0.52	32,377,056	0.23	14,412,585	125

'ISIC' denotes ISIC Rev. 3.1 industry. Export values are given in billion TL. A, direct and indirect imports as share of output. B, value of imports embodied in exports. C, difference in imported input contents, in percent.

- the treatment of imports purchased via non-affiliated or affiliated wholesalers.

Perhaps the most pressing area where further work is necessary, however, concerns the further disaggregation of sectors into importing intensity groups and ownership (foreign or domestic) and indeed the possibility of deriving sub-sectors of these groupings (including exporters) based on intensities or other breakdowns, for example, by breaking down exporters' quartiles based on the proportion of output they export, by size class or more detailed industrial classification. But all of these considerations need to be set against confidentiality constraints. Appendix B on page 206 provides further information on what is possible here.

One other important area of work concerns the nature of importers. Input–output tables in some countries often use limiting assumptions to allocate imports to using sectors. Often this is based on a straightforward proportionality assumption that allocates imports on the basis of their share within total supply. Some countries tackle this allocation using dedicated surveys, but these are not always conducted systematically. Capitalising on the use of existing microdata, in particular that relating to firms recognised as importers in trade registers, could lead to improvements in this allocation, particularly if this microdata is linked to information regarding the nature of the import (*ie* whether it is an intermediate good or one destined for final demand; see Appendix B on page 206). This activity forms part of the research agenda that takes this work forward.

Ultimately the intention is for the OECD to systematically integrate these new statistics into national IO tables, in conjunction with a number of other initiatives, for example, the creation of a Broad Economic Categories (BEC) data set (Zhu *et al* 2011).

7 APPENDIX A. IO TABLES

OECD's Science Technology and Industry Directorate has been updating and maintaining harmonised IO tables, splitting intermediate flows into tables of domestic origin and imports, since the mid-1990s, usually following the rhythm of national releases of benchmark IO tables. The process of compiling OECD's IO database greatly depends on cooperation with national statistical institutes. Ideally, national authorities would provide the latest supply–use tables and benchmark symmetric input–output tables (SIOTs) at the most detailed level of economic activity possible, with a basic price valuation, and, preferably, separating domestically produced and imported intermediate goods and services. However, few countries can meet such requirements. Therefore, in order to maximise country coverage, all relevant *partial* data is used. It should be noted that one of the main reasons that IO analysis has benefited from renewed attention in recent years is the improved availability and quality of IO tables and related statistics from national sources.

The first edition of the OECD IO Database dates back to 1995 and covers 10 OECD countries, with IO tables spanning the period from early 1970 to early 1990. The first updated edition of this database, released in 2002, increased the coverage to 18 OECD countries, plus China and Brazil, and introduced harmonised tables for the mid-1990s. Since 2006, this tradition of growth has continued so that there are now tables available for 46 countries (33 OECD and 13 non-OECD countries) with tables for the mid-2000s (mainly 2005) now available for most of them (Table 8.4).

The IO tables show the transactions between domestic industries. The tables break down total imports by user (industry and category of final demand). Some countries provide the latter import tables in conjunction with their IO tables, but in some cases they are derived by the OECD Secretariat

Table 8.4: *Country coverage of OECD Input–Output 2009 edition (as of May 2011).*

OECD	Mid-1990s	Early 2000s	Mid-2000s
Australia	1994/95	1998/99	2004/05
Austria	1995	2000	2005
Belgium	1995	2000	2005
Canada	1995	2000	2005
Chile	1996	—	2003
Czech Republic	1995	2000	2005
Denmark	1995	2000	2005
Estonia	1997	2000	2005
Finland	1995	2000	2005
France	1995	2000	2005
Germany	1995	2000	2005
Greece	1995	2000	2005
Hungary	1998	2000	2005
Iceland	—	—	—
Ireland	1998	2000	2005
Israel	1995	—	2004
Italy	1995	2000	2005
Japan	1995	2000	2005
Korea	1995	2000	2005
Luxembourg	1995	2000	2005
Mexico	—	—	2003
Netherlands	1995	2000	2005
New Zealand	1995/96	2002/03	—
Norway	1995	2000	2005
Poland	1995	2000	2005
Portugal	1995	2000	2005
Slovak Republic	1995	2000	2005
Slovenia	—	2000	2005
Spain	1995	2000	2005
Sweden	1995	2000	2005
Switzerland	—	2001	—
Turkey	1996	1998	2002
United Kingdom	1995	2000	2005
USA	1995	2000	2005

in producing IO tables directly from supply–use tables, which requires the use of assumptions that will have a significant impact on the results of trade in value-added analysis, particularly at the industry level. The main assumption used 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 IO tables. Improving the way that imports are allocated to users will form a central part of the work-plan going forward. But an important part of the work plan will be the attempt to gain an improved understanding of how countries estimate their import-flow matrices and indeed an attempt to motivate better methods of allocation, at the national level, where possible.

The industry classification used in the current version of the IO database

Table 8.4: *Continued.*

Non-OECD	Mid-1990s	Early 2000s	Mid-2000s
Argentina	1997	—	—
Brazil	1995	2000	2005
China	1995	2000	2005
Chinese Taipei	1996	2001	2006
India	1993/94	1998/99	2006/07
Indonesia	1995	2000	2005
Romania	—	2000	2005
Russia	1995	2000	—
South Africa	1993	2000	2002
Thailand	—	—	2005
Vietnam	—	2000	—
Malaysia*		2000	
Singapore*	1995	2000	2005

A dash means that the available year data is not available. *Not published (internal use only).

is based on ISIC Rev. 3 (Table 8.6), meaning that it is compatible with the other OECD industry-based analytical data sets such as the Structural Analysis (STAN) database, based on System of National Accounts by activity, and bilateral trade in goods by industry (derived from merchandise trade statistics via standard Harmonized System to ISIC conversion keys). By necessity (*ie* to maximise inter-country comparability), the system is relatively aggregated.

8 APPENDIX B: ANALYSIS OF FIRM-LEVEL HETEROGENEITY

8.1 Firm-Level Heterogeneity

This section shows the results of the exploratory work and aims at detailing the level of within-sector heterogeneity found in the key indicators identified above and comparing the values of these indicators at specific points of the distribution with averages computed at the sector level. The analysis is primarily centred on establishing a level of detail that could be provided within IO tables without compromising confidentiality constraints, but very clearly the results themselves are useful in understanding firm dynamics, and even without their integration into IO tables they can prove to be powerful policy tools.

Table 8.5 depicts correlations between the main variables of interest. It shows that there is a positive and highly significant correlation between the share of output exported by firms and the intermediate import ratio. Also, there is a positive correlation between the share of a firm's exports in total sector exports (calculated at the two-digit level) and the intermediate import ratio, except for wholesalers and retailers, which raises concerns about aggregation bias in TVA measures. The same information is depicted in Figure 8.1, which plots the distribution of the intermediate import ratios and the share

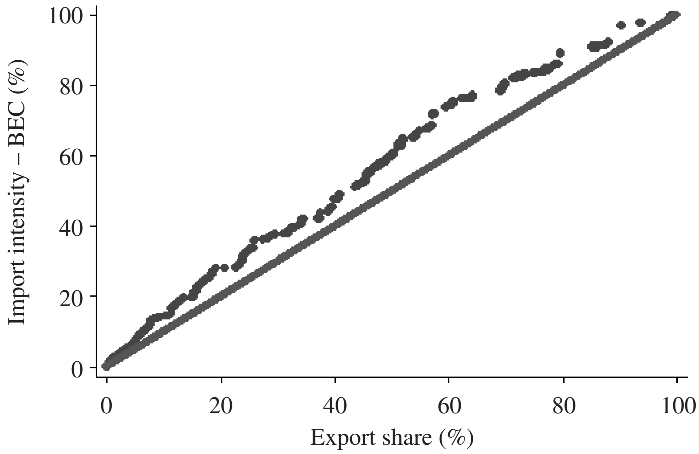

Figure 8.1: *Q–Q plot of intermediate import ratio against export share.*
Source: authors' calculations using TurkStat's databases.

Table 8.5: *Correlation table between selected indicators.*

Correlations between:	Whole economy	Manufacturing	Wholesalers & retailers
Export intensity and...			
· intermediate import ratio (BEC class.)	0.09	0.24	0.02
· value added per unit of output	−0.03	−0.03	−0.02
· value added	0.13	0.27	0.11
· foreign ownership	0.06	0.12	0.02
· firm size	0.15	0.30	0.11
Sector export share and...			
· intermediate import ratio (BEC class.)	0.04	0.11	**0.00**
· value added per unit of output	**0.00**	**−0.01**	**0.00**
· value added	0.03	0.07	0.03
· foreign ownership	0.07	0.10	0.02
· firm size	0.05	0.09	0.04
Intermediate import ratio (BEC classif.) and...			
· value added per unit of output	−0.02	−0.02	−0.01
· foreign ownership	0.10	0.22	0.07
· firm size	0.14	0.33	0.10

Source: authors' calculations using TurkStat's databases. All coefficients are significant at 1% unless indicated in bold.

of exported output at the firm level. From the figure it emerges that higher export shares correspond to more than proportional increases in the import

Table 8.6: *OECD IO industry classification. NACE Classification – Rev. 1.1.*

NACE	Description
01,02&05	Agriculture, hunting and related service industries
10–12	Mining and quarrying (energy)
13&14	Mining and quarrying (non-energy)
15&16	Food products, beverages and tobacco
17–19	Textiles, textile products, leather and footwear
20	Wood and products of wood and cork
21&22	Pulp, paper, paper products, printing and publishing
23	Coke, refined petroleum products and nuclear fuel
24ex2423	Chemicals excluding pharmaceuticals
2423	Pharmaceuticals
25	Rubber & plastics products
26	Other non-metallic mineral products
271&2731	Iron & steel
272&2732	Non-ferrous metals
28	Fabricated metal products, except machinery & equipment
29	Machinery & equipment, nec
30	Office, accounting & computing machinery
31	Electrical machinery & apparatus, nec
32	Radio, television & communication equipment
33	Medical, precision & optical instruments
34	Motor vehicles, trailers & semi-trailers
351	Building and repairing of ships & boats
352–359	Railroad equipment and transport equipment nec
36&37	Manufacturing nec; recycling (including furniture)

intensity measured as the share of BEC intermediates over intermediate consumption.

8.2 Export Shares

Table 8.7 shows the distribution of sector export shares (calculated as total exports over total output) for the Turkish economy in 2006. Sectors with cells suppressed due to confidentiality are not displayed in the table. The second column reports values for export intensity calculated directly at the sector level (*ie* by summation of total export and total output values at the two-digit sector and then taking the ratio between the two), while the third column presents average sector values of export intensity calculated at the firm level. The next columns display values for selected the middle and upper part of the distribution, more specifically the 50th, 75th, 90th and 95th percentiles.

It is clear from the table that there is a large discrepancy between the export share at the sector level reported in the second column and the average firm-level share displayed in the third column. This is easily explained by the large percentage of firms which do not export. Indeed, the initial idea was to display also values for the lower part of the distribution, but results showed what

Table 8.6: *Continued.*

NACE	Description
401	Production, collection and distribution of electricity
402	Manufacture of gas; distribution of gaseous fuels through mains
403	Steam and hot water supply
41	Collection, purification & distribution of water
45	Construction
50–52	Wholesale & retail trade; repairs
55	Hotels & restaurants
60	Land transport; transport via pipelines
61	Water transport
62	Air transport
63	Supporting & auxiliary transport activities; activities of travel agencies
64	Post & telecommunications
65–67	Finance & insurance
70	Real estate activities
71	Renting of machinery & equipment
72	Computer & related activities
73	Research & Development
74	Other business activities
75	Public admin. & defence; compulsory social security
80	Education
85	Health & social work
90–93	Other community, social & personal services
95–99	Private households and extraterritorial organisations

is already a stylised fact about export performance: only very few firms in the economy export (Araújo and Gonnard 2011; Ottaviano and Mayer 2008). As such, the values for the lower part of the indicators' distributions are not displayed, as they are mostly equal to zero, except for sector 16 (manufacture of tobacco products).

In the specific case of the Turkish economy, except for 'manufacture of tobacco products' (sector 16), and to a much lesser extent 'mining of metal ores' (sector 13), all the economy is characterised by the fact that almost 75% of the firms in a sector sell only to the domestic market. Not only is the export base is small, but also only a few firms within sectors have very high export intensities. Focusing on the manufacturing sector, and with the exception of the tobacco industry, the ratio of exports to output is higher than 25% only in sector 27 (manufacture of basic metals) at the 95th percentile.

Export shares computed at the sector level convey a different picture: export intensity calculated at this level is typically higher than the average export intensity calculated at the firm level and higher than the 75th percentile value. The only exception is the case of the tobacco industry, where 50% of the firms export around 40% or more of their total output, while the sector average is about half this figure. Conversely, aggregate export intensity is among the highest for motor vehicles, trailers and semi-trailers and other transport

Table 8.7: *Distribution of export shares (%).*

NACE Rev. 1.1	Total sector	Average across firms	50th perc.	75th perc.	90th perc.	95th perc.
13	25.76	13.55	0	0.43	71.25	84.59
14	21.48	5.84	0	0	30.49	47.61
15	10.08	0.68	0	0	0	0
16	23.09	40.62	39.79	78.57	85.63	93.75
17	13.89	1.43	0	0	0	5.50
18	16.66	1.35	0	0	0	0.32
19	9.22	1.86	0	0	0	5.51
20	5.47	0.18	0	0	0	0
21	6.31	1.41	0	0	2.86	9.20
22	1.82	0.21	0	0	0	0
24	10.25	2.64	0	0	5.29	14.77
25	15.60	1.57	0	0	0	8.64
26	6.12	1.17	0	0	0	1.82
27	20.03	3.48	0	0	8.13	28.15
28	11.07	0.61	0	0	0	0
29	17.92	2.20	0	0	0.76	13.58
31	22.43	2.52	0	0	0	16.13
33	9.63	2.52	0	0	2.50	19.96
34	43.98	2.82	0	0	4.97	18.24
35	26.73	2.65	0	0	6.89	15.42
36	10.14	0.97	0	0	0	0
40	0.68	1.27	0	0	0.61	3.14
45	1.41	0.10	0	0	0	0
50	0.66	0.12	0	0	0	0
51	7.49	1.99	0	0	0	2.02
52	0.44	0.10	0	0	0	0
55	1.13	0.02	0	0	0	0
60	0.20	0.02	0	0	0	0
61	3.20	0.17	0	0	0	0
63	0.59	0.03	0	0	0	0
64	0.08	0.03	0	0	0	0
71	0.01	0	0	0	0	0
72	1.75	0.10	0	0	0	0
74	0.42	0.02	0	0	0	0
80	0.01	0.01	0	0	0	0
85	0.05	0.01	0	0	0	0
90	0.10	0.28	0	0	0	0
92	0.09	0.03	0	0	0	0

Source: Source: authors' calculations using TurkStat's databases. Data have been made confidential for missing two-digit NACE sectors.

equipment (sectors 34 and 35, respectively), while the firm-level ratio shows that at least 95% of the firms operating in these sectors export less than 20% of their output.

Excluding from total exports the exports of those products that do not have a code matching the products that each firm have declared they produced

Table 8.8: *Distribution of intermediate import ratios (%).*

NACE Rev. 1.1	Total sector	Average across firms	50th perc.	75th perc.	90th perc.	95th perc.
(a) All imports						
10	5.68	1.37	0	0	0	0.77
13	15.83	2.42	0	0	5.29	13.42
14	5.29	0.78	0	0	0	0.35
15	8.85	0.26	0	0	0	0
16	38.4	15.65	0.59	20.49	65.27	70.92
17	22.78	1.72	0	0	0	6.62
18	11.48	0.54	0	0	0	0
19	17.49	0.99	0	0	0	2.03
20	24.07	0.18	0	0	0	0
21	36.07	4.31	0	0	11.6	34.27
22	9.11	0.5	0	0	0	0
24	55.09	9.88	0	0.77	47.79	66.42
25	36.21	2.09	0	0	0	9.7
26	14.41	0.92	0	0	0	0.11
27	51.91	4.52	0	0	10.66	35.09
28	16.08	0.5	0	0	0	0
29	27.48	1.83	0	0	0	11.25
31	38.25	1.91	0	0	0	9.14
32	79.18	7.9	0	3.49	31.64	49.01
33	34.02	3.88	0	0	7.59	29.77
34	58.66	5.94	0	0	37.48	44.09
35	31.15	2.16	0	0	0.57	15.07
36	9.57	0.34	0	0	0	0
40	1.95	3.29	0	1.15	5.3	15.72
45	1.45	0.18	0	0	0	0
50	7.14	0.21	0	0	0	0
51	10.72	2.91	0	0	0	8.9
52	1.8	0.25	0	0	0	0
55	1.03	0.04	0	0	0	0
60	1.67	0.01	0	0	0	0
61	2.26	0.32	0	0	0	0
63	1.55	0.11	0	0	0	0
64	2.32	0.21	0	0	0	0
70	0.11	0	0	0	0	0
71	0.17	0.14	0	0	0	0
72	5.84	1.25	0	0	0	0.37
74	1.07	0.1	0	0	0	0
80	1.05	0.07	0	0	0	0
85	4.05	0.06	0	0	0	0
90	2.15	21.31	0	8.34	96.86	96.86
92	1.15	0.03	0	0	0	0
93	0.48	0.02	0	0	0	0

Source: authors' calculations using TurkStat's databases. Data have been made confidential for missing two-digit NACE sectors.

according to the Industrial Production Survey scales down export to output shares by 60% (not shown). One possibility which is advanced in the literature for this disparity is misreporting. The misreporting hypothesis was checked

Table 8.8: *Continued.*

NACE Rev. 1.1	Total sector	Average across firms	50th perc.	75th perc.	90th perc.	95th perc.
(b) Only intermediate imports according to the BEC classification						
10	5.23	1.07	0	0	0	0
13	13.71	1.54	0	0	2.47	7.02
14	3.68	0.32	0	0	0	0
15	5.78	0.16	0	0	0	0
16	32.2	13.91	0.59	13.94	61.68	65.26
17	19.66	1.36	0	0	0	3.8
18	9.63	0.47	0	0	0	0
19	14.4	0.77	0	0	0	0.39
20	21.48	0.16	0	0	0	0
21	30.96	3.73	0	0	11.48	33.68
22	5.01	0.12	0	0	0	0
24	42.82	7.89	0	0	35.19	54.9
25	32.72	1.69	0	0	0	2.97
26	11.51	0.65	0	0	0	0
27	50.59	3.97	0	0	6.73	29.02
28	13.57	0.36	0	0	0	0
29	15.32	1.2	0	0	0	3.21
31	29.15	1.5	0	0	0	5.24
32	37.95	5.83	0	1.92	18.00	37.38
33	19.61	2.3	0	0	2.73	12.24
34	42.98	2.18	0	0	2.17	11.25
35	19.61	1.46	0	0	0.57	10.04
36	6.31	0.23	0	0	0	0
40	1.61	2.42	0	0.75	4.01	8.81
45	0.81	0.14	0	0	0	0
50	1.22	0.08	0	0	0	0
51	7.4	1.89	0	0	0	1.24
52	0.33	0.1	0	0	0	0
55	0.22	0	0	0	0	0
60	0.52	0	0	0	0	0
61	0.67	0.14	0	0	0	0
63	0.89	0.04	0	0	0	0
64	0.47	0.05	0	0	0	0
70	0.03	0	0	0	0	0
71	0.05	0.12	0	0	0	0
72	1.48	0.29	0	0	0	0
74	0.76	0.09	0	0	0	0
80	0.17	0.01	0	0	0	0
85	0.37	0.01	0	0	0	0
90	0.92	8.79	0	4.05	40.7	40.7
92	0.6	0.01	0	0	0	0
93	0.08	0	0	0	0	0

Source: authors' calculations using TurkStat's databases. Data have been made confidential for missing two-digit NACE sectors.

by matching customs and product data at a higher level of aggregation at the CPA six-digit level instead of at the PRODCOM ten-digit level. Export shares are scaled down by a smaller amount (40% on average), but there are significant differences across sectors. However, there are substantial discrepancies in the relative sizes of the reduction of export shares within sectors.

8.3 Intermediate Imports Ratio

As discussed above, for the purpose of analysis of the use of imports of intermediate goods, three measures of imports were constructed. However, matching the codes of imported products with those of the products produced by each firm did not reveal significant discrepancies between import shares, both at the sector level and at the firm level. Table 8.8 consequently displays intermediate import ratios according to only two criteria: the first part of the table takes all imports made by firms as imports of intermediate goods used up in the production process, while second part of the table identifies as intermediates only those products which are so identified by the BEC classification. As with export shares, Table 8.8 only reports non-confidential cells.

Table 8.8 shows that, as for exports, the import activity of firms within sectors is strongly heterogeneous, with a small share of firms reporting non-zero imports, regardless of the definition of intermediate imports used. Across sectors, imports tend to be more important in manufacturing sectors (corresponding to NACE codes 15–37).

As for the specific definitions used, as expected, considering all imports as intermediate inputs yields higher intermediate import coefficients, both at the aggregate sector level and in terms of firm-level averages. These discrepancies are, however, higher in terms of total sector averages, particularly in sector 32 (radio, television and communication equipment apparatus), and with the exception of sector 90 (sewage and refuse disposal), where the average across firms is higher than the aggregate sector value.

8.4 Firm Size, Ownership and Value Added

We have further explored within-sector heterogeneity by looking at the distribution of export shares, the intermediate imports ratio and the ratio of value added to output by firm size and ownership status of the firm.[15]

Although disaggregated tables with within-sector decompositions were also produced, the small number of foreign firms and their important role in the Turkish economy made it impossible to disclose cells for a number of sectors. Table 8.9 reports a summary of the results instead.

Of the disaggregated analysis, it is worth highlighting the following.

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[15] The figures in this section refer to import shares calculated only on products classified as intermediates by the BEC classification. However, intermediate imports ratios do not change significantly if all imports are considered. Regarding firm size, values reported refer to employment levels calculated in terms of head counts. Results do not change substantially if head counts are replaced by full-time equivalents.

Table 8.9: *Summary of results.*

Variable	Ownership	
	Domestic	Foreign
Export share (%)	0.34	12.13
imp_all/intermediates (%)	0.45	30.50
imp_bec/intermediates (%)	0.28	19.24

Variable	Firm size			
	0–9	9–49	50–249	250+
Export share (%)	0.22	2.96	5.79	8.96
imp_all/intermediates (%)	0.32	3.19	8.64	15.9
imp_bec/intermediates (%)	0.19	2.08	5.95	11.28

Variable	Export intensity	
	Export intensive	Non-export intensive
Export share (%)	1.77	0.28
imp_all/intermediates (%)	1.53	0.42
imp_bec/intermediates (%)	1.11	0.25

Source: authors' calculations using TurkStat's databases.

- The export share of foreign-owned enterprises is much larger than the export share of purely domestic ones, except in sectors 28 and 29 (fabricated metal products, machinery and equipment); on average, foreign-owned firms account for about 18% of total exports in the economy, but the sector-specific weight of foreign companies is particularly high in the automotive industry, where they account for more than half of exports. A significant share of wholesalers' exports is also made by foreign firms (about 40%).
- Foreign wholesalers are much more import intensive than indigenous wholesalers, which is consistent with the fact that the former are heavily engaged in intra-firm trade.[16]
- Export share increases with firm size, with small firms displaying export values of almost zero and large firms displaying very high export shares.
- The intermediate import ratio also increases with firm size.
- For the few sectors for which it is possible to disaggregate export and import shares simultaneously by size and ownership, foreign firms have higher import and export shares for firms with more than 49 employees.

[16]Indigenous firms are those which are controlled by entities resident in Turkey.

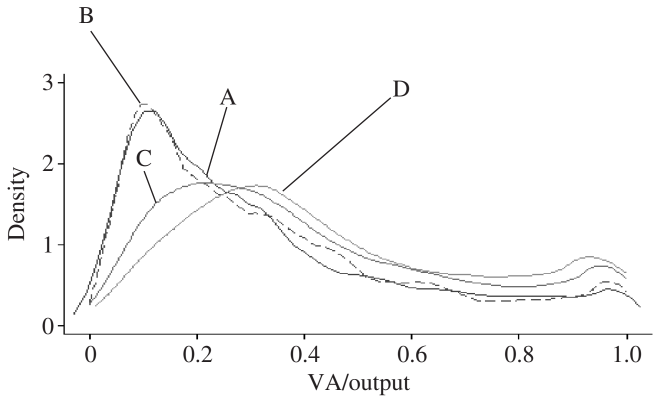

Figure 8.2: *Distribution of value added per unit of output by firm size.*

Source: authors' calculations using TurkStat's databases. Kernel = Epanechnikow. Bandwidth = 0.277. A, 1–9; B, 10–49; C, 50–249; D, 249+.

- Differences in 'import to output' shares are larger than 'for export' shares, which suggests that foreign firms source a higher share of their inputs from abroad, compared with domestic firms. However, the difference is less pronounced for the groups of firms having between 50 and 249 employees.
- Domestic firms exhibit, on average, a ratio of value added to output which is about 90% that of foreign-owned firms. However, there are sectors where the average firm-level value added per unit of output is higher than that of foreign-owned enterprises by a significant amount: 21% in NACE sector 33 (manufacture of medical, precision and optical instruments, watches and clocks), 22% in NACE sector 17 (manufacture of textiles) and 41% in NACE sector 18 (manufacture of wearing apparel). In sectors NACE sectors 29 (manufacture of machinery and equipment, nec) and 34 (motor vehicles) domestic and foreign-owned firms exhibit a similar performance.
- Value added increases with firm size. Figure 8.2 shows the distribution of the value added per unit of output for firms in different size segments. It shows that a randomly drawn medium-sized or large firm (with more than 49 employees) is likely to generate a higher value added per unit of output than micro and small firms (those with up to 49 employees).

The breakdown of the distribution of value added per unit of output between indigenous and foreign firms (Figure 8.3) shows that foreign-owned firms exhibit a higher share along most of the distribution and are more likely than indigenous firms to display a value-added share of output above 80%. It is quite interesting that the distribution for indigenous firms resembles the

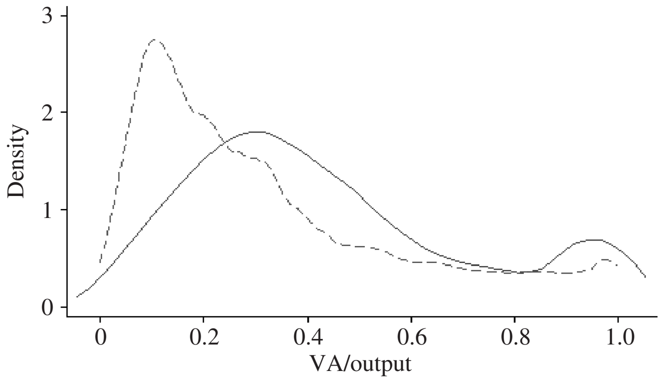

Figure 8.3: *Distribution of value added per unit of output by firm ownership.*

Source: authors' calculations using TurkStat's databases. Kernel = Epanechnikow. Bandwidth = 0.0545. ———, foreign firms; – – – –, domestic firms.

distribution for smaller firms in Figure 8.2, while the foreign firms' distribution mimics that of larger firms.

There are differences at the sector level, however. In NACE sectors 17 (manufacture of textile) and 18 (manufacture of wearing apparel), smaller firms (those with less than 50 employees) have a higher value added per unit of output than medium and large firms (those with 50 or more employees).[17] Within-sector differences in value added per unit of output between foreign and indigenous firms are not as striking as the differences in intermediate import ratios. Indigenous firms account for the majority of value added over sector output in manufacturing, while foreign firms' value added represents an important share of value added in some service sectors, such as in NACE sectors 64 (post and telecommunications), 71 (renting of machinery and equipment) and 72 (computer and related activities).

Disaggregating the ratio of imported inputs over intermediate consumption by firm ownership and firm size reveals that resourcing to foreign inputs dramatically increases with firm size. Table 8.1 shows that there is a positive and highly significant correlation between the ratio of intermediate imports to intermediate consumption and firm size.

When firms are split according to their ownership status and firm export share is plot against its input import intensity (Figure 8.4), the general relationship found in Figure 8.1 is not verified. It is clear from Figure 8.4 that higher export shares in foreign firms correspond to lower import ratios, regardless of the overall higher import and export orientation of foreign firms.

[17] Sector disaggregation is not shown to save space, but it can be provided upon request, within the limits of confidentiality.

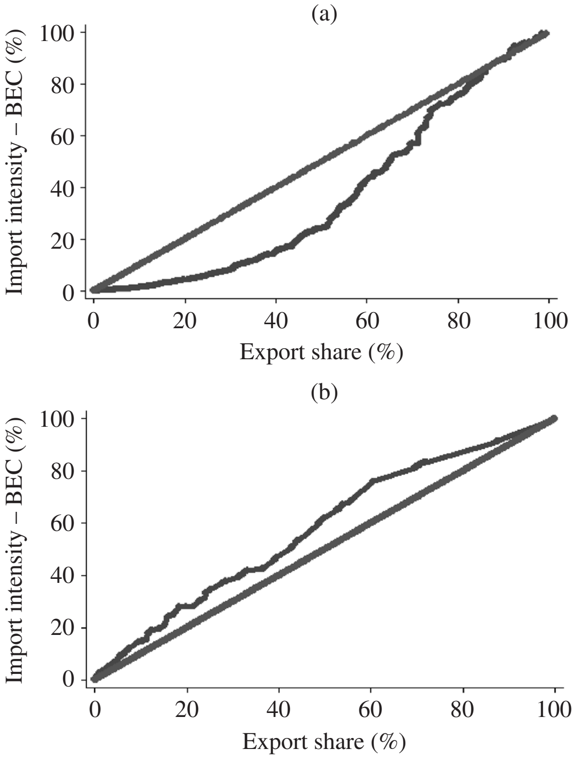

Figure 8.4: *Q–Q plot of intermediate import ratio against export share by firm ownership.*

Source: authors' calculations using TurkStat's databases. (a) Foreign controlled firms; (b) domestic firms.

Finally, Table 8.10 highlights differences in the mean of intermediate import ratios between exporters and non-exporters along firm size class and ownership status: it confirms that the difference in the means of the import ratios between exporters and non exporters are significantly positive and large regardless of the size class or ownership status considered.

REFERENCES

Ahmad, N., and A. Wyckoff (2003). Carbon Dioxide Emissions Embodied in International Trade of Goods. OECD Science, Technology and Industry Working Paper 2003/15. http://dx.doi.org/10.1787/421482436815.

Ahmad, N., H. Escaith, S. Miroudot, C. Webb and N. Yamano (2011). Trade in Value-Added: Concepts, Methodologies and Challenges, OECD/WTO Report.

Table 8.10: *Differences in intermediate import ratios between exporters and non-exporters.*

(a) Total

	Mean	Std. Err.
Exporters	8.10	0.10
Non-exporters	0.18	0.00

(b) By firm size

	0–9		0–49		50–249		249+	
	Mean	Std. err.	Mean	Std. err.	Mean	Std. err.	Mean	Std. err.
Exporters	5.23	0.12	8.61	0.17	14.41	0.32	20.75	0.65
Non-exporters	0.15	0.00	0.95	0.03	1.46	0.09	1.58	0.21

(c) By ownership

	Domestic		Foreign owned	
	Mean	Std. err.	Mean	Std. err.
Exporters	7.65	0.10	28.92	1.08
Non-exporters	0.18	0.00	3.68	0.64

Source: authors' calculations using TurkStat's databases.

Ali-Yrkkö, J., P. Rouvinen, T. Seppälä and P. Ylä-Anttila (2011). Who Captures Value in Global Supply Chains? Case Nokia N95 Smartphone. Discussion Paper 1240. The Research Institute of the Finnish Economy, Helsinki.

Araújo, S., and E. Gonnard (2011). Selling to Foreign Markets: a Portrait of OECD Exporters. *OECD Statistics Brief 16*, February.

Bernard, A., J. B. Jensen, S. Redding and P. K. Schott (2011). The Empirics of Firm Heterogeneity and International Trade. NBER Working Paper 17627.

Crozet, M., G. Lalanne and S. Poncet (2010). Wholesalers in International Trade. CEPII Working Paper 2010-31. CEPII, Paris.

Daudin, G., C. Rifflart and D. Schweisguth (2011). Who Produces for Whom in the World Economy? *Canadian Journal of Economics* **44**(4), 1403–1437.

Escaith, H. and F. Gonguet (2011). International Supply Chains as Real Transmission Channels of Financial Shocks. *Journal of Financial Transformation* **31**, 83–97.

Escaith, H., R. Teh, A. Keck and C. Nee (2011). Japan's Earthquake and Tsunami: International Trade and Global Supply Chain Impacts. VoxEU, April. URL: http://www.voxeu.org/index.php?q=node/6430.

Isakson, H., and E. Wajnblom (2011). Made in Sweden? A New Perspective on the Relationship between Sweden's Exports and Imports. Swedish National Board of Trade, Stockholm.

Johnson R. C., and G. Noguera (2010). Accounting for Intermediates: Production Sharing and Trade in Value-Added, Paper presented at the *World Bank Trade Workshop: The Fragmentation of Global Productions and Trade in Value-Added – Developing New Measures of Cross-Border Trade*, June, Washington, DC.

Jones, R., and H. Kierzkowski (2001). A Framework for Fragmentation. In *Fragmentation: New Production Patterns in the World Economy* (ed. S. Arndt and H. Kierzkowski), pp. 17–34. New York: Oxford University Press.

Koopman R, Z. Wang and S. Wei (2008). How Much of Chinese Exports is Really Made in China? Assessing Foreign and Domestic Value-Added in Gross Exports. Office of Economics Working Paper 2008-03-B. US International Trade Commission, Washington.

Koopman, R., W. Powers, Z. Wang and S.-J. Wei (2011). Give Credit to Where Credit is Due: Tracing Value Added in Global Production Chains. NBER Working Paper 16426.

Lee, H., V. Padmanabhan and S. Whang (1997). The Bullwhip Effect in Supply Chains. *Sloan Management Review* **38**(3), 93–102.

Linden, G., K. L. Kraemer and J. Dedrick (2009). Who Captures Value in a Global Innovation Network? The Case of Apple's iPod'. *Communications of the ACM* **52**(3), 140–144.

Maurer, A. and C. Degain (2010). Globalization and Trade Flows: What You See Is Not What You Get! World Trade Organization Staff Working Paper ERSD-2010-12, Geneva.

Miroudot, S., R. Lanz and A. Ragoussis (2009). Trade in Intermediate Goods and Services, *OECD Trade Policy Papers* **93**. http://dx.doi.org/10.1787/5kmlcxtdlk8r-en.

Newhouse, J. (2007). *Boeing* vs *Airbus, The Inside Story of the Greatest International Competition in Business.* New York: Random House.

Ottaviano, G., and T. Mayer (2008). The Happy Few: The Internationalisation of European Firms. *Intereconomics: Review of European Economic Policy* **43**(3), 135–148.

Tempest, R. (1996). Barbie and the World Economy. *Los Angeles Times*, September 22.

Wang, Z. (2008). Domestic Value-Added in China's Exports and Its Impact on China's National GDP and GNP Accounting, Mimeo.

WTO (2011). World Trade Report 2011: The WTO and Preferential Trade Agreements – From Co-Existence to Coherence. Report. World Trade Organization, Geneva.

WTO and IDE-JETRO (2011). Trade Patterns and Global Value Chains in East Asia. Report. World Trade Organization and Institute of Developing Economies–Japan External Trade Organization, Geneva.

Yi, K. M. (2003). Can Vertical Specialization Explain the Growth of World Trade? *Journal of Political Economy 11*(1), 52–102.

Xing, Y., and N. Detert (2010). How iPhone Widens the US Trade Deficits with PRC. Discussion Paper 10-21, National Graduate Institute for Policy Studies, Tokyo.

Zhu, S., N. Yamano and A. Cimper (2011). Compilation of Bilateral Trade Database by Industry and End-Use Category. Science, Technology and Industry Working Paper 6. OECD, Paris.

9

Developing International Input–Output Databases: IDE-JETRO and OECD Experiences

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1 INTRODUCTION

In response to the recent development of spatial economics ('New Economic Geography'), 'new' new trade theory and global value chains related issues, it is increasingly recognised that the concepts of 'space' and 'networks' play an important role in the analysis of economic development and globalisation. Many policymakers and researchers alike, therefore, have come to pay greater attention to the spatial aspect of the economies nowadays.

In this regard, the international input–output table as an extension of inter-regional or national input–output (IO) techniques has become a significant analytical tool for the issues of current concern. The Institute of Developing Economies (IDE) has for the last 40 years been making many efforts to construct international IO tables in collaboration with the statistical offices and research institutes of East Asian countries. Now, facing the rapid growth of the Chinese economy and the deepening economic interdependency in the Asia-Pacific region, IDE's Asian International Input–Output (AIO) table is an indispensable apparatus for the analysis of Asian economic development from a spatial perspective. On the other hand, the OECD has also been maintaining harmonised non-competitive-type IO tables since the mid-1990s. The latest version of OECD's IO database includes 48 countries/economies (including 33 OECD members) with industry-by-industry tables covering 48 sectors (maximum), based on the ISIC Rev. 3 classification, for the mid-1990s, early 2000 and mid-2000s. Based on this database and additional IO tables for reference years (1995, 2000 and 2005), the OECD has been developing an inter-country input–output (ICIO) model that covers 57 economies and 37 industrial sectors for the reference years.

The remainder of the chapter is structured as follows. The first part (Sections 2–4) introduces estimation methodologies applied at IDE-JETRO to develop international input–output databases. The second part (Sections 5–8) outlines the methods used for developing an OECD ICIO model with the main data sources, *ie* national IO tables and bilateral trade statistics. In both parts, we review the availability of underlying source data, summarise the assumptions made and describe the harmonisation techniques used.

2 HISTORY OF THE ASIAN INTERNATIONAL INPUT–OUTPUT TABLES

2.1 Pioneering Work

Interregional IO models were pioneered by the prominent economists of the time, including Leontief (Leontief 1953; Leontief and Strout 1963), Isard (1951), Chenery (1953) and Moses (1955). The first international IO model was developed in 1961 by R. J. Wonnacott for the Canadian and US economies. At IDE, Watanabe (1964) proposed the idea of using international IO models as analytical tools for the North–South trade issue. In 1965 IDE developed an international IO model covering six regions: North America, Europe, Oceania, Latin America, Asia and Japan. In 1966 and 1971, IDE constructed international IO models for ten Asian countries. Yet the IO tables compiled in these studies were subject to a number of limitations, *eg* estimation techniques were too simple, the industrial sector classification was too crude. These problems notwithstanding, the models were credited with facilitating empirical analyses of structural relationships between developed countries and developing countries.

In addition to such research-oriented projects, IDE's IO tables were also used for evaluating the credibility and preciseness of statistical materials of developing countries. From the basic premise of data coherency between demand and supply sectors, the misspecification of estimates by local statistical agencies can be logically inferred if any deviation or inconsistency is observed in the table. The 'targets' to be scrutinised ranged from production data to consumption data.

2.2 First Phase (1973–77)

In 1973 IDE decided to launch development of a comprehensive international IO table to explore the situation of interindustrial transactions among East Asian countries. The Republic of Korea and the five Association of Southeast Asian Nations (ASEAN) countries plus the USA were chosen to be included, as these countries have close economic relationships with Japan. Had all the countries compiled their national IO tables for the same referential year, the project would not have been so laborious. However, Indonesia, Thailand and Singapore had not constructed any IO tables by that time. Also, IDE was not sufficiently experienced in compiling a comprehensive IO table. Thus, the project had to begin with two preliminaries: one was to construct national IO tables for these three countries; the other was to compile bilateral IO tables for the countries in which the national tables were already available. Under this project, three national IO tables (Indonesia for 1971, Singapore for 1973 and Thailand for 1975) and three bilateral IO tables (Korea–Japan for 1970, USA–Japan for 1970 and Philippines–Japan for 1970) were constructed in collaboration with the national statistical offices and research institutes of the countries concerned.

2.3 Second Phase (1978–82)

In 1978, IDE started the second phase of the IO project, with the aim of constructing the 1975 multilateral IO table for the ASEAN countries, Japan, Korea and the USA. This project proceeded via the following three steps:

1. estimation of national IO tables for the countries that did not have 1975 national tables,
2. construction of 1975 bilateral IO tables for the countries that had already compiled national tables by the time, and
3. construction of the 1975 multilateral IO table.

First, existing tables had to be updated to the year 1975 for Malaysia, the Philippines, Singapore and the USA. Next, the 1975 bilateral IO tables for Indonesia–Japan, for Thailand–Japan, and for Korea–Japan were constructed. Finally, these national and bilateral tables were linked together under a single multilateral IO table for 1975, which was completed in 1983. The 1975 multilateral table was used for various analyses of East Asian industrial structure, and the table became the prototype for the subsequent international IO projects.

2.4 Third Phase (1988–)

After completion of the 1975 international IO tables, IDE soon launched a new project for construction of the 1985 international IO tables, to cover more Asia-Pacific countries. Since China commenced an Open-Door policy as one of its key development strategies it has rapidly increased its external trade with the USA, Japan, and others. China now plays an important role in the Asia-Pacific region, not only in providing a gigantic market but also in receiving investment from the neighbouring countries. Thus, China and Taiwan (Chinese Taipei) were covered in the 1985 multilateral table, making it even more comprehensive than the previous 1975 version. Since then, IDE has successfully completed the multilateral tables every five years, providing powerful analytical tools for dynamic structural changes in the Asia-Pacific region.[1]

[1] The 2005 AIO table and 2005 BRICs international IO table will be released by IDE-JETRO in 2013.

3 COMPILATION PROCEDURE AND METHODOLOGY OF THE ASIAN INTERNATIONAL IO TABLE

Compilation of international IO (IIO) tables is an artistic practice. A number of statistical experts from various countries are involved, exchanging considerable amounts of valuable information and technical expertise.[2]

Roughly speaking, the compilation process goes through three distinctive phases:

1. adjustment of presentation format;
2. preparation of sector concordance and supplementary data;
3. linking and balancing.

What follows is a step-by-step illustration of how the Asian International IO Table is compiled. The first subsection presents a description of the format adjustment for every constituent national table based on the general survey on national tables, which was conducted by IDE in 2003–4 in order to establish a common rule for the format adjustment of the tables. The second subsection briefly explains construction of the system of sector concordance, followed by a brief introduction of estimation methods for supplementary data. Finally, the linking procedure is illustrated, with detailed explanations of the manual balancing/reconciliation work.

3.1 Adjustment of Presentation Format

Despite the fact that IO tables constitute the central apparatus of the System of National Accounts, each national table of an individual country exhibits more or less different features and characteristics, reflecting the country's economic idiosyncrasies and availability of data. Such a variety in form, however, poses a practical difficulty when compiling international IO tables (see Table 9.1), for even though the international table is composed of the segments taken from each national IO table, the interpretation of the data should be mutually consistent and comparable for any part of the whole.

Accordingly, one of the most complicated, nerve-racking tasks of compilation is the adjustment of national tables to conform to a common format. In general, it is the detailed, information-rich table that has to compromise with less-detailed ones, as the other way round would require the costly (yet often unrewarding) effort of obtaining supporting data. Therefore, there always exists a trade-off between the level of uniformity and the level of information, and hence careful and thorough consideration is called for in making adjustment rules.

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[2] IDE's IIO projects involve many participating organisations from different economies. Most of these organisations are governmental or quasi-governmental statistical institutes. More than 70 experts from 10 different economies have contributed to the compilation of the 2000 AIIO table.

Table 9.1: *Different features and characteristics in national IO tables across the AIO target economies.*

	China	Indonesia	Japan	Korea	Malaysia	Taiwan	Philippines	Singapore	Thailand	USA
1. Conversion of valuation										
1.1 Basic price to producer's price								✓		
1.2 Private consumption expenditure					✓			✓		✓
1.3 Export vectors					✓			✓		
1.4 Import matrix/vector			✓	✓			✓		✓	✓
2. Negative entries				✓						
3. Dummy sectors	✓		✓	✓	✓			✓		✓
4. Machine-repair	✓		✓				✓			✓
5. Financial intermediaries			✓		✓			✓	✓	
6. Special treatment of import/export										
6.1 Water transportation										✓
6.2 'Pure import' of gold										✓
6.3 Re-export					✓					
6.4 Telecommunication				✓						
7. Computer software products						✓				
8. Producers of government services									✓	✓

This section reports on the general survey on the characteristic features of national tables of AIO member economies. The survey was conducted in the period 2003–4, in order to construct the basic information reserves for designing the AIO common format and adjustment rules. To our knowledge, such an extensive and detailed survey on national tables has never been carried out, and we believe that no institution but the IDE, with a history of significant cooperative relationships with IO experts of various Asian economies, would be able to make such a substantial survey possible and successful.

Questionnaire and the Survey Result

In the survey, a questionnaire was carefully designed so as to capture every important aspect of an IO table. The questions are grouped under seven broad categories, namely:

1. benchmark year and recording principles;
2. availability of national tables and supporting tables;
3. valuation;
4. form and coverage;
5. special treatment;
6. public/semi-public sectors;
7. response to the 1993 SNA.

Major Findings

Based on the results of general survey, the major findings can be summarised as follows.

Similarity to the Japanese IO table. In Figure 9.1, which is based on the information in Tables 9.2 and 9.3, the degree of similarity to the Japanese IO table is illustrated. The horizontal axis is the level (number) of industrial classification, while the vertical axis is concerned with presentation format, giving the percentage rates of the number of questions in the questionnaire to which the country gave the same answers as Japan's. (The rates are calculated against the sum of valid answers only.) The diagram shows that the most similar table of all is the Korean IO table (the first group), as its industrial classification has just one sector difference with that of the Japanese table, and the rate of the same answer is more than 70%.

Then, we can identify the second group, including Indonesia, the Philippines, Thailand and Malaysia. Not to mention about the Korean table, it is no wonder that these tables (except Malaysia) show a high degree of similarity to the Japanese table, since their national IO projects are known to have been initiated and conducted under the advice and support of Japanese IO experts.

The US table is indicated as having some degree of similarity, but in the survey result it is observed that many answers remain 'unknown', so that no

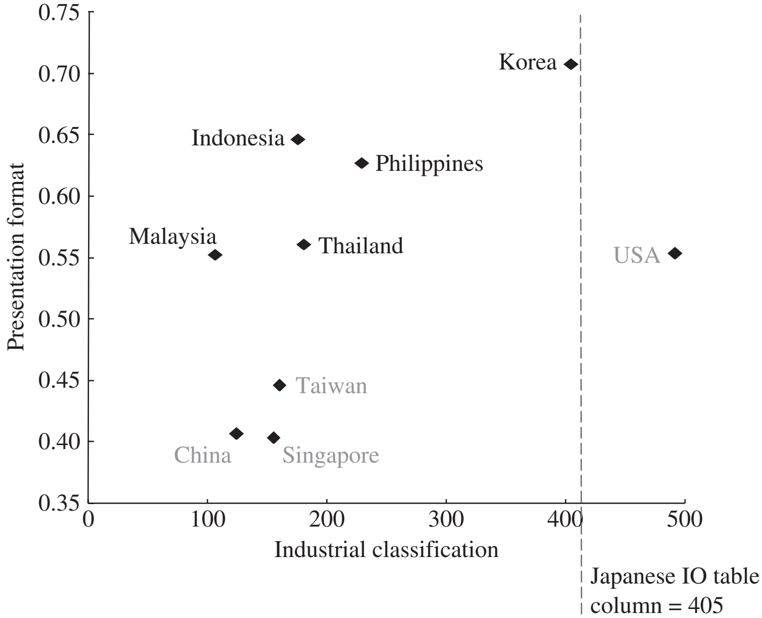


Figure 9.1: *Similarity to the Japanese IO table.*

Table 9.2: *Similarity in the presentation format.*

Rank	Country	Rate*	Classification
1	Korea	0.7077	404
2	Indonesia	0.6462	175
3	Philippines	0.6269	229
4	Thailand	0.5606	180
5	USA	0.5536	491
6	Malaysia	0.5522	106
7	Taiwan	0.4462	160
8	China	0.4063	124
9	Singapore	0.4032	155

*The percentage rates of the number of questions in the questionnaire to which the country gave the same answers as Japan's.

conclusive evaluation can be made against this table (although it is true that the classification difference is the second smallest after the Korean table).

The third group, which is least similar to the Japanese table, includes Taiwan (Chinese Taipei), Singapore and China. In addition to the dissimilarity of the format and of the level of industrial classification, the benchmark years of these national tables differ from that of Japan, *ie* with '0' or '5' in the last digit

Table 9.3: *Similarity in the industrial classification number.*

Rank	Country	Difference in the number of industrial sectors	Classification
1	Korea	1	404
2	USA	86	491
3	Philippines	176	229
4	Thailand	225	180
5	Indonesia	230	175
6	Taiwan	245	160
7	Singapore	250	155
8	China	281	124
9	Malaysia	299	106

Table 9.4: *Responsiveness to the 1993 SNA.*

Rank	Country	Rate*
1	Philippines	0.5714
1	USA	0.5714
3	Thailand	0.5385
4	Korea	0.5000
4	Japan	0.5000
6	Singapore	0.4545
7	Indonesia	0.4286
7	Malaysia	0.4286
9	China	0.3077
10	Taiwan	0.2143

*The percentage rates of the number of questions in Section 7 of the questionnaire to which the country gave the answer that follows the SNA recommendation.

of the year. So the official tables had to be updated to the year 2000 with the help of some estimation methods, such as the RAS algorithm, which further decreased the accuracy of the tables. The same is true for the national table of the USA.

The responsiveness to the 1993 SNA. The System of National Accounts is a comprehensive guideline for compiling national statistical data. If properly followed, the resulting statistics will be mutually consistent and internationally comparable. The latest version of the SNA, the 1993 SNA, underwent an extensive revision of its predecessor, the 1968 SNA, to bring the statistical notions and methods up to date. IO tables (or, more precisely, supply and use tables), which constitute a core apparatus of the system, did not remain unaffected, and many countries, including our project partners, have made every effort to make their tables accordant to the new scheme.

The survey result (Table 9.4) shows that the most 'responsive' countries are the Philippines and the USA. Yet again one must be careful about the result on the US table as it contains a number of 'unknowns'. The Thai IO table comes next, followed by the Korean and Japanese tables. Although the Korean table and Japanese table ranked the same, the former can be evaluated higher, as it had already succeeded in introducing one of the most challenging schemes in the 1993 SNA, *ie* the Financial Intermediary Services Indirectly Measured (FISIM). On the other hand, it is rather surprising to observe that Singapore and Malaysia had low rankings, as these national tables are known to have followed the previous, 1967 SNA schemes quite extensively.

The areas of conflict. Finally, we briefly examine the areas of conflict, where each country's treatment is not in line. The most prominent example is the treatment of scraps and by-products. There are normally four adjustment methods for this problem. Each of them has both advantages and disadvantages, and the member countries employed the various schemes in quite an uncoordinated fashion. In the absence of supplementary information on the generation and use of scraps/by-products, it is not possible to convert from one scheme to another, making it difficult to reach a common agreement on the adjustment method.

The second area of conflict is about the treatment of imputed interest. The previous 1968 SNA recommended that the output of imputed interests (= the difference between the interests receivable and the interests payable) should all go to intermediate transaction, not to final demand. The countries like Japan, Singapore and Malaysia strictly follow this stipulation, while other countries' tables have output in final demand as well. The introduction of FISIM under the 1993 SNA may provide an integrated guideline for this issue, but so far no member country except Korea is successful in introducing this new scheme.

The last prominent area of conflict is the treatment of inventory. The related question in the questionnaire is:

> Suppose that a car industry (demand-side sector) purchased a set of tyres (supply-side sector) but did not use them this time. How does this input enter in the table?

Most of the countries answered that the input should be recorded at the intersection between 'tyre' (supply-side) industry and 'change in stocks', but some countries like China, Taiwan (Chinese Taipei) and Singapore answered the opposite, *ie* at the intersection between 'tyre' (supply-side) industry and 'car' (demand-side) industry. Singapore gave an explanatory comment on this. It treated this input as a stock of car since 'tyres are regarded as a ⟨work-in-progress⟩ of a car'. It is quite surprising to find out that even the very basic economic concept like an 'inventory' in fact yields different interpretations among countries.

3.2 Preparation of Sector-Concordance and Supplementary Data

The Table of Industrial Sector Concordance

Each national table has its own industrial classification. In the case of the benchmark tables for the 2000 AIO table, the number of industrial sectors ranges from 98 for the Malaysian table to 517 (row) for the Japanese table. The weight of the industrial category also differs. The countries with large agro-based economies have relatively detailed classification of agricultural sectors, while industrialised economies give more comprehensive coverage to manufacturing sectors. Thus, the sector classification reflects the characteristics of the economy concerned, and a precise conversion system that bridges national codes and AIO codes is absolutely essential for the compilation of consistent international IO tables.

The system of sector concordance has a treelike image, where AIO classification (the broadest category) rests on the top, and each AIO code corresponds to one or several national codes. The national codes are subclassified into the Harmonized System of Foreign Trade Statistics (HS), which may be further converted to SITC, another classification system for the trade data.

If the concordance system has such a clear-cut tree structure, the aggregation of national tables into AIO classification poses no difficulty. The problem arises when a national code is associated with more than two AIO codes. For example, Singapore's national code SIO092 'Land transport equipment' corresponds to both AIO055 'Motor vehicles' and AIO056 'Motorcycles'. Here, the sector splitting of the national IO table is called for before the aggregation procedure.

Supplementary Data

For the compilation of international tables, the following supplementary data should be prepared by each country at AIO sector classification:

1. import data by commodity and by 11 countries of origin;[3]
2. export data by commodity and by 11 countries of destination;
3. import duties and import commodity taxes by commodity;
4. domestic trade and transportation margins (TTM) and domestic freight transport costs on exported goods by commodity;
5. international freight and insurance, by commodity and by 11 countries of origin;
6. other relevant information, such as the distribution ratios of imported goods.

[3]The 11 countries are the project member countries plus Hong Kong, EU, the Rest of the World.

The import and export data can be directly constructed from the Foreign Trade Statistics, with the help of the HS (or SITC)–national IO–AIO sector concordance. The data on import duties and import commodity taxes, on the other hand, are independently presented in the original national IO tables in most cases, but if not (as in the case of the US table), they must be also collected from the Foreign Trade Statistics.

The data of TTM on export comes from the supporting tables of the national IO tables. Ideally, those levied on exported goods (for the delivery from factories to ports) should be used, but if they are not available from the table the average figures of the TTM matrices can be used as proxies.

Finally, the data on international freight and insurance are collected from the Foreign Trade Statistics, where available. Yet, because not all countries have these data, it is necessary to apply some estimation methods to make up for the missing information. As illustrated below, this is done in two steps: the first step is to obtain the parameter values by creating transport-cost equations for each AIO sector, using the available data; the second step is to project the missing values based on the parameter estimates.

In most of the empirical literature on international trade that uses gravity equations, it is a common exercise to use the distance between countries as a proxy for transport costs, owing to the limited availability of direct transport-cost data (see, for example, Anderson 1979). This treatment assumes that the transport cost is a function of geographic distance:

$$C_{ijk} = f(D_{ij}) \tag{9.1}$$

represents transport costs for country i's imports from country for sector k, and D_{ij} is the distance between them. The rationale for using distance is that, for a given mode of transport, the greater the distance, the more time and energy are consumed, and hence the transport cost rises. Based on this convention, the following simple variation of transport-cost equations is created:[4]

$$C_{ijk} = \alpha_k + \beta_k D_{ij} + \varepsilon_{ijk}. \tag{9.2}$$

The data for international freight and insurance rates (C_{ijk}) are available for nine countries (China, Indonesia, Japan, Korea, Malaysia, the Philippines, Singapore, Thailand and the USA), but the quality of data varies across countries, and data for many transactions are missing. For Taiwan (Chinese Taipei), no information on international shipping costs is available.

As the distance variable (D_{ij}), two measures of distance are calculated, *ie* the shipping-route distance and the straight-line distance. The shipping-route distance is taken from Japan Shipping Exchange (1983), in which the distances

[4]Several studies have investigated the appropriateness of the relationship between transport costs and the distance (see Geraci and Prewo 1977; Limao and Venables 2001). However, in our estimation only distance was used as the explanatory variable, owing to data constraints.

between major ports are reported. The straight-line distance, which can be regarded as an analogue of the air-flight distance, is calculated between commercial centres of the countries concerned. Of these two measures, the one that better explains variation in the international freight and insurance rates is employed for projection.

By running regressions of Equation (9.2), the parameter estimates $\hat{\alpha}_k$ and $\hat{\beta}_k$ for each AIO sector are obtained. In cases in which the estimates for β_k are negative, they are replaced by estimates obtained from regressions in more aggregated classifications, *ie* twenty-four sectors or seven sectors. If the estimates in aggregated classifications are still negative, positive estimates for related industries are used for projection (*eg* estimates for 050 'Electronic computing equipment' are used in lieu of those for 051 'Semiconductors and integrated circuits').

Using the parameter estimates $\hat{\alpha}_k$ and $\hat{\beta}_k$, projection of the missing values for international freight and insurance rates (C_{ijk}) can be done by stacking the distance measures between countries concerned (D_{ij}) into the transport-cost equation:

$$\hat{C}_{ijk} = \hat{\alpha}_k + \hat{\beta}_k D_{ij}. \tag{9.3}$$

In addition, the quality of import matrices plays a critical role in determining the accuracy of the international IO table. In order to increase the accuracy of import matrices, a special survey on imported commodities have been done in the current AIO project.

The main purposes of the survey are:

1. to identify using industries of the imported commodities by country of origin;
2. to determine the value/rate of the international freight and insurance on each imported commodity;
3. to determine the value/rate of import duties and commodity taxes levied on each import commodity.

The respondents of the survey will be the establishments that import the commodities (manufacturers, trading firms, *etc*), as they are considered to possess the information on amount imported by country of origin and their distribution amount to domestic industries.

The survey is basically carried out as an independent sample survey. Alternatively, it may be conducted as a rider survey attached to other official surveys (which is more efficient and comprehensive). (The sample form of the questionnaire in order to collect the information described above is presented in Figure 9.2).

Several problems arise in carrying out the special survey described above.

First is the feasibility of the survey. It is difficult for some countries to conduct the survey, owing to lack of resources (funds, personnel, connections with related authorities and firms, knowledge, *etc*). For countries where the

Commodity		Code of Origin Country	C.I.F. Import Value (Unit Pesos)	Duties & Import Commodity Taxes (Unit: Pesos)	International Freight and Insurance (Unit: Pesos)	Distribution of C.I.F. Import Value (Using Sector / Destination)		
Description	SITC Code					I-O Code	Value (Unit Pesos)	Share (%)
rice	042	1	26	5	7	022	1	3.85
						023	2	7.69
						HH	23	88.46
meat (dried, salted or smoked)	012	1	203,991	1,563	5,893	019	94,737	46.44
						020	3,586	1.76
						021	5,881	2.88
						063	3,712	1.82
						HH	84,262	42.29
						OH	9,813	4.81

The total of distribution value should be the same as the import value	The total of the percentage share should be 100%

Figure 9.2: *Sample format of questionnaire.*

Source: IDE (2008).

survey is infeasible, alternative solutions should be sought. One possible alternative is to modify the import matrices by referring to other countries' survey results.

Second is the sampling issue. Even if the survey can be carried out, it is not easy to collect reliable information. For instance, the samples should be selected in order to represent the characteristics of the industry appropriately. However, identifying the typical samples that appropriately reflect the distribution structures is not easy.

Third, it may also be difficult to determine the distribution structure, even if samples are chosen appropriately. This problem has two different aspects. The first is the difficulty of determining the final users of imported commodities by country of origin. As discussed above, the imported commodities are usually delivered to the final users through wholesale and retail agents. The respondent to the questionnaire, the importing firm, may not have information on the final users if they sold their imports to domestic wholesalers or retailers. The second aspect of the problem is that it may be difficult to determine the amount of each imported commodity sold, even though the final users can be identified. This may occur if the survey year is different from the reference year, or the respondent may not be able to trace the transaction records, as they may not keep detailed information.

3.3 Linking and Balancing

An international IO table is not just a patchwork of the pieces taken from national tables, but a product of careful utilisation of supplementary data and manual reconciliation/fine-tuning. This section gives a brief description of the linking and balancing work for compiling the AIO table.

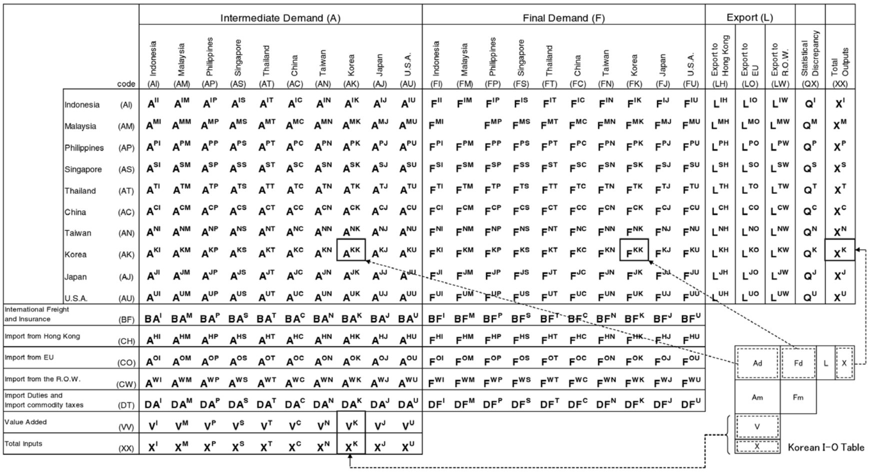


Figure 9.3: *Layout of the AIO table.*

Step 1: So far, all the parts except the highlighted segments have been prepared and are ready for linking. The remaining parts are in fact directly transplanted from the corresponding parts of national tables, after due aggregation into AIO classification. The diagram shows an example of Korea's case, with arrows indicating the parts' correspondence between the AIO table and the Korean IO table. All the other member countries should be treated similarly. Step 2: After linking, all the row-wise statistical discrepancies due to the difference in data sources are dumped into a single column vector, QX. (Note that the export vectors to the member countries are *not* used in the end, to avoid double counting with the corresponding import matrices.)

Linking of National Tables

All the parts of each member country prepared in the previous steps are linked together in one big table, as shown in Figure 9.3. Figure 9.4 illustrates the process of linking. In this example, the linking of IO tables for countries 1 and 2 is illustrated. As shown in this example, the basic idea of linking is to replace the export vector by the import matrix of the trading partner. At this stage, the valuation of imports in each country's national IO table is also converted from the cost, insurance and freight (CIF) price to the producer's price by using the data of international freight and insurance, and domestic transport costs and trade margins compiled in the previous steps.

Reconciliation of Data

The final step of compilation is the manual balancing and reconciliation work, following the linking of all the parts provided so far. The table is balanced with respect to the input composition, but total demand is not necessarily consistent with total supply for each country at this stage. Such an imbalance stems from the following facts.

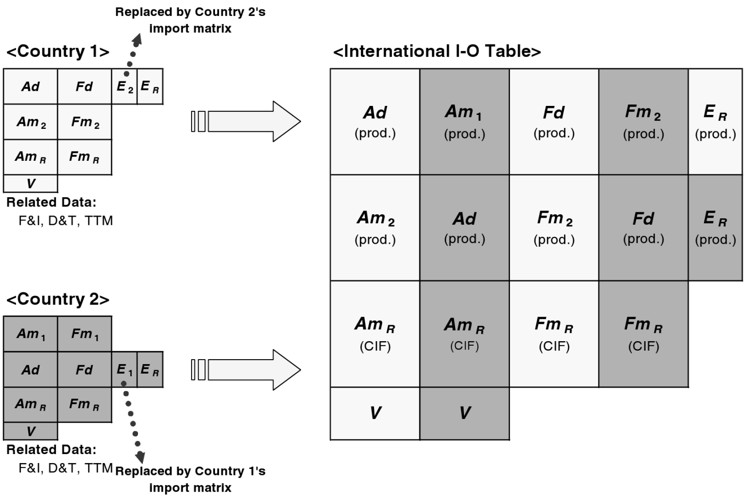


Figure 9.4: *Linking of national IO tables (two-country case).*

Source: IDE (2011).

Here, let us consider the case of Korea. As explained in the previous section, the blocks A^{KK}, F^{KK} and L^{KZ} $(Z = H, O, W)$ in Figure 9.3 are calculated from Korea's input–output table, and they should conform to the transactions recorded in the Korean input–output table. However, the other blocks, A^{KZ} and F^{KK} $(Z \neq K)$, are estimated from the import matrices of other countries, and there is no guarantee that they will be consistent with Korea's export figures. For example, for the blocks A^{KM} and F^{KM}, at which Korea's rows and Malaysia's columns intersect, if the export and import data are to be consistent, the following equation must hold true:

$$D_i^{KM} = \left(\sum_j A_{ij}^{KM} + \sum_k F_{ik}^{KM}\right) - L_i^{KM} = 0, \tag{9.4}$$

where D_i^{KM} represents the difference between Malaysia's import data and Korea's export data for the ith industry, the subscripts j and k respectively denote the jth industry and kth final demand, and L_i^{KM} represents the exports of Korea's ith industry to Malaysia (expressed in producer's prices). In practice, whether or not Equation (9.4) holds true depends on the reliability of the international trade statistics for the two countries and the difference between the import and export figures in the national IO table and international trade statistics. As stated above, the results of our linking work show that $D_i^{KM} \neq 0$. Of course, the same imbalance occurs with all the other member countries of the project. Therefore, we consider that D_i^{KM} denotes the discrepancies in international trade statistics of the two countries, as well as to include the margins of error in estimating blocks A^{KM} and F^{KM}.

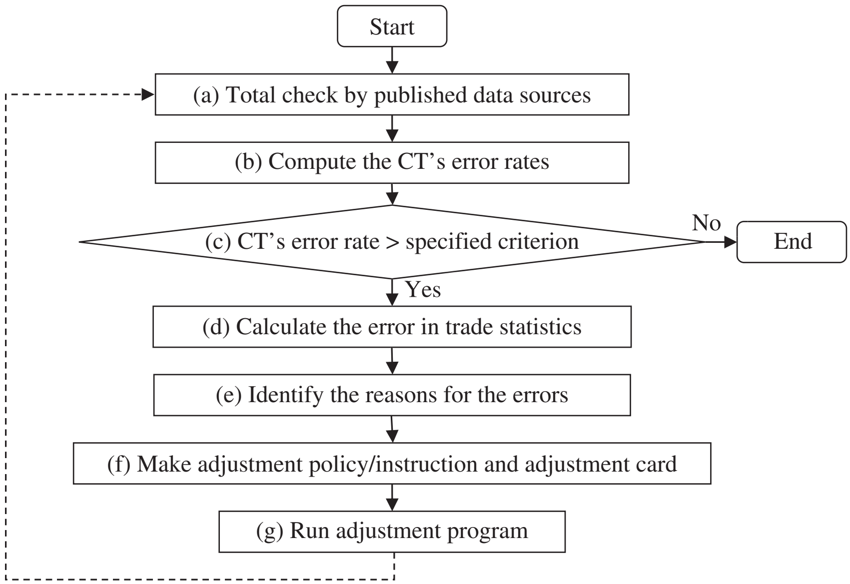


Figure 9.5: *Adjustment procedure.*

Source: IDE (2006). CT: the figure of output by sector is used as the Control Total in our adjustment procedure.

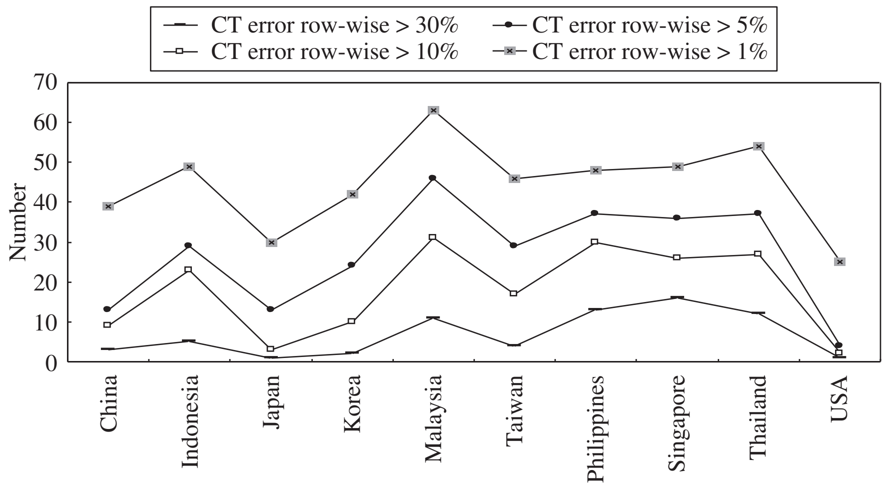


Figure 9.6: *Distribution of CT error.*

Source: IDE (2006).

In order to rationally and efficiently decrease the discrepancies generated through the linking process, the procedure shown in Figure 9.5 is employed in final reconciliation of the AIO table.

(a) Initially, we use the linking results to summarise the transactions among the industries of all countries and compile an AIO table that there is only one sector per country. Then it becomes easy to check whether or not the present data in the AIO table at the national level are consistent with the published data sources, such as the GDP statistics for the country, or the IMF statistics. Through the above checking, we gain knowledge of the preliminary linking results.

(b) For determining the size of the final adjustment in detail, we calculate the error rates of CT row-wise by sector for each country. Figure 9.6 shows the distribution of the summarised absolute CT error rates for different levels. The vertical axis represents the number of sectors in which CT errors are larger than the specified levels. Obviously, China, Japan and the USA. have relatively smaller numbers, which are counted in each level. On the other hand, Indonesia, Malaysia, the Philippines, Singapore and Thailand have relatively larger numbers. Korea and Taiwan (Chinese Taipei) exhibit a similar pattern. The distribution shown in Figure 9.6 not only depends on the economic scale but also relates to the statistic system of each country. Considering the large scale of the AIO table and the distribution pattern of error rates, any sector that has a CT error rate over 5% is determined as a target for preliminary adjustment.

(c) Though 5% is determined as the criterion for the preliminary adjustment, considering that positive errors may offset some negative errors in the row sector, we have to investigate the structure of the error row-wise. As stated in the previous section, the AIO table is based on the import matrices for each country, and the matrices conform to import statistics, but the export statistics are not necessary consistent. In order to discuss the structure of the error in detail, for example, in the case of Korea, we calculate the matrix

$$D_i^{KM} = \left(\sum_j A_{ij}^{KZ} + \sum_k F_{ik}^{KZ} \right) - L_i^{KZ},$$

which represents the difference between country Z's imports from Korea and Korea's exports to country Z for the ith industry. If one refers to this matrix, the structure of Korea's CT error row-wise becomes easy to understand, and it offers us information about which sectors and which countries should be the main targets for adjustment.

(d) The discrepancy is mainly caused by the following three factors.

(i) The inconsistency between each country's sector classifications: though each country is required to make its own code concordance from HS code to AIO sector classification, the possibility of differences in statistical concept still exists.

(ii) Entrepôt trade is counted in different ways by the trade partners. For example, in the case of China, export via Hong Kong to the USA may be counted by the USA as import from China. In the case of Singapore, where international trade is extremely large compared with the scale of its economy, and there is a large volume of entrepôt trade, there are especially large statistical discrepancies in its international trade matrices.

(iii) Other statistical reasons.

(e) According to the analysis of 'matrix *D*' introduced above and careful investigation of the HS–AIO code concordance, most errors can be specified. Then the adjustment policy will be determined. In our project, since the portion for each country has a professional in charge, that person will give instructions to other staff based on the adjustment policy. Then the staff member who is in charge of a country will aggregate all the instructions coming from those who are in charge of other countries into the adjustment card for his or her country.

(f) The adjustment cards are used as input files in the adjustment program. Basically, the adjustment is merely executed on the import matrices, and it moves the same amount vertically from one sector to another. This means that CT balance will be maintained columnwise.[5]

The above procedure (a)–(f) will be repeated until the results satisfy the specified criteria. Additionally, a spot check is conducted at the end of the adjustment. This is to 'spot out' any unnatural entries in the table that might have been brought in during the course of the adjustment. For example, the output of 'Electricity, Gas and Water Supply' or other service sector is not supposed to enter any cells along 'Fixed Capital Formation' or 'Change in Stocks'. Any of such mistabulation should be cleared and dealt with properly.

It is extremely rare for the international trade statistics of different countries to be consistent with one another. There are usually rather large gaps and errors. While a number of existing studies have analysed the extent and nature of this problem, a standardised methodology for reconciling the international trade statistics of various countries has not yet been established. Even though in our project we require each country to make a code concordance between the AIO's sector classification and HS code, it is extremely difficult to eliminate the discrepancies completely, because of the large number of codes involved and differences among statistical systems from one country to another.

[5]Basically, the remaining CT error row-wise will be moved to the vector QX (Statistical Discrepancy).

4 FUTURE CHALLENGES FOR THE ASIAN INTERNATIONAL IO TABLES PROJECT

Given the increasing economic interdependence between countries caused by the extension of globalisation and regional integration, international IO tables are considered a very useful data source for the analyses of production networks, international fragmentation production, global value chains and so on. In response to the increasing attention and requirements from many policymakers and researchers, there are a lot of challenges ahead for the project.

Changes to this paragraph and section heading OK?

The first challenge is about the time lag of publication. IDE compiles the AIO tables every five years. However, there is always more than five-year time lag between the benchmark year and reference year. Since most countries construct their national IO table every five years, and also the benchmark years across countries are different, this makes it difficult to speed up the process of linking every country's data together in time. If the statistic system in many more Asian countries can switch to or follow the Supply and Use Tables (SUTs), national IO tables can be estimated easily. This will help the compilation of international IO table to become speedy.[6]

The second challenge is about how to minimise the discrepancy arising from the linking process. As mentioned in the previous sections, the most important reasons for the discrepancy are

1. the inconsistency of export/import figures between national IO table and international trade statistics,
2. the mirror problem in bilateral trade statistics caused by the treatment re-export and reimport,
3. the different treatment of valuation between export statistics (free on board, FOB) and import statistics (CIF).

One possible solution to the above problems is to apply the recent UN Broad Economic Categories (BEC) classification to the current trade statistics. Under this classification, trade data can be grouped into different end-use categories, such as intermediate goods, final consumption goods, capital goods. This can improve the precision of allocating bilateral trade data when linking the national IO tables. In addition, according to the new recommendations for International Merchandise Trade Statistics (IMTS) proposed by the United Nations Statistics Division (UNSD), import figures on the FOB basis in addition to the standard CIF valuation are expected to be published in the near future. This may help us make bilateral trade data much more consistent. Finally, the re-export statistics by country of origin and destination should play an important role in solving the mirror problem that occurs in trade statistics.

[6]For example, in recent years, many more Asian economies have been considering establishing or improving their SUT systems under an international joint project supported by Asian Development Bank (ADB); see http://www.adb.org/data/icp/reta-6483-activities.

The third challenge is about the valuation. The AIO tables are in producers' prices. There is no doubt that the most preferable valuation concerning the requirement of economic analysis is basic price. However, even at present, most of our target countries construct their national IO tables in producers' prices.

In the second part of the chapter we examine the OECD Inter-Country IO Model.

5 INTRODUCTION TO THE OECD INTER-COUNTRY IO MODEL

The OECD has been updating and maintaining harmonised IO tables, splitting intermediate flows into tables of domestic origin and imports, since the mid-1990s, usually following the rhythm of national releases of benchmark IO tables from the national statistical institutes. This harmonised data set has been used for our various country comparative analyses, such as measurement of global value chains, vertical specialisation and carbon dioxide emissions embodied in international trade.

As countries have increased dependencies on external markets both for inputs (imports of intermediates and final expenditure goods) and outputs (exports), the limitations of single-country-based analytical frameworks have become apparent, *ie* international feedback and spillover effects are no longer negligible. As outlined in the previous section, the international IO framework is an ideal tool for linking national production chains. However, the development of inter-country IO models requires a number of very data intensive steps. Notably, it requires internationally harmonised sources of industry statistics for measuring inter-country economic spillovers. Therefore, maximum statistical cooperation across national statistical institutes is very important in pursuing this avenue of research.[7]

6 PROCEDURES FOR DEVELOPING AN INTER-COUNTRY IO (ICIO) MODEL

The estimation procedures of an OECD ICIO model are summarised as follows.

(a) Preparation of inter-industry tables for reference years using the latest published data sources, *eg* symmetric IO tables, supply and use tables, other System of National Accounts (SNA) sources and international trade statistics. The OECD ICIO explicitly includes the economic structures of the rest of the world as one endogenous economy in order to *close* the world economy (See Figure 9.7). The initial input coefficient of the rest of the world economy is based on a proxy country's structure (Indonesia).

[7] See, for example, the World Input–Output Database (http://www.wiod.org/), the EU-KLEMS accounts (http://www.euklems.org/) and IDE-JETRO AIO Project (http://www.ide.go.jp/).

		Intermediate						Final expenditure																		Output
		Cntry 1	Cntry 1	Cntry 2	Cntry 2	RoW	RoW	Household consumption			Household consumption			NPISH			Government expenditure			Gross fixed capital formation			Changes in inventories			
		Ind A	Ind B	Ind A	Ind B	Ind A	Ind B	Cntry 1	Cntry 2	Row	Cntry 1	Cntry 2	Row	Cntry 1	Cntry 2	Row	Cntry 1	Cntry 2	Row	Cntry 1	Cntry 2	Row	Cntry 1	Cntry 2	Row	
Country 1	Industry A																									
Country 1	Industry B																									
Country 2	Industry A																									
Country 2	Industry B																									
Rest of the world	Industry A																									
Rest of the world	Industry B																									
OTHER ADJUSTMENTS(Purchases on the domestic territory by																										
Non comparable imports(cif/fob adj, Direct purchases abroad by																										
International trade margin																										
Intermediate total (basic price																										
Net taxes on products																										
Total																										
Value Added																										
Gross Operating Surplus (=net Oper.Surp+ depreciation of fixed capital)																										
Compensation of Employees																										
Net taxes on production																										
Industry Output																										

Example of 3 regions (2 countries and one Rest of the world) and 2 industris (A and B)
Shaded cells are for domestic transactions

Figure 9.7: *Format of an OECD inter-country input–output model.*

(b) Preparation of bilateral merchandise trade data by industry and end-use categories for reference years, which requires aggregation of published trade statistics from product classifications to industries and end-use categories via standard conversion keys. The import flows are primarily chosen because the export flows are more biased by the issues of re-exports. In principle, import flows record the country of origin as partner, while the export flows record the country of next consignment as partner. These are further adjusted for *analytical* purposes to deal with confidential trade flows, trade in waste and scrap products and movements of high volumes of valuable goods, *eg* diamonds.

Trade coefficients of utility services are estimated based on cross-border gas and electricity transmissions.

Other trade coefficients of service sectors are based on OECD's Trade in Services by Partner Country (TISP), Eurostat's Balance of Payments (EBOPS) and UN Service Trade statistics. The categories of services are classified by EBOPS are converted to industry classifications (ISIC Rev. 3) based on the recommendation in the IMF's Balance of Payment Manual (BPM5). However, many missing flows need to be estimated using econometric modelling techniques, in particular for years before 2000. The estimation steps are summarised as follows (Benz and Miroudot 2012):

- collection of data sources;
- estimation of predicted zero flows based on gravity model with multilateral resistance (Anderson–van Wincoop model) by Poisson maximum likelihood estimation;
- estimated bilateral flows are finally adjusted to balance the trade coefficients with those consistent with the trade columns of IO tables.

(c) Conversion of merchandise import figures from a CIF valuation to an FOB valuation to minimise 'mirror trade' inconsistencies (import = export) in the international IO system, *ie* minimise differences between reported imports by A from B and reported exports by B to A.

Table 9.5: *Data sources for OECD inter-country IO model.*

· National IO tables
· Bilateral merchandise trade in goods statistics (OECD's ITCS and UN's Comtrade databases)
· National Supply–Use Tables (if necessary)
· Balance of Payments. Trade in Services by EBOPS categories
· National Accounts (SNA93) time series (for output and value added by industry and expenditures by sector)
· Electricity transmissions across countries
· Transport network information on freight shipment (road and maritime distances, *etc*)

(d) Separation of import matrices for each country by *cleaned* trade coefficients.

(e) Total adjustments for the remaining discrepancies. It is preferable to prepare as many of the above data sources as possible to minimise the discrepancy between columns and rows of ICIO system, *ie* increase country coverage and estimate trade coefficients for all industries by end-use categories. However, this statistical approach cannot fully solve the issues of discrepancies generated in international transactions due to, for example,

- inconsistent notions of IO's trade based on the concept of Balance of Payment and merchandise trade statistics based on customs data,
- assumptions of the proportionality between sourcing partner shares and intermediate goods and services for all industries in each country; this hypothesis, known as multiregional input–output (MRIO) framework, is widely used to develop various inter-regional models because it is impossible to pursue the 'alternative' approach, which is to perform special surveys of all target industries in order to gain the information on origin country of intermediate supplies.

Thus, the rest of the world discrepancies are treated using the mechanical biproportional method at the final stage.

(f) Merge the inter-country database with regional blocs (optional).

7 OECD DATA SOURCES USED FOR ICIO MODEL

The first version of OECD's ICIO database is based on methodologies previously established for interregional analyses (see, for example, Chenery 1953;

Available data sources	Symmetric I-O (i x i) e.g. Canada and Denmark	Supply (or make) and Use (or input) tables e.g. United States (non-benchmark)	Symmetric I-O (p x p) and Supply (make) – Use tables e.g. Many European countries
Confidential values	If necessary (fill the missing cells by biproportional method)		
Convert to basic prices	If necessary (estimating tax and transport margins information)		
Separate domestic and import matrices	If necessary (straight forward proportional, BEC based intermediate, household consumption and capital		
Convert SUT to Symmetric		Using fixed product sales structures	
Sector concordance	Preparation of sector concordance table between ISIC Rev.3 and national system		
Sector aggregate	Sector aggregate to OECD harmonized sector level		

Figure 9.8: *Estimation procedures for harmonised format IO.*
i × i, industry by industry. p × p, product by product.

Moses 1955; Isard 1951). To link national IO tables by bilateral trade coefficients, we have compiled national data and carried out estimations to produce harmonised intermediary databases such as harmonised IO tables and bilateral trade in goods data by industry and end-use (Table 9.5).

OECD Input–Output Database

Ideally, national authorities would provide the latest Supply–Use Tables and benchmark symmetric input–output tables (SIOTs) at the most detailed level of economic activity possible, with a basic price valuation and, preferably, separated into domestically produced and imported intermediate goods and services. However, few countries can meet such requirements. Therefore, in order to maximise country coverage, all relevant *partial* data is used. It should be noted that one of the main reasons that IO analysis has benefited from renewed attention in recent years is the improved availability and quality of IO tables and related statistics from national sources.

Compilation methodology. The process of compiling OECD's IO database greatly depends on cooperation with national statistical institutes. Methods used for transformation to the harmonised industry-by-industry tables depend on national data availability. Some countries have been able to provide symmetric industry-by-industry IO tables at basic prices in ISIC Rev. 3 based classification, whereas others have only been able to provide supply and use tables and symmetric product-by-product IO tables.

An industry-by-industry format is chosen for various reasons (Yamano and Ahmad 2006).

- To contribute to harmonised industry analysis with other industry-based data collections, *eg* OECD STAN, labour statistics, and Research & Development expenditures.
- Policy focus: many OECD databases are fundamentally concerned with industrial structures.
- Simplicity of the conversion techniques: assuming a fixed product sale structure, no negative numbers appear in the estimated symmetric industry-by-industry tables.

The process of transformation is described as in Figure 9.8.

Coverage: countries and years. The first edition of the OECD IO Database dates back to 1995, and covered 10 OECD countries, with IO tables spanning the period from early 1970 to early 1990. The first updated edition of this database, released in 2002, increased the country coverage to 18 OECD countries plus China and Brazil, and introduced harmonised tables for the mid-1990s. Since 2006 this tradition of growth has continued, so that there are now tables available for 48 countries/economies (including 33 OECD members) with tables for the mid-2000s (mainly 2005) now available for most of them (Table 9.6).[8]

Industry classification. The industry classification used in the current version of the IO database is based on ISIC Rev. 3 (Table 9.7), meaning that it is compatible with the other OECD industry-based analytical data sets such as the Structural Analysis (STAN) database based on SNA by activity, and bilateral trade in goods by industry and end-use (derived from merchandise trade statistics via standard Harmonized System to ISIC conversion keys).

8 OECD BILATERAL TRADE DATABASE BY INDUSTRY AND END-USE CATEGORY (BTDIXE)

The OECD has recently developed estimates of bilateral trade data by industry and by end-use covering 65 countries/economies for the period 1988–2010 (Zhu *et al* 2011). The OECD Bilateral Trade Database by Industry and End-Use Category (BTDIxE) is derived from OECD's International Trade by Commodities Statistics (ITCS) database and UN's Comtrade database, where values (and quantities) of imports and exports are compiled according to product classifications and by partner country. Figure 9.9 shows a summary of the world export structure in 2009, while Figure 9.10 shows the evolution of export structures for selected countries.

[8]For more details, and information on how to access the OECD IO tables, go to http://www.oecd.org/sti/ind/input-outputtables.htm.

Table 9.6: *Country coverage of OECD Input–Output 2009 edition (as of March 2012).*

OECD	Mid-1990s	Early 2000s	Mid-2000s
Australia	1994/95	1998/99	2004/05
Austria	1995	2000	2005
Belgium	1995	2000	2005
Canada	1995	2000	2005
Chile	1996	—	2003
Czech Republic	1995	2000	2005
Denmark	1995	2000	2005
Estonia	1997	2000	2005
Finland	1995	2000	2005
France	1995	2000	2005
Germany	1995	2000	2005
Greece	1995	2000	2005
Hungary	1998	2000	2005
Iceland	—	—	—
Ireland	1998	2000	2005
Israel	1995	—	2004
Italy	1995	2000	2005
Japan	1995	2000	2005
Korea	1995	2000	2005
Luxembourg	1995	2000	2005
Mexico	—	—	2003
Netherlands	1995	2000	2005
New Zealand	1995/96	2002/03	—
Norway	1995	2000	2005
Poland	1995	2000	2005
Portugal	1995	2000	2005
Slovak Republic	1995	2000	2005
Slovenia	—	2000	2005
Spain	1995	2000	2005
Sweden	1995	2000	2005
Switzerland	—	2001	2006
Turkey	1996	1998	2002
United Kingdom	1995	2000	2005
USA	1995	2000	2005

The OECD International Trade by Commodities Statistics (ITCS) database is updated on the basis of annual data submissions received from OECD member countries as well as from Chinese Taipei and, in some cases, from Eurostat. Due to the convergence of OECD ITCS and UN Comtrade updating processes, data sharing and other related cooperation between the two organisations, tables can also be computed for non-OECD members as declaring countries, notably the countries which belong to the OECD Enhanced Engagement Program: Brazil, China, India, Indonesia and South Africa.

In ITCS and UN Comtrade, data are classified by declaring country (*ie* the country supplying the information), by partner country (*ie* origin of imports and destination of exports) and by product (*ie* according to the HS). In both data sources, trade flows are stored according to the product classification used by the declaring country at the time of data collection. In general, source

Table 9.6: *Continued.*

Non-OECD	Mid-1990s	Early 2000s	Mid-2000s
Argentina	1997	—	—
Brazil	1995	2000	2005
China	1995	2000	2005
Chinese Taipei	1996	2001	2006
India	1993/94	1998/99	2006/07
Indonesia	1995	2000	2005
Latvia	—	—	2004
Lithuania	—	—	2005
Malaysia	—	2000	—
Malta	—	2000	2004
Romania	—	2000	2005
Russian Federation	1995	2000	—
Singapore*	1995	2000	2002
South Africa	1993	2000	2002
Thailand	—	—	2005
Vietnam	—	2000	—
EU27	—	—	2005

A dash means that the available year data is not available. *Not published (internal use only).

data are held according to Standard International Trade Classification (SITC) Rev. 2 for the 1978–87, the Harmonized System (1988) for 1988–95, HS Rev. 1 (1996) for 1996–2001, HS Rev. 2 (2002) for 2002–6 and HS Rev. 3 (2007) from 2007 onwards.

To generate estimates of trade in goods by industry and by end-use category, six-digit product codes from each version of HS from ITCS and Comtrade were assigned to a unique ISIC Rev. 3 industry and a unique end-use category according to the BEC classification, and hence SNA basic classes of goods. Thus, eight sets of conversion keys were estimated by using classification correspondence tables, developed internally by the Directorate for Science Technology and Industry, OECD, and available classification correspondence tables published by UNSD.

9 WISH LIST FOR IMPROVING THE INTERNATIONAL INPUT–OUTPUT TABLE

There is no doubt that the international Input–Output database opens up an opportunity to examine the comprehensive economic effects of global value chains. However, further statistical challenges remain for both IO tables and trade statistics.

9.1 Input–Output Tables

Firstly, more data sources of symmetric IO and/or Supply–Use Tables are necessary in order to develop better models of global production chains. The smaller portion of the rest of the world economy would theoretically reduce

Table 9.7: *OECD IO industry classification.*

ISIC Rev. 3		Description
01,02&05	1	Agriculture, hunting and related service industries
10–12	2	Mining and quarrying (energy)
13&14	3	Mining and quarrying (non-energy)
15&16	4	Food products, beverages and tobacco
17–19	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 & plastics products
26	12	Other non-metallic mineral products
271&2731	13	Iron & steel
272&2732	14	Non-ferrous metals
28	15	Fabricated metal products, except machinery & equipment
29	16	Machinery & equipment, nec
30	17	Office, accounting & computing machinery
31	18	Electrical machinery & apparatus, nec
32	19	Radio, television & communication equipment
33	20	Medical, precision & optical instruments
34	21	Motor vehicles, trailers & semi-trailers
351	22	Building and repairing of ships & boats
353	23	Aircraft and spacecraft
352–359	24	Railroad equipment and transport equipment nec
36&37	25	Manufacturing nec; recycling (including furniture)

the discrepancies generated by misallocated import transactions by sourcing country.

While the national statistical institutes of most countries have been able in recent years to publish the official figures of import matrices, the frequency of update is still about every five years when each country performs special surveys for benchmark year IO tables. Given the import penetration ratios of some industries are not annually stable for economic and social reasons, it is preferable to have more frequent reports on the transaction structures of imported goods and services.

In addition, many detailed industrial-level IO tables are required to plan the policy interventions. Only a few countries are currently able to provide over information on transactions of 400 industry levels (*eg* USA, Japan and Korea).

9.2 Trade Statistics

In the current data submission framework, the trade flows of goods and services are available only for reported flows. In other words, we do not have enough information on unreported flows. Each unreported flow could be zero flow, confidential value or missing information.

Table 9.7: *Continued.*

ISIC Rev. 3		Description
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 & distribution of water
45	30	Construction
50–52	31	Wholesale & retail trade; repairs
55	32	Hotels & restaurants
60	33	Land transport; transport via pipelines
61	34	Water transport
62	35	Air transport
63	36	Supporting & auxiliary transport activities; activities of travel agencies
64	37	Post & telecommunications
65–67	38	Finance & insurance
70	39	Real estate activities
71	40	Renting of machinery & equipment
72	41	Computer & related activities
73	42	Research & Development
74	43	Other business activities
75	44	Public admin. & defence; compulsory social security
80	45	Education
85	46	Health & social work
90–93	47	Other community, social & personal services
95–99	48	Private households and extraterritorial organisations

Since confidential values are aggregated in the two-digit chapter level of HS, if a country decided to make one individual flow a confidential entry, at least one other commodity of the same two-digit chapter could be masked as a confidential value. This is why identification of zero flows is an important factor to minimise the unknown trade coefficients.

Clarify sentence?

The official submission of re-exports of country of origin and destination by commodity and reimports of country of transhipment would be also helpful in order to identify the deviation of both physical flows of goods and monetary flows (Guo *et al* 2009). Ideally, the unit quantity used in the trade statistics should be harmonised for each commodity group.

Lastly, some industrial waste and by-products are explicitly recorded at the six-digit Harmonized System level of merchandise trade statistics. However, international transactions of second-hand capital goods, *eg* machinery and vehicles, are not explicitly coded in the current framework of the Harmonized System. It would be ideal to include the international recycling and sorting industries and to separate the production chains of new products and redistribution of used household goods and industrial capital goods.

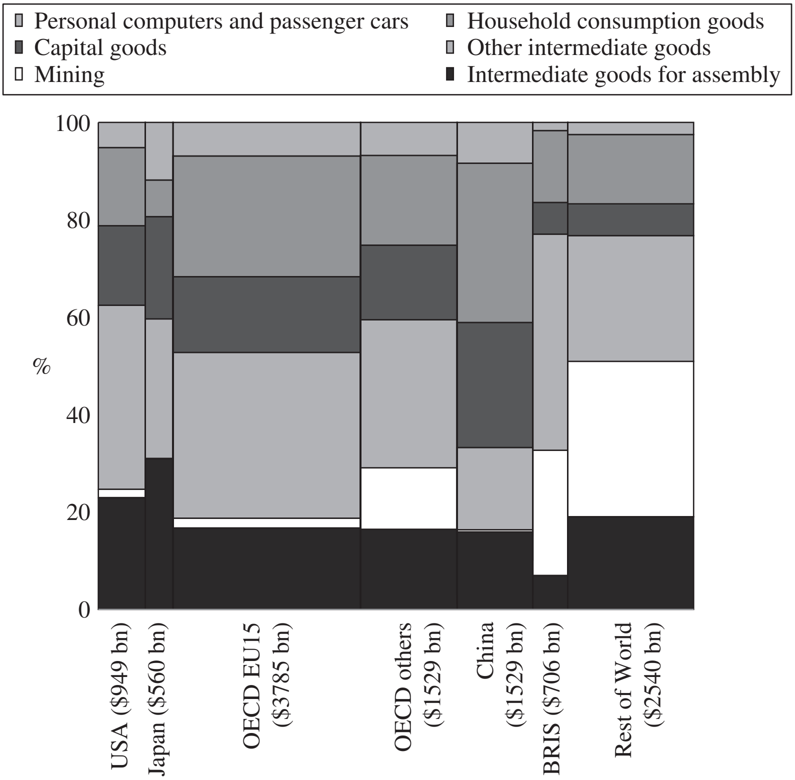


Figure 9.9: *Export share by industry and category (world, 2009).*

REFERENCES

Anderson, J. E. (1979). A Theoretical Foundation for the Gravity Equation. *American Economic Review* **69**(1), 106–116.

Benz, S., and S. Miroudot (2012). Building the OECD Estimated Bilateral Trade in Services by Industry (EBTSI) Dataset. Mimeo.

Chenery, H. B. (1953). Regional analysis. In *The Structure and Growth of the Italian Economy* (ed. H. B. Chenery, P. G. Clark and V. C. Pinna), pp. 91–129 (Rome: US Mutual Security Agency).

Eurostat (2008). *Eurostat Manual of Supply, Use and Input–Output Tables.*

Fujita, M., P. Krugman, and A. J. Venables (1999). *The Spatial Economy: Cities, Regions, and International Trade.* (Cambridge, MA: The MIT Press).

Furukawa, S. (1986). *International Input–Output Analysis: Compilation and Case Studies of Interaction between ASEAN, Korea, Japan, and the USA, 1975.* Occasional Papers Series, No. 21.

Furukawa, S., and S. Inomata (1993). Significance of construction and analysis of international input–output table of Asia-Pacific region. In *International Industrial*

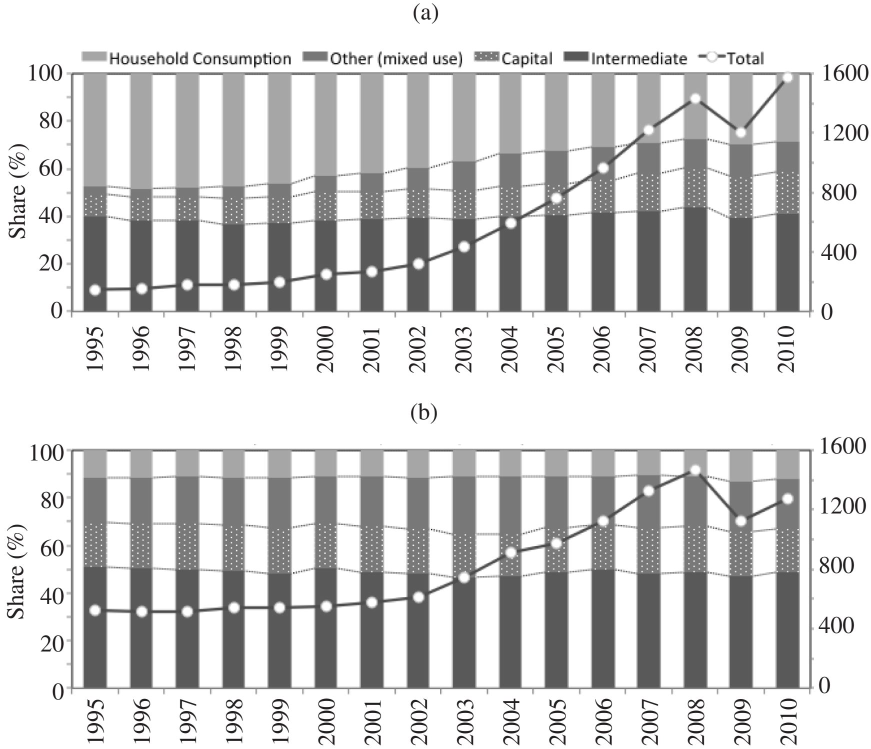


Figure 9.10: *Export share by industry and category.*

(a) China, (b) Germany. 'Total' given in US$ billions.

Linkages and Economic Interdependency in Asia-Pacific Region, Chapter 1, pp. 2–20 (Tokyo: Institute of Developing Economies).

Geraci, V. J., and W. Prewo (1977). Bilateral Trade Flows and Transport Costs, *Review of Economics and Statistics* **59**(1), 67–74.

Guo, D., C. Webb and N. Yamano (2009). Towards Harmonised Bilateral Trade Data for Inter-Country Input–Output Analyses: Statistical Issues, OECD Science, Technology and Industry Working Papers 2009/4.

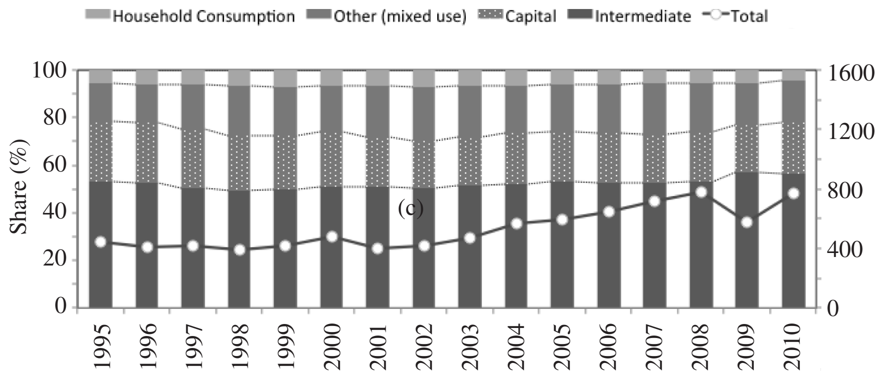
IDE (2006). JETRO, Asian International Input–Output Table. Volume 1 Explanatory Notes. Statistical Data Series, No. 89 (Chiba: Institute of Developing Economies).

IDE (2008). *JETRO, Compilation and Use of the 2005 Asian International Input–Output Table* (ed. S. Inomata and H. Kuwamori), Asian International Input–Output Series, No. 70 (Chiba: Institute of Developing Economies).

IDE (2011). *JETRO, Compilation and Use of the 2005 Asian International Input–Output Table* (ed. S. Inomata and H. Kuwamori), Asian International Input–Output Series, No. 76 (Chiba: Institute of Developing Economies).

Isard, W. (1951). Interregional and Regional Input–Output Analysis: A model of a Space Economy. *Review of Economics and Statistics* **33**, 318–328.

(c)



(d)

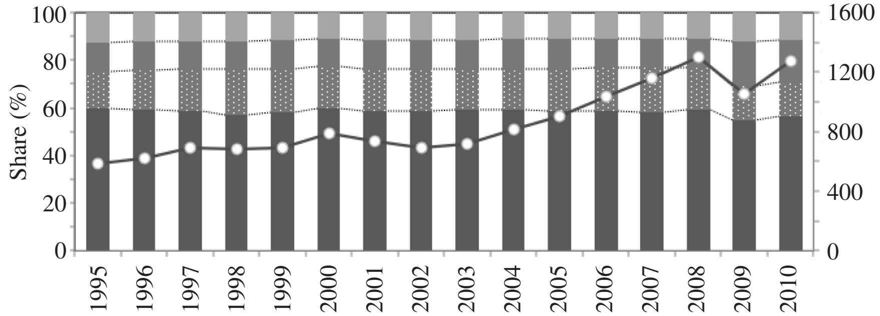


Figure 9.10: *Continued.*

(c) Japan and (d) USA. 'Total' given in US$ billions.

Japan Shipping Exchange (1983). *Distance Tables for World Shipping* (8th edition). Japan Shipping Exchange, Inc.

Kuroiwa, I. (1995). The Spatial Structure of the Asia-Pacific Economy: Applications of International Input–Output Analysis. PhD Dissertation, University of Pennsylvania.

Leontief, W. (1953). Interregional Theory. In *Studies in the Structure of the American Economy*, Chapter 4, pp. 93–115 (New York: Oxford University Press).

Leontief, W., and A. Strout (1963). Multiregional Input–Output Analysis. In *Structural Interdependence and Economic Development* (ed. T. Barna). (New York: St. Martin's Press).

Limao, N., and A. J. Venables (2001). Infrastructure, Geographical Disadvantage, Transport Costs, and Trade. *World Bank Economic Reviews* **5**(3), 451–479.

Miller, R. E., and P. D. Blair (1985). *Input–Output Analysis: Foundations and Extensions* (Prentice-Hall, 1985).

Moses, L. N. (1955). The Stability of Interregional Trading Patterns and Input–Output Analysis. *American Economic Review* **45**, 803–832.

Okamoto, N., T. Sano and S. Inomata (2005). *Estimation Technique of international Input–Output Model by Non-Survey Method*, IDE Discussion Paper Series, No. 28.

Polenske, K. R. (1970). An Empirical Test of Interregional Input–Output Models: Estimation of 1963 Japanese Production. *American Economic Review* **60**(1), 76–82.

United Nations (1999). Handbook of Input–Output Table Compilation and Analysis. *Studies in Methods*, Series F, No. 74 (New York: United Nations).

Watanabe, T. (1964). International Input–Output Table: Structure and Possibilities, IDE Research Documents, No. 92. (In Japanese.)

Wonnacott, R. (1961). *Canadian-American Dependency, An Interindustry Analysis of Production and Prices* (Amsterdam: North-Holland).

Yamano, N., and N. Ahmad (2006). The OECD Input–Output Database: 2006 Edition, OECD STI Working paper 2006/7.

Zhu, S., N. Yamano and A. Cimper (2011). Compilation of Bilateral Trade Database by Industry and End-Use Category, OECD STI Working Paper 2011/6.

10

A Three-Stage Reconciliation Method to Construct a Time Series International Input–Output Database

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1 INTRODUCTION

There is increasing attention on global value chains and what has been described as trade in value added to better understand the importance of trade to economic growth, jobs and material well-being in both academic and policy circles. A global value chain can be characterized as a chain that reveals how, and by how much, each industry involved in the production of a particular good or service contributes to the production of that good or service. Within such a supply chain or production network, each producer purchases inputs and then adds value, which then becomes part of the cost (inputs) of the next stage of production. The sum of the value that is added at every stage in the chain equals the value of the final goods purchased at the end of the chain. Historically these chains were typically constrained within the economic borders of one country, but in recent decades, driven by cheaper transport costs and lower tariffs, there has been an increasing number of chains that cross international borders (international fragmentation of production). This phenomenon has complicated analysis and policymaking. Because goods and services can cross borders many times before they reach their final destination, the value of exports can overstate the importance of a given export to the exporting economy, as the export will embody value that has been added along the supply chain by industries in other countries.

Prior to this international fragmentation of production period, a single national input–output (IO) table could be used to give reasonably reliable estimates of how different industries within an economy participated in producing final goods, whether for domestic or export markets. But increased fragmentation has significantly changed the landscape. Imports of manufactured

[1] The views in the paper are solely the authors' own. They are not meant to represent in any way the views of the OECD or US International Trade Commission or any of its individual Commissioners. The authors thank Li Xin at CCER, Perking University, for efficient data processing and research assistance.

goods and services are increasingly being used as intermediate inputs in the production of goods and services within global value chains, and in addition the intermediate imports themselves are increasingly embodied with value that was added in an upstream part of the value chain by the importing economy itself. The weaknesses in using a single country's IO table to analyse and provide evidence on global value chains was recognised by a team of experts contracted by the US National Research Council (NRC)[2] to study how much US content was embodied in its imports and how much foreign content was embodied in its exports. They concluded (National Research Council 2006) that while it was possible to derive proxies of foreign contents in US exports using US input–output statistics, the results themselves, particularly those relating to the US content of imports, were highly dependent on the underlying assumptions. The most serious reservation the team had was the absence of harmonised supply and use (IO) tables that could be linked across countries.

Significant progress has been made since the NRC report, however. The 1993 System of National Accounts, for example, recommended the development of supply–use tables, which has led to widespread use and development of these tables as a tool to balance GDP in most developed economies. Indeed, within the European Union (EU) it is a legal requirement to produce these tables, and the international statistics community has engaged in a number of initiatives to assist developing economies in this area.[3]

More recently, the European Commission funded a consortium of 11 European research institutions and the Organisation for Economic Co-operation and Development (OECD), to develop a time series of 'world' IO tables, the World Input Output Database (WIOD), covering 27 EU countries and 13 other major economies from 1995 to 2009. (Timmer *et al* 2012). In addition, the OECD has been actively involved in this area since the early 1990s, when it produced a set of harmonised IO tables for 10 countries, expanding the coverage to over 20 in the early 2000s and to 58 economies today.

There has been widespread recognition within the official international statistics community that international fragmentation requires a new approach to how we measure trade, in particular the need to measure trade in value added (see United Nations Statistics Division 2011). The needs and improvements in national statistics information systems led the OECD and WTO to launch a joint initiative on March 15, 2012, 'Measuring Trade in Value Added',[4] which is designed to mainstream the production of trade in value-

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[2]The committee was chaired by Professor Edward Leamer and consisted of members drawn from the councils of the National Academy of Sciences, the National Academy of Engineering and the Institute of Medicine.

[3]The Asian Development Bank organised a project with participation of 17 developing countries (RETA 6483) in Asia Pacific to construct supply and use tables for each participating country.

[4]See http://www.oecd.org/trade/valueadded.

added statistics and make them a permanent part of the statistical landscape. The first official data was released on January 16, 2013.

Underpinning this initiative is the creation of a global IO table database (or tables that are as global in their coverage of countries as possible: the 58 countries in the OECD database, for example, reflect 95% of global GDP). But creating these tables is non-trivial and requires the leaping of a number of statistical hurdles. There have been a number of attempts to compile global IO tables in recent years (Lenzen *et al* 2012; Wang 2011; Wang *et al* 2012; Johnson and Noguera 2012; and the WIOD project), which has led to important improvements in the qualities of the estimated global IO tables. These include the following:

- benchmark to official national accounts estimates of output and final consumption (as not all countries' supply–use tables are necessarily benchmarked to, nor revised in line with, their GDP by expenditure account);
- assumptions used to allocate imports to users have moved away from the traditional crude 'proportionality' assumption and now capture heterogeneities in imports from different sources based on the end-use category that is available in trade statistics (UN Broad Economic Category classification);
- a recognition that shares rather than values per se are what matter in official bilateral trade statistics.

Besides these common features, each of these recent works has also provided additional useful experience in the construction of global IO tables, particularly in the context of balancing; an important point to note in this context concerns deficiencies in official trade statistics which show that global exports differ from global imports. A number of different approaches have thus far been adopted to estimate the balance tables. For example, Wang (2011) introduced estimates of initial data reliability to guide the balancing process, Lenzen *et al* (2012) proposed a method to estimate the standard error for each cell in the global IO tables to assess their reliability and uncertainty using data of constraint violation and discrepancies between balanced IO table and unbalanced initial estimates.

Another important improvement is the use of Supply and Use Tables (SUTs) as the starting point to integrate trade statistics and derived the final symmetric world IO table, the approach adopted by WIOD. Intuitively, this approach makes sense, as it links trade statistics (which are product based) with the product statistics in the supply–use table on the one hand, and value-added/employment data (that is industry-based) with industry statistics in the supply–use tables on the other hand. It also avoids errors inherent in the assumptions imposed when transferring SUTs to symmetric IO tables before the reconciliation process even start. However, as pointed out by Streicher and Stehrer (2012) the current WIOD method has two major unsolved issues: first, its international transportation margins were assumed as being produced in the rest of the world by the 'Panama assumption' and not linked back to the world economy. Second, exports to rest of the world were derived as residuals to balance world exports and imports, which resulted in negative exports from some countries in several products.[5] To overcome these problems, Streicher and Stehrer (2012) proposed a method to construct a trade matrix of cost, insurance and freight/free on board (CIF/FOB) margins together with supply and use tables for the Rest of the World. This resulted in a consistent global SUT system with international transportation services also balanced at the global level.

Building on the experiences of these recent works this chapter develop mathematical programming model to integrate individual country SUTs with detailed bilateral trade statistics using a three-stage reconciliation procedure to produce a consistent annual global SUT database. The procedure solves the inconsistencies in trade statistics and data from different sources using a system of simultaneous equations that minimise a quadratic penalty function that only allows minimum deviation from both official SUTs and trade statistics.

The model deals with the data reconciliation problem at the global level first by reconciling official estimates of each country's total merchandise and service trade statistics reported in each country's national accounts with reported total exports to and imports from the world at product level in that country's SUTs. It results in a set of country product level total exports and imports which satisfy the condition that world total exports (FOB) plus a shipping margin (CIF) equals world total imports (CIF). The use of international margin services is also balanced with its supply from margin producing industries at the global level simultaneously, similar to Streicher and Stehrer (2012) but achieved in a unified modelling framework. At the second stage, the model reconciles each country's SUTs with the globally consistent exports and imports data from the first stage. At the third and final stage, the model integrates individual countries' statistics with international bilateral trade statistics by distributing each country's total exports and imports in every commodity group to its trading partners based on bilateral trade shares computed from bilateral trade in goods and service data, taking each country's total exports to and imports from the world derived from the first stage as controls and adjusting their distribution among partner countries to produce a consistent annual global SUT.[6]

The rest of the chapter is organised as follows: Section 2 specifies the three-stage procedure for accounts and trade statistics reconciliation. Sec-

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[5] See Timmer *et al* (2012, p. 38) for details.

[6] One important spillover from the model is its ability to produce updated global tables as and when (normal) revisions to GDP and trade statistics occur (*ie* excluding revisions related to conceptual changes in the accounting framework, such as the capitalisation of R&D in the 2008 System of National Accounts).

tion 3 describes the major data sources used to implement and test the procedure. Section 4 presents preliminary test results and describes how the official statistics were adjusted. Section 5 concludes with a discussion on directions for future work.

2 THE THREE-STAGE RECONCILIATION PROCEDURE

2.1 Stage 1

In the first stage, model reconciles global trade statistics. A key this step is estimate the reconciled value of total global exports and imports and each country's total imports and exports on goods and services that form part of this global total. The starting point is estimates of trade available in official national accounts statistics[7] of GDP by expenditure. Prior to reconciliation of these national estimates, differences between total exports and imports in FOB price are generally less than 2% of global exports for most of the years in the period covered (see Section 3.1 for a detailed discussion).

Using data as controls, we adjust exports and imports in each country's SUTs provided in WIOD (by product) based on a reliability index of exporters and importers, to obtain a set of country by product exports and imports estimates which satisfies the condition that total global exports equals total global imports for each product. Purchases in the domestic territory by non-residents and direct purchases abroad by residents are treated as a special product in the balancing procedure. This globally consistent trade data set is used as a control to rebalance each country's SUTs in stage 2, before bilateral trade by product and end use is introduced to obtain the international SUTs in the final stage.

The notation used to specify the first stage programming model is as follows.

E^s_{ct}: exports to the world of commodity group c by country s at year t, FOB prices.

M^r_{ct}: imports from the world of commodity group c by country r at year t, CIF prices.

WE^s_{kt}: total exports ($k \in \{G = \text{goods},\ S = \text{services},\ T = \text{total}\}$) to the world by country s, FOB price.

WM^r_{kt}: total imports ($k \in \{G = \text{goods},\ S = \text{services},\ T = \text{total}\}$) from the world by country r, FOB price.

CIF^r_{ct}: cost, insurance and freight for country r's total imports of commodity group c from the world at time t.

$E^s_{\text{adj}_{kt}}$: purchase in the domestic territory by non-residents.

$M^r_{\text{adj}_{kt}}$: direct purchases abroad by residents.

[7]Sourced from OECD National Accounts database and UN National Accounts.

RIX_c^s: reporter reliability index of commodity c by exporter s.
RIM_c^r: reporter reliability index of commodity c by importer r.[8]

To be consistent with the official statistics in an individual country's SUTs and national accounts, the product level exports imports are valued at FOB and CIF price, respectively, but total exports and imports of goods and services are valued at FOB prices. Product index c is defined over commodity set $C \in \{1, 2, \ldots, n\}$ and divided into three subsets: goods (CC), non-margin services (CS) and margin service (CT); country indices s and r are defined over country set $G \in \{1, 2, \ldots, g\}$. Variables without zero suffixes are endogenous in the model, and variables with a zero suffix are parameters, exogenous to the model. Using the above notation, the first stage programming model is specified as follows.

Objective Function at Each Year t

$$\begin{aligned}
\min S &= \frac{1}{2}\Bigg\{ \sum_{s=1}^{g}\sum_{c=1}^{n} \frac{(E_{ct}^s - E_{0_{ct}}^s)^2}{(1-\text{RIX}_{ct}^s)E_{0_{ct}}^s} \\
&\quad + \sum_{r=1}^{g}\sum_{c=1}^{n} \frac{(M_{ct}^r - M_{0_{ct}}^r)^2}{(1-\text{RIM}_{ct}^r)M_{0_{ct}}^r} + \sum_{c=1}^{n} \frac{(\text{CIF}_{ct} - \text{CIF}_{0_{ct}})^2}{(1-\text{RIM}_{ct})\text{CIF}_{0_{ct}}} \\
&\quad + \sum_{r=1}^{g}\sum_{k=s,g,t} \frac{(E_{\text{adj}_{kt}}^r - E_{\text{adj}_{0_{kt}}}^s)^2}{E_{\text{adj}_{0_{kt}}}^s} + \sum_{r=1}^{g}\sum_{k=s,g,t} \frac{(M_{\text{adj}_{kt}}^r - M_{\text{adj}_{0_{kt}}}^r)^2}{M_{\text{adj}_{0_{kt}}}^r} \\
&\quad + 100\left(\sum_{s=1}^{g}\sum_{k=s,g,t} \frac{(\text{WE}_{kt}^s - \text{WE}_{0_{kt}}^s)^2}{(1-\text{RIX}_t^s)\text{WE}_{0_{kt}}^s} + \sum_{r=1}^{g}\sum_{k=s,g,t} \frac{(\text{WM}_{kt}^r - \text{WM}_{0_{kt}}^r)^2}{(1-\text{RIM}_t^r)\text{WM}_{0_{kt}}^r} \right)\Bigg\}.
\end{aligned} \tag{10.1}$$

Constraints at Each Year t

The country total exports are given by

$$\sum_c E_{ct}^s + E_{\text{adj}_{kt}}^s = \text{WE}_{kt}^s \quad \text{for all } s \text{ and } k. \tag{10.2}$$

The country total imports are given by

$$\sum_c (M_{ct}^r - \text{CIF}_{ct}^r) + M_{\text{adj}_{kt}}^r = \text{WM}_{kt}^r \quad \text{for all } r \text{ and } k. \tag{10.3}$$

The world market equilibrium at the commodity group level for goods trade is given by

$$\sum_{s=1}^{g} (E_{ct}^r + \text{CIF}_{ct}^r) = \sum_{r=1}^{g} M_{ct}^r, \quad c \in \text{CC for trade only.} \tag{10.4}$$

The world market equilibrium at commodity group level for non-margin services trade is given by

$$\sum_{s=1}^{g} E_{ct}^{s} = \sum_{r=1}^{g} M_{ct}^{r}, \quad c \in \text{CS for margin services trade only.} \tag{10.5}$$

The international margin service supply and demand balance is equal to

$$\sum_{r=1}^{g} \sum_{c \in \text{CS}} \text{CIF}_{ct}^{r} = \sum_{r=1}^{g} \sum_{c \in \text{CT}} (E_{ct}^{s} - M_{ct}^{r}), \quad c \in \text{CT for margin services trade only.} \tag{10.6}$$

The world market equilibrium for the goods trade is equal to

$$\sum_{s=1}^{g} \text{WE}_{G,t}^{s} = \sum_{r=1}^{g} \text{WM}_{G,t}^{r}. \tag{10.7}$$

The world market equilibrium for the service trade (including margin trade) is given by

$$\sum_{s=1}^{g} \text{WE}_{S,t}^{s} - \sum_{r=1}^{g} \sum_{c \in \text{CT}} \text{CIF}_{ct}^{r} = \sum_{r=1}^{g} \text{WM}_{S,t}^{r}. \tag{10.8}$$

The total world exports are equal to the total world imports:

$$\sum_{s=1}^{g} \text{WE}_{T,t}^{s} = \sum_{r=1}^{g} \text{WM}_{T,t}^{r}. \tag{10.9}$$

The model is used to reconcile official national account data on *goods* and *services* trade statistics ($\text{WE}_{0_{kt}}^{s} \text{WM}_{0_{kt}}^{r}$) with each country's reported total exports to and imports from the world at commodity group level ($E_{0_{ct}}^{s} M_{0_{ct}}^{r}$) recorded in each country's national SUTs. This results in a set of country product level total exports and imports, along with the value of transport costs by country and commodity group, which satisfies the condition that world total exports plus a shipping cost equal world total imports all products and services, including international transportation services.

2.2 Stage 2

To adjust each country's exports and imports in its SUTs[9] to the globally consistent trade data set solved from stage 1, we also use a constrained quadratic programming model that minimises the weighted sum of squares of deviations from the benchmark SUTs in value-added, intermediate inputs and gross outputs, and in all final-expenditure categories, over all industries, subject to the following five sets of constraints:

[9] And also to estimates in SU tables between benchmark years when annual tables are not available.

1. for each industry, total intermediate inputs purchased from all commodity groups and all sources (domestic and imported) as well as value added generated by the industry sum to the industry's total gross output;

2. for each product group, the amount sold to all industries as domestic intermediate inputs plus the amount sold to final users as domestic final goods and services plus the amount of domestic exports equal the total output produced by the industries;

3. for each product group, the imported intermediates used by all industries plus the amount of imported final goods used by all users plus the amount of goods re-exported minus a re-exports mark-up equal the total imports of that commodity group, which is fixed at the globally consistent level of gross imports solved in stage 1;

4. the domestic exports plus re-exports equals each product groups' gross exports, which is at the globally consistent level solved in stage 1;

5. the sum of each type of final domestic demand by product group plus net tax on products equals total final domestic demand for each category as recorded in each country's GDP by expenditure account.

Let us define x, z, v and y as country r's output, intermediate inputs, value added and final domestic demands, respectively. mg, mgi, mgy, ntx, $ntxi$ and $ntxy$ are the total, intermediate and final goods transportation margins and net taxes respectively, wx, wz, wv, wy, wg and wt are their corresponding reliability weights. We denote products and industries by subscripts (c, i), value-added categories by f, and final domestic demand categories by subscript k, respectively. The variables with suffix '0' stand for the initial estimates of the variables. There are $n+1$ (adjusted for non-resident purchases in domestic markets and residents' direct purchases abroad, which are treated as a special product) groups, m industries, l value-added categories (compensation for employees, indirect tax, operating surplus and depreciation) and h demand categories (household consumption, government spending, gross fixed capital formation and changes in inventory). All variables are evaluated at basic prices, except net taxes, which are evaluated at purchasers' prices.

Using the notation defined above, the second-stage optimisation model be formally specified as follows.

The objective function at each year t for country r is given by

$$\min S = \frac{1}{2}\left\{ \sum_{c=1}^{n}\sum_{i=1}^{m}\frac{(z_{cit}^{r}-z_{0_{cit}}^{r})^2}{wz_{cit}^{r}} + \sum_{i=1}^{m}\sum_{c=1}^{n}\frac{(x_{ict}^{r}-x_{0_{cit}}^{r})^2}{wx_{ict}^{r}} + \sum_{i=1}^{m}\sum_{f=1}^{l}\frac{(v_{ift}^{r}-v_{0_{ift}}^{r})}{wv_{ift}^{r}} + \sum_{c=1}^{n}\sum_{k=1}^{h}\frac{(y_{ckt}^{r}-y_{0_{ckt}}^{r})^2}{wy_{ckt}^{r}} + \sum_{c=1}^{n}\sum_{k=1}^{h}\frac{(mgy_{ckt}^{r}-mgy_{0_{ckt}}^{r})^2}{wg_{ckt}^{r}} + \sum_{i=1}^{m}\sum_{c=1}^{n}\frac{(mgi_{cit}^{r}-mgi_{0_{cit}}^{r})^2}{wg_{cit}^{r}} + \sum_{c=1}^{n}\sum_{k=1}^{h}\frac{(ntxy_{ckt}^{r}-ntxy_{0_{ckt}}^{r})^2}{wt_{ckt}^{r}} + \sum_{i=1}^{m}\sum_{c=1}^{n}\frac{(ntxi_{cit}^{r}-ntxi0_{cit}^{r})^2}{wt_{cit}^{r}} \right\}. \quad (10.10)$$

Constraints at Each Year t for Country r

The balance condition for industrial gross output and input cost at basic prices is given by

$$\sum_{c=1}^{n}(z_{cit}^{r}+ntxi_{cit}^{r}) + \sum_{f=1}^{l}v_{ift}^{r} = \sum_{c=1}^{n}x_{ict}^{r} \quad \text{for all } i. \quad (10.11)$$

The balance condition for total product supply and use at basic prices is given by

$$\sum_{i=1}^{m}z_{ict}^{r} + \sum_{k=1}^{h}y_{ckt}^{r} + E_{ct}^{r} = \sum_{i=1}^{m}x_{ict}^{r} + M_{ct}^{r} \quad \text{for all } c. \quad (10.12)$$

The balance conditions for margin service supply and use are given by

$$\sum_{i=1}^{m}mgi_{ict}^{r} + \sum_{k=1}^{h}y_{ckt}^{r} = mg_{ct}^{r} \quad \text{for all } c, \quad (10.13)$$

$$\sum_{c=1}^{n}mgi_{ict}^{r} = 0 \quad \text{for all } i, \quad (10.14)$$

$$\sum_{c=1}^{n}mgy_{ckt}^{r} = 0 \quad \text{for all } k. \quad (10.15)$$

The balance condition for net taxes in use and supply tables is given by

$$\sum_{i=1}^{m}ntxi_{ict}^{r} + \sum_{k=1}^{h}ntxy_{ckt}^{r} = ntx_{ct}^{r} \quad \text{for all } c. \quad (10.16)$$

The gross exports and aggregate expenditure components constraints are as follows:

$$de^r_{ct} + re^r_{ct} = E^r_{ct} \quad \text{for all } i, \tag{10.17}$$

$$\sum_{c=1}^{n+1} (y^r_{ckt} + mgy^r_{ckt} + ntxy^r_{ckt}) = \text{GDPE}^r_{0_{kt}} \quad \text{for all } k. \tag{10.18}$$

The GDP from the production side is equal to

$$\sum_{i=1}^{m} \sum_{f=1}^{l} v^r_{ift} + \sum_{i=1}^{m} ntxi^r_{ict} = \text{GDP}^r_t \tag{10.19}$$

and that on the expenditure side is equal to

$$\sum_{k=1}^{n} \text{GDPE}^r_{kt} + \sum_{c=1}^{n+1} (E^r_{ct} - M^r_{ct}) = \text{GDP}^r_t. \tag{10.20}$$

Constraints (10.11) to (10.20) show that the supply and use tables are jointly used to ensure all the national accounting identities hold during the data reconciliation process. The adjustment made by the model to *initial* estimates in individual country's SUT does not necessarily change a country's GDP statistics nor any of the major aggregates of domestic expenditure components in the National Accounts, although countries total exports and imports, and so their balance of trade with the world may change due to the adjustment needed to reconcile global trade imports and exports. This seems counter-intuitive because a country's balance of trade (BOT) is part of its GDP accounting identity, so a change in BOT should result in a change in GDP. However, as noted earlier, SUTs compiled by national statistical institutions are not always frequently revised in line with official GDP statistics. Therefore, GDP statistics computed from national SUTs do not necessarily equal official GDP statistics. In addition, statistical discrepancies often exist in some countries' GDP by expenditure account. Therefore, when our model eliminates the small discrepancy between global exports and imports (1–2% global exports each year) in official trade statistics, depending on the weights used in the reconciliation process, the model returns balance GDP (expenditure) estimates, which typically do not differ from official GDP statistics. Typically, the weighting process means that in cases, where modifications occur, they are most likely to occur in those countries where there are statistical discrepancies between GDP computed and published in their SUTs and expenditure-based GDP estimates from the latest national accounts; in other words, the procedure also removes these statistical discrepancies in national accounts (if they exist) together with discrepancies between global exports and imports.[10]

[10]In some ways one can draw analogies here with balancing procedures used in some countries, for example, methods that take an average of GDP income (I), production (O) and expenditure (E) approaches, where a balance is forced by convention. Our approach also forces a balance, but uses an approach that weights initial estimates by their reliability.

2.3 Final Stage

A world supply and use table is a comprehensive account of annual transaction and payment flows within and between countries. use the following notation to describe the elements of the world supply and use table (expressed in annual values).

x^r_{ict}: gross output of product c from industry i in country r.
v^r_{it}: direct value added by production of industry i in country r.
z^{sr}_{cit}: product c produced by industry i in country s and used as an intermediate input by sector i in country r.
y^{sr}_{ckt}: product c produced in country s for final use in final demand type 'k' in country r.
$\mathrm{CIF}i^{sr}_{ct,cit}$: CIF margin by margin service ct for intermediate goods c used in industry i in country r.
$\mathrm{CIF}y^{sr}_{ct,ckt}$: CIF margin by margin service ct for final goods use in final expenditure category k in country r.
TFL^{sr}_c: trade flow of product c from country s to country r.

Thus, the model used in the final stage of the reconciliation process can be defined as follows.

Objective Function at Each Year t

$$\min S = \frac{1}{2}\left\{\sum_{s=1}^{g}\sum_{r=1}^{g}\sum_{c=1}^{n}\sum_{i=1}^{m}\frac{(z^{sr}_{cit} - z^{sr}_{0_{cit}})^2 + (\mathrm{CIF}i^{sr}_{ct,cit} - \mathrm{CIF}i^{sr}_{0_{ct,cit}})^2}{wz^{sr}_{cit}} + \sum_{s=1}^{g}\sum_{r=1}^{g}\sum_{c=1}^{n+1}\sum_{k=1}^{h}\frac{(y^{sr}_{cit} - y^{sr}_{0_{cit}})^2 + (\mathrm{CIF}y^{sr}_{ct,cit} - \mathrm{CIF}y^{sr}_{0_{ct,cit}})^2}{wy^{sr}_{cit}}\right\}. \tag{10.21}$$

Constraints at Each Year t

The balance condition for industrial gross output and input cost at basic prices is given by

$$\sum_{s=1}^{g}\sum_{c=1}^{n}(z^{sr}_{cit} + ntxi^r_{ict}) + \sum_{s=1}^{g}\sum_{c=1}^{n}\sum_{c\in \mathrm{CT}}\mathrm{CIF}i^{sr}_{c,ccit} + \sum_{f=1}^{l} v^r_{ift} = \sum_{c=1}^{n} x^r_{ict}, \tag{10.22}$$

and the balance condition for total product supply and use at basic prices is given by

$$\sum_{i=1}^{m}\sum_{r=1}^{g} z^{sr}_{ict} + \sum_{k=1}^{h}\sum_{r=1}^{g} y^{sr}_{ckt} = \sum_{i=1}^{m} x^s_{ict}. \tag{10.23}$$

Equation (10.22) defines the value of gross i in r as the sum of the values from all of its (domestic plus imported) intermediate and primary factor inputs.

Equation (10.23) states that total gross output of product group c in country s is equal to the sum of deliveries to intermediate and final users all countries (including itself) in the world. This global SUT account has to be consistent with each individual country's SUT account and international trade statistics, which requires the following accounting identities also to be satisfied each year: the constraint for intermediate use in the national use tables, which is given by

$$\sum_{s=1}^{g} z_{cit}^{sr} = z_{0_{cit}}^{r}, \tag{10.24}$$

the constraint for final demand in the national use tables, which is given by

$$\sum_{s=1}^{g} y_{ckt}^{sr} = y_{0_{ckt}}^{r}, \tag{10.25}$$

and the constraints for bilateral trade flows at CIF prices, for which, to include international transportation service in a consistent way, the accounting equation for bilateral trade is split over goods and services,

$$\sum_{i=1}^{m} z_{cit}^{sr} + \sum_{i=1}^{m} \sum_{c\in \mathrm{CT}} \mathrm{CIF}i_{c,cit}^{sr} + \sum_{k=1}^{h} y_{ckt}^{sr} + \sum_{i=1}^{m} \sum_{c\in \mathrm{CT}} \mathrm{CIF}y_{c,ckt}^{sr} = \mathrm{TFL}_{ct}^{sr} \quad \text{for } c \in \mathrm{CC}, \tag{10.26 a}$$

$$\sum_{i=1}^{m} z_{cit}^{sr} + \sum_{k=1}^{h} y_{ckt}^{sr} = \mathrm{TFL}_{ct}^{sr} \quad \text{for } c \in \mathrm{CS} \text{ and } \mathrm{CT}. \tag{10.26 b}$$

The range constraints for bilateral trade flows are based on official mirror trade statistics:

$$\min(\mathrm{TFL}x_{0_{ct}}^{sr}, \mathrm{TFL}m_{0_{ct}}^{sr}) \leqslant \mathrm{TFL}_{ct}^{sr} \leqslant \max(\mathrm{TFL}x_{0_{ct}}^{sr}, \mathrm{TFL}m_{0_{ct}}^{sr}), \tag{10.27}$$

where $\mathrm{TFL}x_{0_{ct}}^{sr}$ and $\mathrm{TFL}m_{0_{ct}}^{sr}$ denote country s's reported exports to country r and partner country r's reported imports from country s.

The constraint for exports at FOB prices in national use tables (solved from the first stage) is split over three product sets, goods CC, non-margin services CS and margin service CT:

$$\sum_{r\neq s}^{g} \sum_{i=1}^{m} z_{cit}^{sr} + \sum_{r\neq s}^{g} \sum_{k=1}^{h} y_{ckt}^{sr} = E_{ct}^{s} \quad \text{for } c \in \mathrm{CC}, \tag{10.28 a}$$

$$\sum_{r\neq s}^{g} \mathrm{TFL}_{ct}^{sr} = E_{ct}^{s} \quad \text{for } c \in \mathrm{CS}, \tag{10.28 b}$$

$$\sum_{r\neq s}^{g} \mathrm{TFL}_{ct}^{sr} + \sum_{i=1}^{m} \sum_{c\in \mathrm{CC}} \mathrm{CIF}i_{ct,cit}^{sr} + \sum_{i=1}^{m} \sum_{c\in \mathrm{CC}} \mathrm{CIF}y_{ct,ckt}^{sr} = E_{ct}^{s} \quad \text{for } c \in \mathrm{CT}. \tag{10.28 c}$$

The constraint for imports at CIF prices in national supply tables (solved from the first stage) is given by

$$\sum_{s\neq r}^{g} \mathrm{TFL}_{ct}^{sr} = M_{ct}^{r}. \tag{10.29}$$

Equation (10.28) indicates that a country's total delivery of final goods and services to other countries for group c must equal its gross exports at the FOB price, which includes both domestic exports and re-exports (if applicable) as well as international transportation services from its margin producing industries. Equation (10.29) states each country's demand for imports of intermediate and final goods and services (plus its re-exports if applicable) equals the country's total gross imports from international markets at CIF prices.

The constraint for country-specific CIF margins (solved from the first stage) is given by

$$\sum_{c\in \mathrm{CT}} \sum_{s\neq r}^{g} \left(\sum_{i=1}^{m} \mathrm{CIF}i_{ct,cit}^{sr} + \sum_{k=1}^{h} \mathrm{CIF}y_{ct,ckt}^{sr} \right) = \mathrm{CIF}_{ct}^{r}. \tag{10.30}$$

The constraint for the margin services product structure is given by

$$\sum_{c\in \mathrm{CC}} \sum_{s\neq r}^{g} \left(\sum_{i=1}^{m} \mathrm{CIF}i_{c,ccit}^{sr} + \sum_{k=1}^{h} \mathrm{CIF}y_{c,cckt}^{sr} \right) = \sum_{r=1}^{g} (E_{ct}^{s} - M_{ct}^{r}), \quad c \in \mathrm{CT}, \tag{10.31}$$

and the GDP and aggregate domestic expenditure constraints are

$$\sum_{c=1}^{n+1} \left(\sum_{s=1}^{g} \left(\sum_{c\in \mathrm{CT}} \mathrm{CIF}y_{c,cckt}^{sr} + y_{ckt}^{sr} \right) + mgy_{ckt}^{r} + ntxy_{ckt}^{r} \right) = \mathrm{GDP}E_{0_{kt}}^{r}. \tag{10.32}$$

GDP from the production side equals

$$\sum_{i=1}^{m} \sum_{f=1}^{l} (v_{ift}^{r} + ntxi_{ict}^{r}) = \mathrm{GDP}_{t}^{r}, \tag{10.33}$$

and the GDP from the expenditure side equals

$$\sum_{k=1}^{n} \mathrm{GDP}E_{kt}^{r} + \sum_{c=1}^{n+1} (E_{ct}^{r} - M_{ct}^{r})] = \mathrm{GDP}_{t}^{r}. \tag{10.34}$$

Equations (10.22) to (10.34) must hold for all $i \in M$, $k \in H$ and $s, r \in G$ in each year.

The optimisation problem in the last stage of our data reconciliation procedure is formulated to minimise a quadratic penalty function (Equation (10.21)) subject to constraints (10.22) through to (10.34).

There are several desirable theoretical properties of such a mathematical programming approach for data reconciliation. As discussed by Harrigan (1990), Canning and Wang (2005) and Wang *et al* (2010), by imposing valid binding constraints, the optimisation procedure will definitely improve, or at least not worsen, the initial statistics estimates. The weights ($wz_{ij}^{sr}, wy_{ic}^{sr}$) in the objective functions play a very important role in the data reconciliation process. By design they minimise the adjustment made to original data known to be of high quality, typically leaving these estimates largely unchanged, but allow changes to be made to data where reliability problems exist.

The advantages of such an optimisation framework in data reconciliation are also significant from an empirical perspective. First, it provides considerable flexibility in achieving global coherence. It encapsulates a wide range of initial information that is used efficiently in the data reconciliation process. Additional constraints can also be easily imposed to allow, for example, upper and lower bonds to be placed on unknown elements (this is very common in mirror trade statistics), or inequality conditions to be added. It is also very flexible regarding to the required known information and accommodates and corrects for missing data in certain blocks of the SUTs, as long as the sum of the elements within the block is known. Such flexibility is important in terms of improving the information content of the final balanced estimates as shown by Robinson *et al* (2001).

Second, the optimisation approach permits alternative measures of the reliability of the initial data to be easily included in the reconciliation process, such that it is able to take account of improvements, say, in the statistical information system used in, and so reliability in the statistics of, a given country. The idea of including data reliability weights in data reconciliation can be traced back to Stone (1942) when he explored procedures for compiling national income accounts. As noted before, these weights should reflect the relative reliability of the initial statistics. Using properly selected reliability weights, the optimal solution should yield estimates that deviate less from the initial estimates with higher degrees of reliability than for those with lower degrees of reliability.

The three-stage reconciliation procedure described above is solved with an optimisation software package GAMS/CPLEX.[11] Optimal solutions from this procedure are equivalent to the estimates produced by generalised least square estimations (GLS).[12]

3 IMPLEMENTATION AND NUMERICAL TESTING OF THE MODEL

The key in implementing the three-stage recompilation procedure to produce a balanced SUT is to carefully link each variable in the model with the best available statistics. This section documents the data sources used to initialise

[11] GAMS/CPLEX is a well-established, versatile, powerful, high-performance optimisation system for solving large linear and quadratic programming models.

[12] Since the optimal solutions are equivalent to the GLS estimates, the term ‘optimal solution’ and ‘estimates’ are sometimes used interchangeably here.

Table 10.1: *Countries/regions included in World Input–Output Database.*

ISO3	Country name	ISO3	Country name
AUS	Australia	ITA	Italy
AUT	Austria	JPN	Japan
BEL	Belgium	KOR	Korea
BGR	Bulgaria	LTU	Lithuania
BRA	Brazil	LUX	Luxembourg
CAN	Canada	LVA	Latvia
CHN	China	MEX	Mexico
CYP	Cyprus	MLT	Malta
CZE	Czech Republic	NLD	Netherlands
DEU	Germany	POL	Poland
DNK	Denmark	PRT	Portugal
ESP	Spain	ROM	Romania
EST	Estonia	RUS	Russia
FIN	Finland	SVK	Slovakia
FRA	France	SVN	Slovenia
GBR	United Kingdom	SWE	Sweden
GRC	Greece	TUR	Turkey
HUN	Hungary	TWN	Chinese Taipei
IDN	Indonesia	USA	United States
IND	India	ROW	Rest of world
IRL	Ireland	WLD	World total

and test the model and introduce the reliability weights used in the objective function at the first and final stages of the recompilation procedure.

3.1 Data Sources

Our objective is to conduct a preliminary test of the model by integrating the individual country Supply and Use Tables, national accounts and international trade statistics. Country SUTs are obtained from WIOD , which covers 27 EU member countries and 13 other major economies in the world from 1995 to 2009 (Table 10.1). We also estimate an SUT for the rest of the world based on official national accounts statistics and the OECD intermediate data sources used to compile the OECD's Inter-country Input–Output Database: the rest of the world is developed from the input–output/supply and trade in services of 15 countries[13] and trade in goods of all countries where UN Comtrade data are available, with industries aggregated to the 35 sectors used in WIOD, based on ISIC Rev. 3. Therefore, the product and industry classification of our testing data sets are the same as WIOD (see Tables 10.2 and 10.3 for details).

We collected and compared various sources for goods and services trade data, including official National Accounts, sourced from the OECD and UNSD,

[13] Chile, Iceland, Israel, Norway, Switzerland, Argentina, South Africa, Hong Kong, Malaysia, Philippines, Thailand, Vietnam, Saudi Arabia, Brunei and Cambodia.

Table 10.2: *Product Classification of World Input–Output Database.*

WIOD	CPA	Description
C1	1	Products of agriculture, hunting and related services
C2	2	Products of forestry, logging and related services
C3	5	Fish and other fishing products; services incidental of fishing
C4	10	Coal and lignite; peat
C5	11	Crude petroleum and natural gas; services incidental to oil and gas extraction excluding surveying
C6	12	Uranium and thorium ores
C7	13	Metal ores
C8	14	Other mining and quarrying products
C9	15	Food products and beverages
C10	16	Tobacco products
C11	17	Textiles
C12	18	Wearing apparel; furs
C13	19	Leather and leather products
C14	20	Wood and products of wood and cork (except furniture); articles of straw and plaiting materials
C15	21	Pulp, paper and paper products
C16	22	Printed matter and recorded media
C17	23	Coke, refined petroleum products and nuclear fuels
C18	24	Chemicals, chemical products and man-made fibres
C19	25	Rubber and plastic products
C20	26	Other non-metallic mineral products
C21	27	Basic metals
C22	28	Fabricated metal products, except machinery and equipment
C23	29	Machinery and equipment nec
C24	30	Office machinery and computers
C25	31	Electrical machinery and apparatus nec
C26	32	Radio, television and communication equipment and apparatus
C27	33	Medical, precision and optical instruments, watches and clocks
C28	34	Motor vehicles, trailers and semi-trailers
C29	35	Other transport equipment
C30	36	Furniture; other manufactured goods nec
C31	37	Secondary raw materials
C32	40	Electrical energy, gas, steam and hot water
C33	41	Collected and purified water, distribution services of water
C34	45	Construction work

UNCTAD, IMF's IFS and BOPS database, Comtrade database, and the OECD database.[14] The same data can often be obtained from several different sources. However, we found there were often significant differences in values between different sources.[15] Because of these differences, it is necessary to analyse the pros and cons of each source to determine which are the most reli-

[14]UNSD, United Nations Statistics Division; UNCTAD, United Nations Conference on Trade and Development; IFS, International Financial Statistics; BOPS, Balance of Payments Statistics.

[15]There are two major reasons for the difference: valuation (trade valued on an FOB or

Table 10.2: *Continued.*

WIOD	CPA	Description
C35	50	Trade, maintenance and repair services of motor vehicles and motorcycles; retail sale of automotive fuel
C36	51	Wholesale trade and commission trade services, except of motor vehicles and motorcycles
C37	52	Retail trade services, except of motor vehicles and motorcycles; repair services of personal and household goods
C38	55	Hotel and restaurant services
C39	60	Land transport; transport via pipeline services
C40	61	Water transport services
C41	62	Air transport services
C42	63	Supporting and auxiliary transport services; travel agency services
C43	64	Post and telecommunication services
C44	65	Financial intermediation services, except insurance and pension funding services
C45	66	Insurance and pension funding services, except compulsory social security services
C46	67	Services auxiliary to financial intermediation
C47	70	Real estate services
C48	71	Renting services of machinery and equipment without operator and of personal and household goods
C49	72	Computer and related services
C50	73	Research and development services
C51	74	Other business services
C52	75	Public administration and defence services; compulsory social security services
C53	80	Education services
C54	85	Health and social work services
C55	90	Sewage and refuse disposal services, sanitation and similar services
C56	91	Membership organisation services nec
C57	92	Recreational, cultural and sporting services
C58	93	Other services
C59	95	Private households with employed persons

able for our reconciliation model. Ultimately, we chose the National Accounts as the best source for a country's total gross exports to and imports from the world. For bilateral trade positions we use the OECD's bilateral merchandise and services trade data ('Bilateral Trade by Industry and End-Use Category' and 'Bilateral Trade in Services by Industry').

Control Totals for Aggregate Trade in Each Country

National Accounts data by design often capture estimates of trade that will not be reflected in underlying customs data, since the National Accounts include adjustments to correct for reporting errors, partner country coverage, and

CIF basis) and coverage (data missing for some countries, for some sectors and for some years).

Table 10.3: *Industrial classification of World Input–Output Database.*

WIOT	NACE	Description
01	AtB	Agriculture, hunting, forestry and fishing
02	C	Mining and quarrying
03	15t16	Food, beverages and tobacco
04	17t18	Textiles and textile products
05	19	Leather, leather and footwear
06	20	Wood and products of wood and cork
07	21t22	Pulp, paper, paper, printing and publishing
08	23	Coke, refined petroleum and nuclear fuel
09	24	Chemicals and chemical products
10	25	Rubber and plastics
11	26	Other non-metallic mineral
12	27t28	Basic metals and fabricated metal
13	29	Machinery, nec
14	30t33	Electrical and optical equipment
15	34t35	Transport equipment
16	36t37	Manufacturing, nec; recycling
17	E	Electricity, gas and water supply
18	F	Construction
19	50	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel
20	51	Wholesale trade and commission trade, except of motor vehicles and motorcycles
21	52	Retail trade, except of motor vehicles and motorcycles; repair of household goods
22	H	Hotels and restaurants
23	60	Inland transport
24	61	Water transport
25	62	Air transport
26	63	Other supporting and auxiliary transport activities; activities of travel agencies
27	64	Post and telecommunications
28	J	Financial intermediation
29	70	Real estate activities
30	71t74	Renting of m&eq and other business activities
31	L	Public admin and defence; compulsory social security
32	M	Education
33	N	Health and social work
34	O	Other community, social and personal services
35	P	Private households with employed persons

also for unobserved (*eg* informal) trade. But there are other reasons why differences across related sources may arise, for example, relating to concepts, including valuation. Table 10.4, for example, shows that UNCTAD, IFS and BOPS world merchandise imports tend to be larger than the National Accounts data we used. This is also a result of valuation differences (UNCTAD and IFS are both in CIF prices; WITS–Comtrade data are also in CIF prices) and definitional differences (IMF's BOPS data are only for merchandise goods, while

Table 10.4: *Comparisons of world goods and service trade (various sources as a percentage of National Accounts data).*

		Exports														
Source	Type	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
UNCTAD	Goods	97	97	97	98	97	98	98	98	99	99	98	99	98	99	98
WITS	Goods	89	92	94	95	95	96	97	97	98	98	97	98	96	97	96
IFS	Goods	94	95	98	98	98	98	98	99	99	99	100	100	98	98	97
BOP	Goods	84	85	83	85	85	84	84	82	83	83	83	82	82	88	87
BOP2	Goods	90	91	91	110	109	107	108	109	110	110	103	108	108	109	107
UNCTAD	Services	101	101	101	101	101	101	101	100	100	100	100	102	104	105	106
BOP	Services	85	84	85	88	88	88	88	87	87	87	87	88	91	90	92
		Imports														
Source	Type	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
UNCTAD	Goods	100	101	101	101	100	101	101	102	102	102	102	102	101	102	101
WITS	Goods	92	95	98	98	99	100	100	101	101	101	101	101	100	101	99
IFS	Goods	98	99	103	103	102	102	102	102	103	103	103	102	102	101	100
BOP	Goods	84	85	84	87	87	87	86	86	86	86	86	86	86	90	89
BOP2	Goods	90	91	91	109	109	109	108	109	110	109	110	110	110	111	110
UNCTAD	Services	101	99	99	99	99	99	100	98	98	98	98	99	101	103	104
BOP	Services	85	83	82	85	86	85	86	84	83	83	82	82	84	85	86

Table 10.5: *Comparing merchandise trade data for selected countries (various sources as a percentage of National Accounts data).*

		Exports								Imports							
Reporter	Source	1995	1997	1999	2001	2003	2005	2007	2009	1995	1997	1999	2001	2003	2005	2007	2009
China	UNCTAD	102	100	100	100	100	100	100	100	107	104	104	105	105	105	106	105
	WITS	102	100	100	100	100	100	100	100	107	104	104	105	105	105	106	105
	IFS	102	100	100	100	100	100	100	100	107	104	104	105	105	105	106	105
	BOP	88	45	43	44	45	45	49	49	89	51	55	61	60	58	61	61
	BOP2	88	100	100	100	100	100	100	100	89	100	100	100	100	100	100	100
Japan	UNCTAD	104	103	104	105	105	105	106	107	113	110	110	111	111	109	109	110
	WITS	104	103	104	105	105	105	106	107	113	110	110	111	111	109	109	110
	IFS	104	103	104	105	105	105	104	106	113	110	111	111	111	109	108	110
	BOP	100	98	99	98	98	98	98	99	100	96	95	96	95	95	95	95
	BOP2	100	100	100	100	100	100	100	100	100	99	99	100	99	100	100	100
Germany	UNCTAD	100	100	100	100	100	99	99	98	101	102	100	101	100	99	99	98
	WITS	100	100	100	100	100	99	99	97	101	102	100	101	100	99	99	97
	IFS	100	100	100	100	100	99	98	97	101	102	100	101	100	99	99	98
	BOP	94	94	93	94	93	93	95	94	92	93	93	93	93	93	95	95
	BOP2	99	99	99	99	99	99	100	100	99	100	99	100	100	100	101	102
USA	UNCTAD	100	100	99	100	100	100	101	99	102	101	101	101	102	102	102	101
	WITS	100	100	99	100	100	100	101	99	102	101	101	101	102	102	102	100
	IFS	100	100	100	100	100	100	101	99	102	102	101	101	102	102	102	101
	BOP	97	97	97	97	98	97	97	96	98	98	98	98	98	98	98	98
	BOP2	98	98	98	98	99	98	98	98	98	98	98	98	98	98	99	98

Source: UN, UNCTAD, WITS–Comtrade, OECD, IMF BOP, and IMF IFS databases.

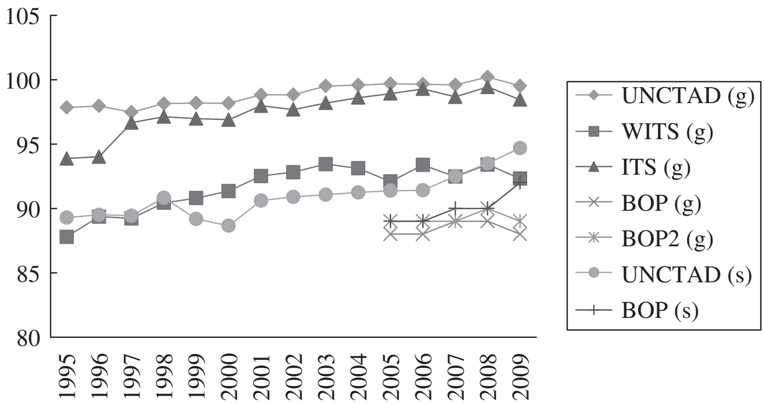

Figure 10.1: *Comparing data sources for goods and services: world imports plus exports (various sources as a percentage of National Accounts data).*

'g' denotes goods; 's' denotes services.

BOP2 include merchandise goods plus goods for processing, repair of goods, goods procured in ports by carriers and non-monetary gold).

Table 10.5 provides the same comparison for merchandise trade, but looking only at the four largest trading countries: China, Japan, Germany and the USA. By focusing on these four major exporters and importers, we can provide a more accurate comparison between the various data sources. By examining these four countries, we can clearly see that the National Accounts data are very close to that of other sources, especially in the case of merchandise exports. For merchandise exports, national accounts data are about 100% for all years for China, Germany and the USA. BOPS data is typically lower but that is expected due to definitional differences with national accounts estimates (see above). Merchandise imports for most sources are clearly larger than the national accounts data, with the exception of the BOP2 database. The data from UNCTAD, WITS, and IFS are on average about 5% larger for China, 1% for Germany, 10% for Japan and 2% for the USA; these differences are a result of the CIF margin.

Similar patterns exist for services trade data. For example, world totals found in UNCTAD data on services trade are almost 100% of those of the national accounts based data (see Table). However, national accounts totals are between 9 and 18% larger than those found in the IMF's BOPS database (Figure 10.1), reflecting the fact that some countries are absent from the BOPS world totals. This difference in totals, however, does not exist in the individual country totals. For example, Table 10.6 shows that services trade data for most years, from most sources, including the BOPS database, are 100% of the national accounts data for both services exports from, and imports to, China and Germany. They are about 30% and 17% larger for Japan's exports

Table 10.6: *Comparing services trade data for selected countries (various sources as a percentage of National Accounts data).*

		Exports								Imports							
Reporter	Source	1995	1997	1999	2001	2003	2005	2007	2009	1995	1997	1999	2001	2003	2005	2007	2009
China	UNCTAD	88	100	100	100	100	100	100	100	89	100	100	100	100	100	100	100
	BOPS	88	100	100	100	100	100	100	98	89	100	100	100	100	100	100	100
	OECD	100	100	100	100	100	100	100	100*	100	100	100	100	100	100	100	100*
Japan	UNCTAD	124	128	130	131	130	131	137	138	111	116	117	117	118	117	120	123
	BOPS	124	128	130	131	130	131	137	139	111	116	117	117	118	117	120	123
	OECD	124	128	130	131	122	126	134	131*	110	111	114	116	115	117	115	116*
Germany	UNCTAD	100	99	95	99	104	105	103	102	100	100	98	98	101	101	101	102
	BOPS	100	99	95	100	104	105	106	109	100	100	101	101	101	101	101	102
	OECD	100	99	96	100	104	104	101	96*	101	102	102	101	101	99	99	101*
USA	UNCTAD	95	95	95	94	95	96	96	98	97	97	97	96	98	98	98	101
	BOPS	95	95	95	94	95	96	98	98	97	97	97	96	98	98	97	99
	OECD	96	96	97	97	97	98	101	100*	97	97	97	96	98	99	99	99*

*Data represent the year 2008.

and imports, respectably. For the USA, the services trade data are about 5% and 3% larger for US exports and imports, respectively. These differences underscore the difficulty in collecting and estimating accurate trade statistics in services and reinforce our position on using National Accounts-based data, where statistics institutes make attempts to deal with inconsistencies or errors within the GDP accounting framework.

Selection of Control Total for Aggregate Trade in the World

Another benefit of national accounts data a control is that it is fairly balanced. Looking at the share of imports over exports of world totals (see Table 10.7) allows us to compare the global trade balance of the different sources; in a perfectly balanced world this share would equal 100% when both exports and imports are valued in FOB. basis. The data show that on average imports account for 99% of exports (goods, services and total). Imports from UNCTAD, IFS and WITS are predictably larger, by about 2%. This difference reflects the fact that in these databases exports are valued on an FOB basis and imports are valued on a CIF basis.

Other Data Sources

Each country's exports to and imports from the world at WIOD product level are obtained directly from WIOD use (for exports at FOB) and supply (for imports at CIF) tables. Initial estimates of CIF margins are also taken from WIOD.

We use the GDP by major expenditure components statistics as each country's macro control variables. The data are downloaded from the 'National Accounts Official Country Data' of UN statistics division, and the OECD's National Accounts database, at current prices, in thousands of US dollars. These provided the source for all countries except Taiwan (Chinese Taipei), which was sourced from the Directorate-General of Budget, Accounting and Statistics (DGBAS) and converted to US dollars.

Bilateral and services trade statistics are from OECD sources, but they are only used for source and destination shares after obtaining a globally consistent set of exports to and imports from the world at the WIOD product level for each country from our first-stage optimisation procedure. However, both exporter and importer reported data are used as the interval control in our final stage reconciliation when bilateral trade flows are estimated.

3.2 Selection of Reliability Indexes in the Objective Function

As pointed out by Wang *et al* (2010), one of the most desirable analytical and empirical properties of the class of data reconciliation models such as the one we specified by Equations (10.1)–(10.34) is that it uses reliability weights in the objective function to control how much an initial estimate

Table 10.7: *World trade in total (share of imports over exports by source).*

	Type	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
NA	Total	98	98	98	99	99	100	100	99	99	99	99	98	98	98	98
NA	Goods	98	98	97	98	99	99	100	99	99	99	99	99	98	99	99
UNCTAD	Goods	101	101	101	101	102	103	103	102	102	102	103	101	101	102	101
IFS	Goods	102	103	102	102	103	103	104	103	103	103	102	101	102	102	101
BOPS	Goods	97	98	99	100	101	103	103	103	103	103	103	103	103	101	101
BOP2	Goods	97	98	98	97	99	101	100	99	99	99	100	100	100	101	100
WITS	Goods	101	102	102	101	103	103	103	102	102	103	103	102	103	103	102
NA	Services	100	100	100	100	100	100	100	100	100	98	98	96	96	96	97
UNCTAD	Services	100	99	98	98	98	98	99	98	98	96	96	94	93	93	94
BOPS	Services	100	98	97	97	97	96	97	96	96	94	92	90	88	94	94

Source: UN, OECD, UNCTAD, WITS–Comtrade, IMF BOPS and IMF IFS databases. 'NA' denotes National Accounts data.

may be adjusted. From a statistical point of view, the best way to systematically assign reliability weights in the objective function is to obtain estimates of the variance–covariance matrix of the initial estimates, using the inverted variance–covariance matrix as the reliability indicators. The larger the variance, the smaller the associated term $(z_{ci}^{sr} - z_{0_{ci}}^{sr})^2 / wz_{ci}^{sr}$ or $(y_{ck}^{sr} - y_{0_{ck}}^{sr})^2 / wy_{ck}^{sr}$ contributes to the objective function, and hence the lesser the penalty for the associated variables to move away from their initial value (only the relative, not the absolute size of the variance affects the solution). However, the lack of consistent historical data often makes the estimation of the variance–covariance matrix associated with the initial estimates very difficult to implement. For example, the common practice in SAM balancing exercises is to assign differing degrees of subjective reliabilities to the initial entries of the matrix, following the method proposed by Stone (1942).[16] To date, very few attempts have been made to statistically estimate data reliability such as error variance of the initial estimates from historical data, except Weale (1985), who developed a statistical method that uses time series information on accounting discrepancies to infer data reliability in a System of National Accounts. Theoretically speaking, a similar statistical method can be applied to the historically reported discrepancies of bilateral trade data to derive those variances associated with international trade statistics. In practice, however, the historical data and knowledge of the changes in related country's trade statistics reporting systems are too demanding and make such a statistical method less attractive for large empirical applications. Therefore, here we use a practical alternative approach to estimate the reliability weights, which is constructed by reporter relative reliability indexes for both exporters and importers.

Reporter Reliability Indexes

Trade data reported by each country and its partners are often used in the international economic literature to check the quality of trade statistics. An approximate match of mirror statistics suggests that trade data reported via that route are reliable. However, such weights treat the reported trade statistics from both reporters equally and do not distinguish which reporter is more reliable. In the case where there is (known) unreliable reporter in the pair, this approach may lead to changes being made to the data reported by the reliable reporter. This is undesirable. To correct this problem, a reporter's relative reliability index needs to be developed. Such an index should be able to deal with three critical issues.

The first issue is related to the difference of reporting countries in their ability to report bilateral commodity trade by end-use categories. Variability

[16] Stone proposed to estimate the variance of x_{ij}^0 as $\text{var}(x_{ij}^0) = (\theta_{ij} x_{ij}^0)^2$, where θ_{ij} is a subjective determined reliability rating, expressing the percentage ratio of the standard error to the initial estimates of x_{ij}^0.

in reporting quality across countries is highly relevant information for the problem we try to solve in our proposed official approach. As discussed earlier, the adjustment process hinges heavily on the relative reliability of each of the reporting countries. An indicator of reporter reliability is a measure of how consistently a country reports its trade in each product relative to all its trading partners. However, judging reliability of a country's trade based on a single bilateral flow is a poor reference, because a partner can misrepresent its trade, thereby potentially discrediting a reliable reporter. Therefore, a good reporter reliability measure should take all reporting countries in the world into account in assessing a country's reporting reliability.

The second issue is what exactly should be captured by the reliability measure. The size of discrepancies could be incorporated into a measure of reliability. However, placing emphasis on the magnitude of discrepancies only may over-penalise the reliability of a legitimate reporter. A poor reporter that makes an error for a given trade flow usually makes a similar error with other partners. For example, a reporter that has mistaken the identity of one of its partners has implicitly made a mistake for others. It brings a systemic bias for that reporter. This type of problem should be detected and reflected in the reporter reliability measure without penalising the reliable reporter.

The third issue is the capability of the measure to reflect both product- and country-specific reliability information for each country as an exporter and as an importer. Countries typically have specific strengths and weaknesses. For example, one exporting country may have an excellent reporting record on steel used as intermediate goods, but is also highly inconsistent in its reporting practice for trade of organic chemical in final goods.

All three issues discussed above are effectively dealt with in the reliability index developed by Gehlhar (1996), where reporter reliability indexes were used to make a discrete choice to disregard or accept reported trade flows. The index is calculated as the share of accurately reported transactions of a reporter's total trade for a particular using a threshold level. It assesses reporter reliability from a complete set of global reporting partners, captures the reporter's ability to accurately report without interferences from gross discrepancies in reporting and contains exporter and importer product-specific reliability information. Specifically, the importer-specific and exporter-specific reliability indexes in the objective function (Equations (10.1) and (10.21)) are defined as

$$\mathrm{RIM}_{ic}^{r} = \frac{\mathrm{MA}_{ic}^{r}}{\sum_s M_{ic}^{sr}}, \quad \text{where } \mathrm{MA}_{ic}^{r} = \sum_{s \in \mathrm{AL}_{ic}^{sr} \leqslant 0.20} M_{ic}^{sr}, \quad \mathrm{AL}_{ic}^{sr} = \frac{|M_{ic}^{rs} - E_{ic}^{sr}|}{M_{ic}^{rs}}, \tag{10.35}$$

$$\mathrm{RIX}_{ic}^{s} = \frac{\mathrm{XA}_{ic}^{s}}{\sum_r E_{ic}^{sr}}, \quad \text{where } \mathrm{XA}_{ic}^{s} = \sum_{s \in \mathrm{AL}_{ic}^{sr} \leqslant 0.20} E_{ic}^{sr}, \quad \mathrm{AL}_{ic}^{sr} = \frac{|M_{ic}^{rs} - E_{ic}^{sr}|}{M_{ic}^{rs}}. \tag{10.36}$$

Under such reliability indexes, the size of the discrepancies becomes immaterial because inaccurate transactions are treated the same regardless of the magnitude of the inaccuracy. The indexes have the flexibility of being implemented at the detailed six-digit HS level and can be aggregated to any commodity group level. We computed such reporter reliability measures for each country and product. Major data are from UN Comtrade with supplements from country sources.[17]

Reliability Weights Used in Objective Function

After obtaining RIM and RIX for each WIOD product by country, there is an additional issue that needs to be solved before we can empirically compute the reliability weights in the objective function (Equations (10.1) and (10.21)) of the data reconciliation model. There is only one unique number for each trade flow in each route in the global SUTs, which should be a combination of both reporter and partner reported trade statistics based on reporters' reliabilities. Therefore, we combine both reporter and partner's reliability indexes and reported statistics for each trade routine at the WIOD product level to compute the final reporter reliability weights in the objective function. They are assigned by multiplying 1 minus each reporter's product weighted reliability index by their corresponding initial values. For example, the complete set of weights in Equation (10.21) is defined as follows:

$$wz_{cit}^{sr} = (1 - \mathrm{RIM}_{ct}^{r})\bar{z}m_{cit}^{sr} + (1 - \mathrm{RIX}_{ct}^{s})\bar{z}x_{cit}^{sr}, \qquad (10.37)$$

$$wy_{ckt}^{sr} = (1 - \mathrm{RIM}_{ct}^{r})\bar{y}m_{ckt}^{sr} + (1 - \mathrm{RIX}_{ct}^{s})\bar{y}x_{ckt}^{sr}, \qquad (10.38)$$

where $\bar{z}m_{cit}^{sr}$, $\bar{z}x_{cit}^{sr}$ and $\bar{y}m_{ckt}^{sr}$, $\bar{y}x_{ckt}^{sr}$ are the intermediate and final goods trade flows computed based on the share reported by importers and exporters, respectively (shares multiple M_{ct}^{r} and E_{ct}^{s}, the total world trade by products of each country in the balanced individual country SUTs). With such a weighting scheme, we our goal of ensuring that the model has a higher probability of changing unreliable initial data compared reliable data.

4 ADJUSTMENT MADE TO OFFICIAL ACCOUNTS AND STATISTICS BY ENFORCING GLOBAL CONSISTENCY

Our model entails enforcing global consistency, which takes place in the first stage. We first establish consistency between country-reported trade in SUTs and official trade statistics in goods and services. The model solves the adjusted country total exports to and imports from the world for each product, and these country/product totals are retained for the second and

[17] We are grateful to Dr Mark Gehlhar at the US Department of Interior for helping us to compute the exporter and importer reliability indexes with WIOD product classification from 1995 to 2007.

Table 10.8: *Reporter reliability indexes, initial inconsistency and mean absolute percentage adjustment of total exports and imports, 1995–2009.*

Countries	RIX	%xerr	%expadj	RIM	%merr	%impadj	Countries	RIX	%xerr	%expadj	RIM	%merr	%impadj
AUS	0.504	−0.1	0.4	0.637	0.0	0.9	ITA	0.763	0.7	0.5	0.693	0.7	1.1
AUT	0.598	0.1	0.2	0.665	0.1	1.1	JPN	0.667	−0.4	1.7	0.611	−0.2	1.0
BEL	0.347	0.7	0.7	0.460	0.6	1.2	KOR	0.564	0.0	0.8	0.613	0.0	0.8
BGR	0.623	4.8	4.8	0.439	4.6	5.7	LTU	0.554	3.1	2.3	0.562	2.6	3.7
BRA	0.627	−0.1	1.1	0.605	−0.1	2.7	LUX	0.394	1.1	3.6	0.530	1.0	2.0
CAN	0.862	−0.2	0.4	0.675	−0.2	1.2	LVA	0.496	0.0	0.7	0.600	0.0	2.4
CHN	0.383	14.5	5.8	0.375	12.9	8.8	MEX	0.836	0.0	0.6	0.484	0.0	0.6
CYP	0.300	0.2	3.1	0.494	0.1	2.1	MLT	0.447	−2.4	1.3	0.532	−2.4	1.7
CZE	0.720	7.7	4.0	0.632	7.2	4.7	NLD	0.538	0.6	0.3	0.517	0.6	1.5
DEU	0.739	−0.1	0.5	0.527	−0.2	1.0	POL	0.689	1.2	1.0	0.624	1.1	1.8
DNK	0.572	0.1	0.7	0.629	0.1	1.6	PRT	0.684	1.2	0.5	0.726	1.0	2.7
ESP	0.765	0.9	0.4	0.620	0.9	1.0	ROU	0.644	4.2	1.6	0.497	3.2	4.3
EST	0.523	0.2	0.6	0.440	0.3	1.6	RUS	0.298	0.0	2.0	0.473	0.0	2.3
FIN	0.636	1.0	0.5	0.548	1.1	2.0	SVK	0.694	0.0	0.4	0.492	−0.1	0.7
FRA	0.732	0.7	0.3	0.611	0.7	1.2	SVN	0.704	0.9	0.8	0.584	1.1	1.0
GBR	0.567	−1.3	0.9	0.613	−0.5	0.6	SWE	0.623	0.1	1.2	0.682	0.1	1.1
GRC	0.547	−1.1	1.5	0.564	−2.1	3.6	TUR	0.635	0.0	8.4	0.492	−0.2	6.4
HUN	0.639	1.4	1.3	0.584	1.3	1.6	TWN	0.003	−0.2	1.5	0.004	0.3	0.7
IDN	0.506	−0.4	0.6	0.455	0.8	1.3	USA	0.620	0.1	1.9	0.702	0.1	1.6
IND	0.445	0.1	4.8	0.361	−1.5	3.5	ROW	0.000	−64.1	36.1	0.000	−58.1	38.8
IRL	0.489	−0.1	1.2	0.478	0.0	0.7	WLD			9.2			9.4

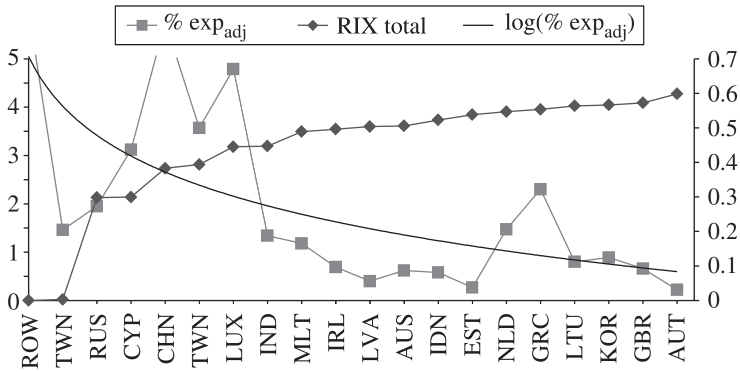

Figure 10.2: *Reporter reliability and mean absolute percentage adjustment of total exports, 1995–2009.*

More reliable data get less adjustment.

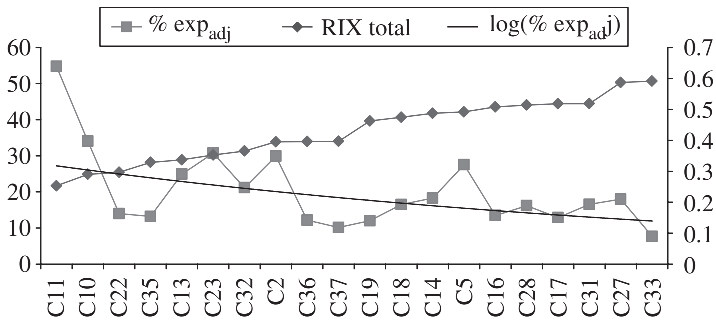

Figure 10.3: *Reporter reliability and mean absolute percentage adjustment of world goods by product, 1995–2009.*

More reliable data get less adjustment.

final stages as controls. The data reconciliation procedure produces a set of estimates for both trade and SUT estimates which are different from official statistics, and so it is desirable and important to know how much each set of estimates differs from the officially reported data. However, it is difficult to use a single measure to compare the original and adjusted data, since there are so many dimensions in the model solution sets. It is meaningful to use several measures to gain more insight on the model performance. Generally speaking, it is the proportionate deviation and not the absolute deviation that matters; therefore, we compute the 'mean absolute percentage adjustment' (MAPA) with respect to the official data for different and aggregations. Consider the following aggregate index measure for country and product group total adjustment:

$$\text{MAPA}^r = \frac{100 \sum_{t=1}^{T} \sum_{c=1}^{n+1} |\bar{E}_{ct}^r - E_{0_{ct}}^r|}{\sum_{t=1}^{T} \sum_{c=1}^{n+1} E_{0_{ct}}^r}, \quad (10.39)$$

$$\text{MAPA}^c = \frac{100 \sum_{t=1}^{T} \sum_{r=1}^{g} |\bar{E}_{ct}^r - E_{0_{ct}}^r|}{\sum_{t=1}^{T} \sum_{r=1}^{g} E_{0_{ct}}^r}. \quad (10.40)$$

We first focus on results for country total adjustments to illustrate some key characteristics of the adjustment process. Each country's reliability as an exporter and importer is a key factor that governs the magnitude of adjustment on its total exports and imports (Figure 10.2). The magnitude of adjustment made by the model is relatively small, less than 2% for most countries except a few outliers reflecting the large inconsistencies between National Account total trade data and product level trade data recorded in WIOD national SUTs. We note also that there is a negative correlation between exporters and importers' reliability and adjustments magnitudes made to covered products (Figure 10.3), although the adjustments are more significant at product level.[18] As expected, both the country and sector patterns of the adjustments reflect their negative relationship with reporter's reliability, with the exception of a few outliers. This indicates that both country and product level adjustments are not only impacted by data reliability but also by the initial discrepancies between product level trade data reported in individual country's SUTs and country totals recorded in the National Accounts. We report in Table 10.8 each country's reliability indexes, the initial inconsistency between total trade reported in WIOD national SUTs and National Accounts data as well as the mean absolute percentage adjustments.

The mean of absolute percentage adjustment for each country's SUTs from WIOD is summarised in Table 10.9. The extent of adjustment depends not only on the difference between the globally consistent trade data from the first stage of our model and the trade data in the national table, but also on the quality of the individual countries' statistics and how far their aggregates differ from those in the National Account (GDP by major expenditure components), which are used as macro controls. Generally speaking, the adjustments to sector level value-added product level final-demand related transactions are smaller than inputs- and gross outputs-related transactions with exceptions. The reasons for the large magnitude of adjustments to output at

[18]The simple correlation coefficient between reporter reliability index with mean absolute percentage of adjustment of trade is −0.46. Using RIX and RIM as regressor against MAPA by detailed product level adjustment data, we get the following liner relations: $\text{exp}_{\text{adj}} = 0.268 - 0.287\text{RIX}$ and $\text{imp}_{\text{adj}} = 0.216 - 0.224\text{RIM}$. Both coefficient estimates are significant at a 1% level.

Table 10.9: *Mean absolute percentage adjustment of national statistics.*

Country	z-int	x-output	y-final	v-VA	Country	z-int	x-output	y-final	v-VA
AUS	47.9	49.6	0.3	2.6	ITA	30.4	33.8	0.2	0.5
AUT	40.4	39.5	0.3	0.6	JPN	45.7	36.8	0.8	2.2
BEL	37.1	36.7	0.2	0.3	KOR	37.5	52.5	1.4	1.4
BGR	35.7	45.4	0.3	4.5	LTU	39.8	40.4	0.4	0.7
BRA	33.9	29.0	0.4	0.5	LUX	47.6	62.7	1.2	0.8
CAN	39.6	33.9	0.7	0.8	LVA	46.5	42.4	0.3	0.5
CHN	37.2	78.3	1.0	1.4	MEX	48.7	28.8	0.5	1.0
CYP	59.3	32.1	6.3	5.0	MLT	30.6	35.2	0.4	0.8
CZE	35.2	49.6	0.2	4.0	NLD	37.3	37.4	0.3	0.2
DEU	36.3	34.6	0.3	0.4	POL	26.0	34.3	0.2	0.1
DNK	36.5	40.4	0.5	0.4	PRT	49.5	41.4	0.3	2.5
ESP	47.6	40.8	0.3	0.3	ROU	39.0	40.9	0.5	0.2
EST	39.3	52.7	0.4	0.6	RUS	37.5	34.1	0.7	1.0
FIN	38.8	38.9	0.4	0.4	SVK	34.0	42.1	0.2	0.2
FRA	33.3	31.0	0.2	0.3	SVN	42.4	44.8	0.3	0.4
GBR	29.7	26.6	0.2	1.2	SWE	35.1	34.7	0.4	0.2
GRC	37.7	30.2	1.1	0.9	TUR	38.2	34.0	1.0	0.8
HUN	31.8	36.6	0.3	0.9	TWN	39.5	36.7	0.6	1.6
IDN	43.8	31.4	1.1	2.8	USA	35.0	23.0	0.3	0.7
IND	39.5	39.5	0.4	2.4	ROW	120.7	233.4	64.3	178.1
IRL	49.6	50.4	0.5	0.9	WLD	41.0	42.5	3.4	9.8

industry level need further investigation.[19] Computing the adjustment index similar to Equations (10.39) and (10.40) by product groups and final demand categories could help us to identify where the large adjustments come from, providing a means to identify and solve potential problems in the data. If the standard error of national SUT statistics or some sort of reliability index could be developed similar to the index for trade data, the resulting global SUT data could be improved.

Finally, we transform the global SUTs in basic prices produced from our data reconciliation model into industry-by-industry ICIO tables using 'Model D' discussed in Eurostat (2008, Chapter 11) similar to WIOD.[20] The mean absolute percentage difference between the adjusted ICIO tables and WIOD WIOTs is reported in Table 10.10. Generally speaking, the differences in sector level gross outputs are relatively small between WIOD WIOT and the estimated ICIO table by our reconciliation procedure, followed by sector level value added.

[19]Ideally, the gross industry or commodity output should be fixed in the reconciliation process, because such data collected by NSI are more reliable than data on intermediate inputs. However, if we fix the gross output recorded in WIOD SUTs, there will be no feasible solution for the model, so we have to relax this constraint. The issue is still under investigation.

[20]The justification of why 'Model D' is chosen is clearly discussed in Section 5 of Timmer *et al* (2012).

Table 10.10: *Mean absolute percentage between WIOD industry-by-industry WIOTs and adjusted ICIO tables, 2005.*

ctr	Dom. int	Imp. int’	Dom. final	Imp. final	Gross output	Value added	ctr	Dom. int	Imp. int’	Dom. final	Imp. final	Gross output	Value added
AUS	62.0	77.1	51.6	317.0	1.0	26.1	ITA	52.2	68.2	47.1	88.9	1.2	23.8
AUT	52.7	63.1	36.7	125.0	1.7	20.0	JPN	56.1	72.1	45.7	103.9	1.4	20.3
BEL	42.7	68.4	34.8	138.2	4.2	19.1	KOR	53.4	77.8	58.5	144.5	2.2	24.1
BGR	52.7	73.9	49.9	243.0	1.8	25.8	LTU	101.7	85.7	52.1	282.5	4.0	27.2
BRA	55.8	68.0	45.0	137.8	1.5	26.8	LUX	88.6	92.7	43.0	355.5	4.8	74.2
CAN	63.8	43.7	48.2	81.9	1.9	13.9	LVA	76.8	85.2	65.6	370.5	3.8	29.2
CHN	41.3	74.3	57.4	91.7	1.8	37.5	MEX	59.7	55.8	31.4	99.6	1.4	9.3
CYP	97.6	102.7	51.1	410.6	8.4	26.3	MLT	76.7	95.9	64.0	500.1	4.9	31.6
CZE	53.8	56.3	55.4	103.4	1.4	29.7	NLD	51.8	65.3	37.0	145.4	6.0	28.5
DEU	51.3	66.8	43.5	99.7	1.3	17.2	POL	34.6	60.3	32.8	97.6	1.3	19.4
DNK	49.6	79.8	43.8	122.4	2.1	18.9	PRT	73.8	68.5	48.4	111.2	1.5	23.8
ESP	59.9	76.3	35.9	62.4	1.3	30.8	ROM	103.9	75.6	70.9	176.7	2.6	41.9
EST	48.3	74.6	69.5	299.2	3.8	15.1	RUS	59.9	75.7	54.3	698.9	1.3	26.9
FIN	51.9	67.9	36.3	182.6	1.3	20.9	SVK	49.0	56.0	40.8	128.1	1.2	25.3
FRA	64.0	62.7	49.3	93.3	1.7	14.7	SVN	60.3	60.9	41.6	132.6	1.3	20.6
GBR	82.2	76.9	61.3	149.2	2.0	34.6	SWE	48.4	72.2	42.6	130.8	1.4	16.3
GRC	76.1	93.7	40.5	311.6	2.2	24.6	TUR	75.4	71.8	51.4	70.8	2.1	39.0
HUN	55.4	63.3	43.3	132.8	1.4	21.8	TWN	57.7	64.8	48.9	206.8	2.2	37.8
IDN	81.3	72.5	59.0	248.7	2.6	40.2	USA	53.5	77.1	37.4	126.0	0.8	14.0
IND	54.6	82.2	33.1	123.1	1.3	19.5	ROW	98.9	69.9	68.7	132.3	48.6	41.9
IRL	88.3	86.7	53.4	131.7	1.2	21.4	WLD	59.9	70.3	46.7	122.2	6.8	23.2

The difference between domestic transactions is generally less than that of imported transactions, for both intermediate inputs and final demand. The largest difference shows up on imported final demand.

5 DIRECTION OF FUTURE WORK AND CONCLUDING REMARKS

This study developed a three-stage mathematical programming model to reconcile detailed bilateral goods and services trade statistics with individual country's Supply and Use Tables to produce a global SUT database. It also documents the major data sources for such a data reconciliation excise and their pro and cons. Tests of the model using WIOD national SUTs and aggregate trade statistics from official National Accounts as well as bilateral trade data from OECD produced encouraging preliminary results and shows that the model is feasible and may have great potential in the estimation of an integrated world SUT account. Most importantly, our empirical exercise to test the model using real world data has shown that imposing global consistency and eliminating 'exports to the Moon' will make no significant changes on NSI's reported GDP and other major aggregate national account statistics in the balanced global SUT database. However, the model is still in its early stages of development; there are many important issues still to be addressed. We list a few of them as our concluding remarks.

5.1 SUTs with Statistical Discrepancies or Balanced SUTs

Both sets of tables may be needed. A globally consistent SUT that keeps major discrepancies may be useful for statistical purposes when evaluating the accuracy of data recorded in the global SUTs, while a balanced global SUT is necessary for analytical purposes, especially for estimating a balanced industry by-industry global IO table that provides the basis for computing trade in value-added estimates. So they are not substitutes but complements. A global SUT with statistical discrepancies could provide initial estimates for a balanced analytical world SUT, with the statistical discrepancy information in major accounting identities used to estimate standard errors for each cell in the balanced analytical global SUTs when combined with the adjustment information from the data reconciliation process, as suggested by Lenzen *et al* (2012). The model developed to produce balanced global SUTs in this chapter can also be used to check the consistency of data from different sources that are needed to construct any global SUTs.

5.2 Re-Exports and Re-Export Mark-Up

Theoretically, re-exports can be integrated into the data reconciliation framework presented in this chapter without any difficulties. However, we do not include re-exports in our current reconciliation exercise due to the lack of reliable total re-exports data at country and product level as controls. We are also not able to estimate exports mark-ups when reconciling individual countries' SUTs. Further work is needed to identify data sources for re-exports and estimate the mark-up margins for major re-exporting countries in the world in order to treat them as the re-exporting country's indirect service exports in our future efforts.

5.3 Reliability Weights for National SUT Statistics

We did not estimate reliability weights for national and use statistics. Without a properly estimated reliability index, we have to adjust these proportionally during our reconciliation process. Obviously this will impact on the quality of the model solutions. Research efforts will be made to better estimate all initial data reliabilities.

5.4 Structure of International Transportation Sector

The use structure of international transportation services in our current reconciliation exercise is based on the supply structure estimated from our stage 1 model. Such information is available from detailed trade statistics by transportation modes. We plan to integrate such information into our reconciliation procedure and make the international shipping services an integrated part of the global inter-country IO structure in our future efforts.

5.5 Conclusions

Our data reconciliation exercise has demonstrated that it is feasible to arrive at a balanced global SUT system that preserves the key identities provided by official statistics, or remains very close to them. This is an important improvement on other attempts in this field, which often take simple conventions or include balancing items that allocate inconsistencies implicitly or explicitly to a residual, for example, Rest of the World adjustment, or by diverging from official statistics in an uninformed manner (*ie* without taking into account the relative reliability of the data produced by a given reporting country).

However, as noted above, much more can be done to improve the method. Central to this is the identification of sources that create better indicators of reliability throughout the system. Nevertheless, notwithstanding these areas of potential improvement, the model is already an improvement on current procedures and demonstrates that it is a tool to create tables in an efficient manner, for example it will be able to accommodate revisions in underlying data sources even though they may not (yet or never) be included in official SUTs. In addition the tool provides a means to create more timely estimates of SUTs than currently produced by official statistics institutes; thus providing a means to develop more timely estimates of trade in value added.

The OECD ICIO tables and so the trade in value-added estimates produced in the OECD-WTO initiative currently take national IO tables linked with bilateral trade statistics as their starting point. In coming years, partly because of the increasing availability of national supply–use tables and partly because SUTs are generally more timely than IO tables, the OECD will begin to develop a global SUT that forms the basis of its ICIO database.

REFERENCES

Canning, P., and Z. Wang (2005). A Flexible Mathematical Programming Model to Estimate Interregional Input–Output Accounts. *Journal of Regional Sciences* **45**(3), 539–563.

Eurostat 2008. Eurostat Manual of Supply, Use and input–output Tables, 2008 Edition. http://epp.eurostat.ec.europa.eu/portal/page/portal/product_details/publication?p_product_code=KS-RA-07-013.

Gehlhar, M. (1996). Bilateral Trade Data for Use in GTAP. GTAP Technical Paper 10, Purdue University.

Harrigan, J. F. (1990). The Reconciliation of Inconsistent Economic Data: The Information Gain. *Economic System Research* **2**(1), 17–25.

Johnson, R., and G. Noguera (2012). Fragmentation and Trade in Value Added over Four Decades. Working Paper 18186.

Lenzen, M., K. Kanemoto, D. Moran and A. Geschke (2012). Mapping the structure of the world economy. *Environmental Science and Technology* **46**(15), 8374–8381.

National Research Council. 2006. *Analyzing the US Content of Imports and the Foreign Content of Exports*. Washington, DC: The National Academies Press.

Robinson, S., A. Cattaneo and M. El-Said. (2001). Updating and Estimating a Social Accounting Matrix Using Cross Entropy Methods. *Economic Systems Research* **13**(1), 47–64.

Streicher, G., and R. Stehrer (2012). Whither Panama? Constructing a Consistent And Balanced World SUT System Including International Trade And Transport Margins. WIOD Working Paper 13. URL: http://www.wiod.org/publications/papers/wiod13.pdf.

Stone, R. (1942). The Precision of National Income Estimates. *The Review of Economic Studies* **9**(2), 111–125.

Stone, R., D. G. Champernowne and J. E. Meade (1942). The Precision of National Income Estimates. *Review of Economic Studies* **9**(2), 110–125.

Timmer, M., A. A. Erumban, J. Francois, A. Genty, R. Gouma, B. Los, F. Neuwahl, O. Pindyuk, J. Poeschl, J. M. Rueda-Cantuche, R. Stehrer, G. Streicher, U. Temurshoev, A. Villanueva and G. J. de Vries (2012). The World Input–Output Database (WIOD): Contents, Sources And Methods. WIOD Background Document. URL http://www.wiod.org/.

United Nations Statistics Division (2011). 'International Trade Information Systems in 2020', *Global Forum on Trade Statistics, Geneva, 2–4 February 2011*. Background Note by UNSD, Eurostat and WTO.

van der Ploeg, F. (1984). General Least Squares Methods for Balancing Large Systems and Tables of National Accounts. *Review of Public Data Use* **12**, 17–33.

Wang, Z. (2011). A Model to Construct Time Series Databases for Global Trade, Production, and Consumption Linkages. Paper presented at World Bank Workshop on

'Fragmentation of Global Production and Trade in Value Added: Developing New Measures of Cross Border Trade', 9–10 June 2011, Washington DC.

Wang, Z., M. Gehlhar and S. Yao (2010). A Globally Consistent Framework for Reliability-Based Trade Statistics Reconciliation in the Presence of an Entrepôt. *China Economic Review* **21**(1), 161–189.

Wang, Z., M. Tsigas and M. Gehlhar (2012). How a Global Inter-Country Input–Output Table with a Processing Trade Account is Constructed from the GTAP Database. Paper Presented at the 15th Annual Conference on Global Economic Analysis, Geneva, Switzerland.

Weale, M. R. (1985). Testing Linear Hypotheses on National Account Data. *Review of Economics and Statistics* **67**, 685–689.

11

Direct Measurement of Global Value Chains: Collecting Product- and Firm-Level Statistics on Value Added and Business Function Outsourcing and Offshoring

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1 INTRODUCTION: WHY NEW FIRM-LEVEL STATISTICS ON VALUE ADDED AND INTERNATIONAL SOURCING ARE NEEDED NOW

International trade and foreign direct investment have long been central features of the world economy, but their importance has been growing rapidly, especially since the late 1980s. Alongside this quantitative change, a qualitative shift has also been taking place. Because of advances in information technology, which enable business processes to be segmented and potentially relocated, and the rise of industrial capabilities in less developed countries, which offer more options for relocating them, the production of goods and services has become increasingly fragmented across borders. In other words, it has become more common for value to be added to a product in two or more countries prior to final use in both goods- and services-producing industries. The emergence of global value chains (GVCs)[1] of this sort has led researchers

[1]Researchers studying this structural shift in the global economy have generated a very long list of terms to describe it. The international trade literature has stimulated a vast body of research and multiple labels, including a new international division of labour (Fröbel *et al* 1980), multistage production (Dixit and Grossman 1982), slicing up the value chain (Krugman 1995), the disintegration of production (Feenstra 1998), fragmentation (Arndt and Kierzkowski 2001), vertical specialisation (Hummels *et al* 2001; Dean *et al* 2007), global production sharing (Yeats 2001), offshore outsourcing (Doh 2005) and integrative trade (Maule 2006). The enduring structures that embody these new forms of trade and investment have been referred to as global commodity chains (Gereffi 1994; Bair 2009), global production networks (Borrus *et al* 2000; Henderson *et al* 2002), international supply chains (Escaith *et al* 2010) and global value chains (GVCs), the term we will use here (Humphrey and Schmitz 2002; Kaplinsky 2005; Gereffi *et al* 2005; Kawakami 2011; Cattaneo *et al* 2010).

and the providers of official economic statistics to acknowledge a growing knowledge gap in regard to the flow of intermediate goods and services and the location of value added.

Why is this important? It used to be safe to assume that all of an import's value was added in the exporting country. This gave trade statistics a great deal of analytic value and policy relevance. In this simpler world, industrial capabilities could be judged by the quality and technological content of exports, trade rules could be tied to gross levels of trade in specific products or product sets, and exports could be directly related to domestic job creation. 'Rules of origin' labelling requirements are also based on the assumption of nationally bounded production, but today it is difficult to know what labels such as 'made in China' or 'made in the USA' really mean. With GVCs complicating the picture, we simply cannot know what share of an imported product's or service's value is added in the country that declares it as an export, and thus, we are less able to judge that country's level of development from the technological sophistication of its exports, following Lall (2000). Flows of intermediate goods provide hints about the structure of GVCs (see Feenstra 1998; Brülhart 2009; Sturgeon and Memedovic 2010), but because we do not generally know how imported inputs are used in specific products, or how they are combined with domestic inputs and value added, it is not possible to extract concrete information about the geographic distribution and flow of value added from trade statistics alone.

What is certain is that using the gross value of trade as a yardstick distorts our view of where in the world industrial capabilities lie, creates uncertainty about the fairness of trade agreements and even calls into question such fundamental measures as gross domestic product (GDP) and productivity (Houseman 2011). These data and policy gaps have triggered innovative efforts to link national input–output (IO) tables into larger international (global and regional) input–output tables (IIOs) that researchers can use to estimate trade in value added, among other things (OECD 2011b). With data of this sort, we can begin to answer the question 'who wins and who loses from globalisation?' from the supply side (*ie* winners and losers in terms of value added, value capture and employment), rather than only the demand side (*ie* winners and losers in terms of consumer prices versus jobs and wages).

Despite the progress that IIO tables represent, the estimation and cross-border harmonisation required to construct them decrease detail and accuracy. National IO matrices, in countries where they exist, are based on very partial data to begin with, and rely on a range of inferences and (sometimes controversial) assumptions, such as the proportionality of imported inputs across all sectors (Grossman and Rossi-Hansberg 2006; Winkler and Milberg 2009). When national IO data sets are linked across borders, these problems are compounded as industry categories are harmonised at high levels of aggregation and additional layers of assumption and inference are added to fill in missing data. Statisticians must 'cook the books' to bring IO tables from multiple countries into alignment.

Such data gaps are especially acute in services, where product detail is sorely lacking and vast inferences are made to settle national accounts.[2] Almost all of the defining features of services (that is, they are non-tradeable, non-storable, customised and insensitive to price competition) are changing in ways that enable and motivate the formation of GVCs. As a result, task fragmentation and trade in services are burgeoning, both domestically and internationally, through the twin processes of outsourcing and offshoring. Computerisation is allowing a growing range of service tasks to be standardised, codified, modularised and more readily and cheaply transmitted among individuals and organisations that might be at great distance from one another.

Clearly, the assumptions behind current data regimes have changed and statistical systems are struggling to catch up. In this chapter, we confront the obvious. It will be exceedingly difficult to fill data gaps without new data. Using existing data in new ways, including generating groupings of traded products that better reflect GVCs, (see, for example, Sturgeon and Memedovic 2010) and linking 'microdata' from surveys to administrative sources such as business registers (see, for example, Bernard *et al* 2005, 2006; Nielsen and Tilewska 2011) can lead to new insights, but they may never be enough. Statistical analysis that relies solely on existing data sources will always reflect the limits of the content of surveys and data sources. New data will be needed and, because GVCs are by definition a cross-border phenomenon, international standardisation will be essential. At the same time, resources for data collection and the political will required to burden private sector respondents with surveys are declining in many countries. Clearly, current priorities will need to be adjusted so new data can be collected without unduly increasing the burden on respondents.

[2]Why are the data resources related to services so poor? One reason is that the data are difficult to collect. While companies might track the source of every physical input to manufacturing, for warranty or quality control purposes, services expenditures are typically grouped into very coarse categories, such as 'purchased services'. The absence of tariffs on services, and their non-physical character, mean that when service work moves across borders, no customs forms are filled out and no customs data are generated. Another reason is that service work has historically been thought to consist of non-routine activities that require face-to-face contact between producers and users. Services as different as haircuts and legal advice have traditionally been consumed, in place, as soon as they are produced. The customised and ephemeral nature of many services has led them to be considered 'non-tradeable' by economists, or at least very 'sticky' in a geographic sense relative to the production of tangible goods. Finally, services have long been viewed as ancillary to manufacturing, either as direct inputs (*eg* transportation) or as services provided to people who worked in manufacturing (*eg* residential construction, retail sales, *etc*). As such, services have been viewed as a by-product, not a source, of economic growth. Thus, data collection on services has historically been given a low priority by statistical agencies (Sturgeon *et al* 2006; Sturgeon and Gereffi 2009), although the need for statistical evidence for policymaking has been clearly articulated (Commission of the European Communities, 2003).

While collecting new data on a globally harmonised basis, for this is what is needed, is a daunting task, we need to begin to test the results of research using IIOs with standardised case studies and proof-of-concept surveys, and, eventually, to replace inferred data with real data in both goods- and services-producing industries. The solution will inevitably include new 'bottom-up' business surveys to complement the 'top-down' efforts of IIOs. This chapter outlines two such efforts: product-level GVC studies and business function surveys.

2 PRODUCT-LEVEL GVC STUDIES

The most direct way to measure the geography of value added is to decompose individual goods and services into their component parts and trace the value added of each stage of production to its source. The procedure yields product-level estimates that identify the largest beneficiaries in terms of value added, value capture (*ie* profits) and employment. Beneficiaries can be firms, workers, countries or all of the above. Studies in this vein have shown that China's export values often bear little relation to domestic value added because many exported products contain expensive imported inputs, and the lion's share of profits tends to be captured upstream from production, in the design and branding activities of the 'lead firm' in the value chains, and downstream by distributors, value-added resellers, and retailers.

This situation is common when assembly is performed by domestic or foreign-owned contract manufacturers on behalf of multinational brand name or 'lead' firms, a pattern of industrial organisation that has been a key driver of economic development in China, elsewhere in developing East Asia, and other places in the world with deep linkages to GVCs, such as Eastern Europe and Mexico (Grunwald and Flamm 1985; Gereffi and Korzeniewicz 1994; Borrus *et al* 2000; Sturgeon and Lester 2004). Because foreign components are commonly specified in designs worked out in the lead firm's home country, key components and subsystems are often sourced from vendors close to the lead firm, in addition to a palette of well-known component suppliers from countries across the globe. In technologically intensive industries and value chain segments, these supplier and component manufacturing firms tend to be concentrated in OECD or newly industrialised countries, especially Taiwan (Chinese Taipei). To add to the complexity of GVCs, each of these supplier firms might outsource production or have an affiliate in a third country, in a pattern Gereffi (1999) refers to as 'triangle manufacturing'.

Product-level GVC studies are designed to shed light on where value is added and captured in these complex cross-border business networks. The first product-level GVC study, on a specific Barbie doll model, appeared in the *Los Angeles Times* (Tempest 1996). The Barbie case was then included in a classic paper by trade economist Robert Feenstra (1998) to bolster his

Table 11.1: *The location of value added and capture for a 'Tea Party Barbie' doll, 1996.*

Production, inputs and contract management	Value ($)
Materials	0.65
Saudi Arabia: Oil	
Hong Kong: management, shipping	
Taiwan (Chinese Taipei): refines oil into ethylene for for plastic pellets for Barbie's body	
Japan: nylon hair	
US: cardboard packaging, paint pigments, moulds	
Production: China (factory space, labour, electricity)	0.35
Overhead and coordination of production and	1.00
outbound shipping: Hong Kong	1.00
Export value (factory price):	**2.00**
US: shipping, US ground transportation, wholesale and retail markups	6.99
US: Mattel Inc. (lead firm: design, marketing)	1.00
US retail price:	**9.99**

Sources: Tempest (1996) from US Commerce Department, Chinese Ministry of Foreign Trade Economic Cooperation, Mattel Inc., Hong Kong Toy Council.

argument that the rise of intermediate goods trade was caused, in part, by 'the disintegration of production in the global economy' leading to double counting of intermediate goods as they wended their way through international production networks. The findings of this widely publicised case are summarised in Table 11.1, which shows that only 35 cents (3.5%) of the value of a US$10 'Tea Party' Barbie doll (3.5%) was added in mainland China, where it was assembled, largely of imported materials.

The lead firm most commonly used in subsequent product-level GVC research is Apple Inc., the company behind the popular iPod, iPhone and iPad consumer electronics devices, as well as the Macintosh line of personal computers (Linden *et al* 2007, 2009 2011; Hesseldahl 2010). Most recently, the OECD (2011b, p. 40), examining the sources of components for a late-model Apple smartphone (the iPhone 4) that retails for about $600, estimates that only $6.54 (3.4%) of the total factory *price* of $194.04 was actually added in China, where the product is assembled by the Taiwanese electronics contract manufacturer Foxconn. This is because $187.50 (96.6%) of the factory *cost* came from imported materials and components, most notably from South Korea, the USA and Germany.

Analysis of traded goods from other electronics firms has yielded similar results. For example, a study of a 2005 Hewlett-Packard (HP) notebook computer model (model nc6230) found that none of the major components originated in China, where a Chinese Taiwan-based contract manufacturer assembled it (Dedrick *et al* 2010). Yet the full factory price of $856.33 would have counted as part of the gross value of mainland Chinese exports. Ali-Yrkkö *et al* (2010) obtained similar results in their study of a Nokia mobile-phone handset.

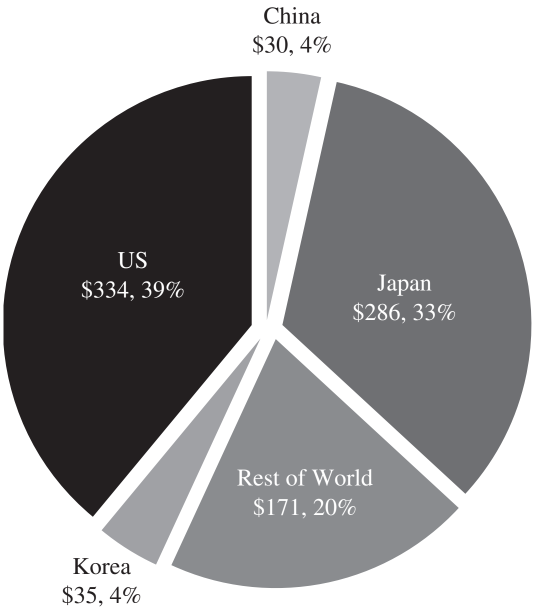

Figure 11.1: *Geography of value added in a Hewlett-Packard notebook computer.*

Source: based on Dedrick *et al* (2010, Table A-3). The factory cost of the product in 2005 was $856. The amounts shown for each country, except China, are the total cost of inputs from firms headquartered in that country. No inputs came from Chinese companies, so the $30 assigned to China is an estimate of value added that was subtracted from the cost of inputs from 'Rest of World'.

Clearly export value is a highly misleading measure of China's benefit from export trade. A more meaningful measure of the benefit to China's economy would be calculated in value-added terms. A simple approximation of value added is the sum of operating profit, direct labour wages, and depreciation. Going back to the study of the HP notebook computer by Dedrick *et al* (2010), because there were no Chinese firms among the major suppliers, China earned no profit (and thus booked no depreciation related to this product). That leaves direct labour as a source of value added. The cost of assembly and test, which took place in China and is mostly wages, came to $23.76, some of which would be retained as profit by the Taiwanese assembly company. Some of the smaller inputs may have received final processing in China, but this typically amounts to a very small percentage of value added, no more than a few dollars in this case. On this basis, Dedrick *et al* estimate that China's value added to this product at $30. In this example, then, assigning China the full factory price of $856.33 overstates its value added by more than 2,800%! This is because $826.33 (96.5%) of the factory *cost* went to imported materials and components, mainly from firms based in South Korea, the USA and Japan (see Figure 11.1).

Judging from prior research on similar GVCs (Sturgeon 2003), it is very likely that most if not all high-value components were specified by HP's design group in the USA, and purchased by the company's contract manufacturer under terms that HP negotiated directly with its main component suppliers. This underscores the powerful role played by HP—the 'lead firm' in the GVC—even though the company may have taken no physical ownership of work-in-process inventory. HP's role is as a buyer of manufacturing and logistics services, a conceiver and marketer of the product and an orchestrator of the GVC. While this role allows HP to extract the lion's share of profit from the ultimate sale of the computer, it is mostly or even entirely invisible in trade statistics. This creates a difficult methodological problem. To fill in this gap Linden *et al* (2009, 2011) estimated value added and employment in upstream activities, such as research and development (R&D) and marketing, from the ratio of the target product's sales in total firm revenues. One outcome of this exercise was an estimate that the share of US-based employees in the total iPod-related wages (from R&D to retail) paid worldwide in 2006 was 70%, considerably higher than the estimated share of US-based companies in the global distribution of gross profit from the iPod hardware alone.

Product-level GVC studies typically look only one value-chain level upstream from final assembly. However, a sub-system company may produce or purchase high value sub-assemblies and components in a third country (*eg* Singapore and Malaysia are common locations for the production of head assemblies for hard drives). Estimates of the actual geography of value added must be made, and these require a great deal of industry knowledge. In IO analysis, industry knowledge is not required because both direct and indirect value added for any imported or domestic intermediate inputs are taken into account as a standard part of the estimates. However, as discussed below, GVC analysis can potentially separate the geographical assignment of the two chief elements of value added (wages and profits), whereas IO analysis cannot.

The focus of the product-level GVC research cited in this section is on highly popular consumer electronics products such as those from Apple, Hewlett-Packard and Nokia.[3] This is no accident, since the research mainly relies on data from private consulting firm 'teardown reports' itemising and naming the suppliers of the high-value components used in each product. These reports are based on physical disassembly and examination of component parts. Because such reports are available for only the most high profile items, product-level GVC study methods have been difficult to generalise. Moreover, the electronics products that teardown reports analyse typically contain hundreds of clearly identifiable components with relatively transparent world

[3] An exception is a set of five case studies from the shoe industry conducted by the Swedish National Board of trade (2007).

For the finished product...

1. Make, model/SKU and average selling price of the product.
2. Value when it leaves the factory ('factory price').
3. The percentage of factory costs accounted for by 'materials', 'labour' and 'other (specify)'.
4. List of top material inputs (however many it takes to account for 75–80% of factory costs), typically listed in the BOM.
5. The cost of assembly (converting inputs into final products) as they were in a specific time period (*eg* late 2010) when the product was being made.
6. Approximate number of units manufactured in the specified period.
7. Share of shipments within the specified period to each type of recipient (*eg* direct to consumer, OEM customer, distributor, value-added resellers, retailers).
8. Share of shipment in 2010 by country or regional location (*eg* USA, Japan, China, other Asia, Europe, other North America).

For each of the inputs...

1. Short description.
2. Name of manufacturere/supplier.
3. Country where manufactured.
4. Average cost (price) of input to company assembling the product in the specified time period.

Figure 11.2: *Basic data needed for product-level GVC studies.*

prices. The most valuable components tend to bear the names of their manufacturers, and can thus be traced to their country of manufacture. Studies of automobiles, which have many model-specific parts without published prices, or apparel products made from fabrics that might have been produced by a number of suppliers in multiple locations, are more difficult to decompose and value after the fact. Asking firms for the data directly is possible, but most firms tend to be unwilling to share this sort of strategically sensitive information with researchers, even with assurances of confidentiality.

Despite the difficulties of extending the method to different industries, product-level GVC studies continue to proliferate. Although it has not yet been used in published work, we are aware of several active research projects that are using the product-level GVC approach to study a variety of industries, including wind turbines and other mechanical products, small cc motorcycles and women's apparel. For consistency and comparability, a standardised, or least mutually compatible, approach is needed. In the interest of moving in this direction, we specify a set of research requirements for product-level GVC studies below. The best-case approach we lay out here assumes full cooperation or mandatory compliance by participating firms. While such compliance may be difficult or even impossible to come by, our goal is to set a high initial standard that can be adjusted in the face of pragmatic considerations. Ideally, factory prices and costs would be directly from manufacturing companies, at the point of production, or from some other corporate office where data itemising the bill of materials (BOM) for specific products is held. A BOM typically designates the part number (or other designation) and cost of each input. The basic data needed to collect information on value added at the product level are presented in Figure 11.2.

First, the product needs to be identified, either by its make and model or by its stock keeping unit (SKU) number. Then, the factory price of the product is collected, along with internal costs for labour, materials and other costs (mostly overhead) directly related to production. Then, a list of the most valuable materials and other inputs, perhaps derived from the BOM, is collected.

The next step is to estimate the profit margins and/or employment associated with the final product and with each of the key inputs. If the analysis extends to the retail end of the value chain, then data about the structure and geography of sales channels (items 7 and 8 in Figure 11.2) should also be analysed and the average selling price at retail estimated. As this brief description shows, the data requirements for a product-specific analysis are considerable. Again, the data are often hard to obtain because of their commercial sensitivity and the results are difficult to generalise because they only represent a single product.

An approach that avoids targeting a single product or company is the use of average breakdowns of component values for a generic product type (*eg* notebook PC, 2 MW wind turbine). Sometimes data of this sort can be obtained through industry associations willing to cooperate with researchers by requesting data from their membership. These average values can be combined with qualitative value chain analysis (see Gereffi and Fernandez-Stark 2011) to identify the industry's key lead firms and main suppliers. With this information it is possible to construct industry- or subsector-level estimates of the geography of value capture. Again, although it has not yet been used in published work, we are aware of active research using this approach.

As we mentioned earlier, product-level GVC studies can complement studies using official statistics. For example, Koopman *et al* (2008) combine standard IO tables with information that separates processing and normal trade, all from official sources in China. This study estimates that about half of the gross value of total Chinese exports is derived from imported inputs, rising to 80% for technology-intensive sectors such as electronics. For export processing production as a whole, primarily consisting of products branded by non-Chinese firms, foreign value added was estimated to be 82% in 2006 (Koopman *et al* 2008, p. 19). These findings suggest that the product-level cases of iPods, iPhones, iPads and similar consumer electronics goods produced in China for export, may not be that extreme.

Again, the product-level approach makes it conceivable to go further and separate out the labour and profit components of value added.[4] Consider the example of a Japanese-branded hard disk drive assembled in China from imported parts before it is included in a notebook PC such as the Hewlett-Packard model nc6230 notebook computer discussed above. According to information from an executive in the hard drive industry, the value added attributable to hard drive assembly wages is about 7% ($4.76) of the $68 wholesale price of the drive, and the value added corresponding to the Japanese firm's gross profit is about 20% ($13.60). If all of the value added of the hard drive (*ie* 27% of the wholesale price, or $18.36) is assigned to China (assuming the drive was assembled there), then local value added is overestimated by nearly 300%. If, on the other hand, all of the value is assigned to Japan, then Japanese value added is only overstated by 35% and Chinese value added is underestimated by a relatively small amount. Since pragmatic considerations may limit the number of value-chain levels in which these types of detail can be collected, it is clearly better to err on the side of assigning value to the country where the sub-system company is headquartered in industries where labour accounts for a much smaller share of value added than does profit. International IO studies, however, would do the opposite, assigning all the value added to the location where the work is performed.

Product-level GVC studies are demanding in terms of industry knowledge, but they are the only method to enable separate treatment of the labour and profit components of value added. They require knowledge of the headquarter locations of participating firms (for profit accounting) and their factory locations (for labour accounting) and must have a means to estimate the split between them. International IOs, by default, assign all the value added to the factory location. Despite the challenges, product-level studies are worth performing from time to time as a check on the robustness of measures of the distribution of value from world trade that are derived from official statistics.

Product-level GVC studies are important not only because they suggest that the local value in manufactured goods exports can be vastly overstated, but also because exports may overstate the exporting country's technological attainments. Goods manufactured in developing countries are often leading edge in terms of markets and technology. Hence, the technological sophistication and competitive stature of an exporter's industrial base can be exaggerated when exports are used as a measure of industrial capability. Not only are most technology-intensive parts produced in industrialised countries, but so too are the 'knowledge work' and the intangible assets involved in system-level design, product strategy, marketing, brand management and supply chain orchestration.

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[4]Value added is the difference between the selling price and the cost of acquired inputs. In practice, however, this is equal to some measure of profit plus wages plus some accounting values such as depreciation.

This is important not only for the value that these activities create, but also because they are the key elements in competitive performance, innovation and new industry creation: the bedrock of economic development. Even the cutting-edge production equipment and logistics systems used for the manufacture of products such as notebook computers and smart phones are not 'native' to mainland China or other less developed countries in East Asia, but implanted there by firms based in Taiwan (Chinese Taipei), South Korea and OECD countries (Steinfeld 2004). This has important policy implications. While product-level GVC studies suggest that the competitive 'threat' to advanced economies posed by indigenous Chinese capabilities may be vastly overstated, not only in the popular press but in policy circles, massive exports do reflect large-scale employment, even if they are based on non-indigenous innovations and market success. The result could be an increasing disjuncture between innovation and employment that will lead, if not to wholesale economic decline, at least into uncharted waters.

3 BUSINESS FUNCTION SURVEYS

There is a pervasive dynamic working against the usefulness of current business statistics. On the one hand, production is becoming increasingly bundled with services. On the other hand, it has become easier to fragment the value chain geographically. Thus, value added cannot be fully determined by tallying up the physical inputs to products listed as outputs. A range of largely intangible 'support' functions (*eg* R&D, sales, marketing, IT systems) also add value and, like production, these support functions are available from suppliers and service providers outside the firm and in a variety of locations around the world.

Thus, GVCs are expanding the arena of sourcing and competition beyond main products to the vertical *business function* that can be offered (horizontally, to diverse customers) as more or less generic goods and services within and across industries. Firms not only outsource the assembly of goods, and source tangible inputs in GVCs (as captured by product-level GVC studies), but they increasingly outsource and sometimes even offshore intangible services and support functions as well. These include IT services, back-office work such as payroll and accounting, call centres for sales or customer support, and even engineering and elements of R&D (Dossani and Kenney 2003; Gereffi and Fernandez-Stark 2010).

We argue that these trends require a new statistical unit of analysis to supplement the main activity/industry of the firm—*ie* the business function—and new surveys to capture how they are sourced and to quantify their value. Business function surveys are ideal for collecting data on the location of value added for three reasons. First, because they consist of intangible services, the value added by support functions has proven very difficult to capture, classify and quantify. Second, the parsimony of business function lists (see Box 11.1) reduces respondent burden, while still generating data that can be compared and aggregated across firms, countries and industries. In fact, the business function approach does away with any hard distinction between goods- and services-producing firms. The primary output of a firm may be a good or a service, but the array of support functions that may or may not be done by the firm are roughly the same. Third, experience with ground-breaking surveys (Brown 2008) suggests that data quality tends to be high because business functions are in keeping with the way many managers think about and account for their operations.

Box 11.1. Seven business functions used in the european survey on international sourcing.[5] In the European International Sourcing survey, seven business functions (plus a residual 'other' category) were identified using the European Central Product by Activity (CPA) classification.

1. *Core/primary business functions:* production of final goods or services intended for the market or third parties carried out by the enterprise and yielding income. The core business function usually represents the primary activity of the enterprise. It may also include other (secondary) activities if the enterprise considers these to comprise part of its core functions.

2. *Support business functions:* support business functions (ancillary activities) are carried out in order to permit or facilitate production of goods or services intended for sale. The outputs of the support business functions are not themselves intended to be directly for sale. The support business functions in the survey are divided into the following.

   (a) *Distribution and logistics:* this support function consists of transportation activities, warehousing and order processing functions. In figures and tables, 'distribution' is used as an abbreviation for this function.

   (b) *Marketing, sales and after-sales services including help desks and call centres:* this support function consists of market research, advertising, direct marketing services (telemarketing), exhibitions, fairs and other marketing or sales services. It also includes call-centre services and after-sales services, such as help desks and other customer support services. In figures and tables 'marketing, sales' is used as an abbreviation for this function.

   (c) *Information and communications technology (ICT) services:* this support function includes IT services and telecommunications. IT services consist of hardware and software consultancy, customised software data processing and database services, maintenance and repair, web-hosting, other computer related and information services. Packaged software and hardware are excluded. In figures and tables 'ICT services' is used as an abbreviation for this function.

(d) *Administrative and management functions:* this support function includes legal services, accounting, bookkeeping and auditing, business management and consultancy, HR management (*eg* training and education, staff recruitment, provision of temporary personnel, payroll management, health and medical services), corporate financial and insurance services. Procurement functions are included as well. In figures and tables 'Administration' is used as an abbreviation for this function.

(e) *Engineering and related technical services:* this support function includes engineering and related technical consultancy, technical testing, analysis and certification. Design services are included as well. In figures and tables 'Engineering' is used as an abbreviation for this function.

(f) *Research & Development:* this support function includes intramural research and experimental development. In figures and tables 'R&D' is used as an abbreviation for this function.

Not only is the business function classification useful for tracing the organisational and geographic location of value added, but also as a high-level stand-in for occupational categories, since jobs can also be tallied according to their general function within the organisation. Since the business function approach aggregates product and services into a limited number of well-defined categories, it has proven feasible for large-scale surveys. Two of these implementations are described in some detail in the latter sections of the chapter.

3.1 Business Function Lists

We are only just beginning to develop standard methods for collecting economic data according to business functions. In this section we provide some examples from recent and current surveys.

Firms or their main operations units[6] typically have a main output, be it a good or service. In a statistical context, the function that produces this output typically determines the firm's industry classification using standardised activity/industrial codes such as its ISIC, NACE or NAICS classification. Instead of counting all output and employment under this main output classification,

[6]Large firms may have several distinct operational units with distinct outputs. These are variously called divisions, lines of business or business segments. For such firms it is sometimes best to collect data at this level.

as business censuses typically do, business function surveys supplement the primary output function with a standardised, generic list of support functions (see Box 11.1). In other words, firm-level data (*eg* occupational employment, wage levels paid, internal, external and international sourcing costs) is collected for specific functions rather than for the firm as a whole. In the business function frameworks developed so far, the main productive function of the firm has been designated variously as ‘production’ (Porter 1985), the ‘core function’ (Nielsen 2008), ‘operations’ (Brown 2008) and the ‘primary’ business function (Brown and Sturgeon, forthcoming). Even if the terminology used differs, the approach is similar in the sense that it distinguishes between the primary business function and a generic list of functions that ‘support’ it.

Conceptually, Michael Porter pioneered the business function approach. In his 1985 book, *Competitive Advantage*, he identified a list of nine generic business functions: R&D; design; production; marketing and sales; distribution; customer service; firm infrastructure; human resources; and technology development.

To our knowledge, the earliest use of a business function list to collect economic data was for the EMERGENCE Project (Huws and Dahlman 2004), funded by the European Commission. This research used a list of seven business functions tailored to collect information about the outsourcing of information-technology-related functions, such as software development and data processing. Such industry-specific bias in business function lists can simplify data collection and focus research on specific questions (such as IT outsourcing), but the results cannot be easily compared with or aggregated with other data, and they increase the risk of creating non-exhaustive lists. When business function lists are non-exhaustive, they leave some functions unexamined and block a comprehensive firm-level view of employment or value added. Again, while non-exhaustive business function lists are useful for examining specific business practices and firm-level characteristics, they are not well suited for general use as a parsimonious alternative for, or supplement to, industry and occupational classifications. An exhaustive list similar to Porter’s was developed for the European Union (EU) Survey on International Sourcing (Nielsen 2008) and adopted by Statistics Canada for the 2009 Survey of Innovation and Business Strategy (SIBS)[7] (again, see Box 11.1).[8]

Business function data can be used to inform a wide variety of research and policy questions. For example, they can be used to characterise patterns of business function bundling in respondent firms (*ie* organisational design

[7]See http://www.ic.gc.ca/eic/site/eas-aes.nsf/eng/h_ra02092.html.

[8]In contrast, the EMERGENCE project list (Huws and Dahlman 2004) and a more recent list developed by the Offshoring Research Network for the purpose of detecting R&D offshoring (Lewin *et al* 2009) did not include a category for the firm’s main operational function, but instead used a list of commonly outsourced functions (product development, IT services, back-office functions, call centres, *etc*). Again, non-exhaustive lists of this sort cannot provide a full picture of firm organisation or sourcing patterns.

as indicated by employment or costs/revenues by function), to collect data on wages by function as a high-level stand-in for detailed data on occupational employment and, critically for the purposes of this volume, to examine firm-level patterns of domestic and international sourcing (value added). Potentially, business function lists might supplement, or even partially substitute for, the long lists of industry-specific product trailers that underlie IO tables in settings with severe resource constraints. The main strength of the business function approach is its potential to identify and measure support activities and other intangible assets within the firm (R&D or customer service capabilities) in a way that is easily comparable across sectors and countries.

3.2 Using Business Function Surveys to Collect Data on External and International Sourcing: The Eurostat International Sourcing Survey

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This section provides some illustrations of business function data from the 2007 Eurostat International Sourcing Survey (Nielsen *et al* 2008). The results show how business function surveys can provide insights into a complex and hard-to-research topics such as international sourcing.

The survey was an economy-wide ad-hoc survey carried out by 12 European countries in 2007, covering the so-called non-financial business economy. The survey asked about sourcing decisions made by European firms in the period 2001–6. The focus of the survey was on larger enterprises, as multinational groups of enterprises were considered to be the key players and drivers for international sourcing. A bottom threshold of 100 or more employees was used, although statistical offices in several countries decided to lower the threshold to enterprises with 50 or more employees. This section uses the information from 4–12 European countries, based on data availability. The survey did not ask respondents to quantify the value of their external and international sourcing, only to indicate if they had made such choices or not. (However, subsequent business function surveys have quantified the value of sourcing by business function, as we will see in the following section.)

For the 12 European countries listed in Figure 11.3 the 2007 Eurostat International Sourcing Survey found that 16% of the enterprises with 100 or more employees had sourced one or more business function abroad. More than twice as many enterprises in Ireland and the United Kingdom did so (38% and 35%, respectively). The two small and open Nordic economies, Denmark (25%) and Finland (22%), were also significantly above the average. Germany (13%) was just below the average. Figure 11.3 shows the frequency of international sourcing for R&D and engineering functions.

The business function most frequently outsourced internationally was the core (primary) function. Interestingly, the core business function is the only function sourced more frequently internationally than domestically. This was especially true for manufacturing firms in high wage countries such as Denmark. More surprisingly, R&D was as frequently sourced internationally as it was domestically.

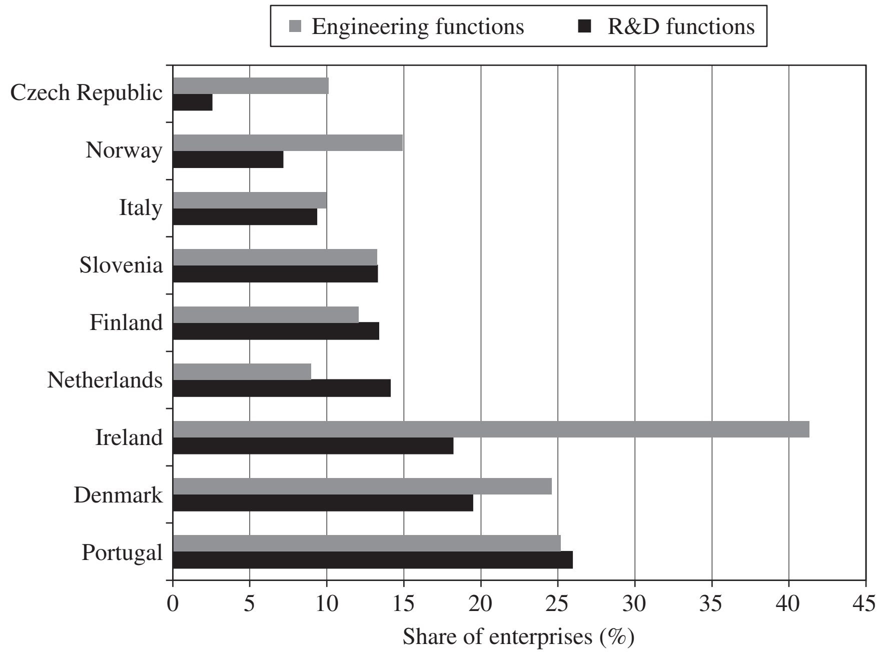

Figure 11.3: *R&D and engineering functions sourced internationally by enterprises in selected European countries, 2001–6.*

Source: Eurostat report data, http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Global_value_chains_-_international_sourcing_to_China_and_India.

In the four Northern European countries listed in Table 11.2, the study found that 30–40% of the firms surveyed made decisions to source support functions internationally. Manufacturing enterprises sourced a variety of support functions internationally, but engineering, distribution and ICT functions were the most common. Compared to manufacturing enterprises, service enterprises were more likely to keep their core function in-house while sourcing support functions internationally, as shown in Table 11.3. For services enterprises, the functions most commonly sourced internationally are ICT and administration.

3.3 Using Business Function Surveys to Shed Light on the Relationship Between International Sourcing and Employment

International sourcing has mainly been perceived as a driver of lower-skilled job loss, especially in labour-intensive manufacturing activities, such as product assembly. Indeed, as we have just shown, the 2007 Eurostat International Sourcing Survey found that manufacturing enterprises were more likely to be engaged in international than other enterprises. Why are some jobs vulnerable

Table 11.2: *Business functions sourced internationally by manufacturing enterprises in selected European countries, 2001–6: share of enterprises carrying out international sourcing (%).*

	Denmark	Finland	Netherlands	Norway
Core/primary function	70	71	73	60
Distribution	20	21	17	13
Marketing and sales	12	23	15	13
ICT services	17	21	25	12
Administration	9	14	19	11
Engineering	22	11	7	17
R&D	14	10	15	7
Other functions	5	2	2	20

Source: Nielsen (2008). Enterprises have 50 or more employees, except for the Netherlands, covering 100 or more employees.

Table 11.3: *Business functions sourced internationally by services enterprises in selected countries, 2001–6: share of enterprises carrying out international sourcing (%)*

	Denmark	Finland	Netherlands	Norway
Core/primary function	28	39	42	16
Distribution	28	18	27	7
Marketing and sales	24	28	10	27
ICT services	41	33	27	42
Administration	30	30	25	37
Engineering	17	9	4	11
R&D	17	21	11	7
Other functions	6	10	3	12

Source: Nielsen (2008). Enterprises have 50 or more employees, except for the Netherlands, covering 100 or more employees.

to international sourcing while others are less so? Economists have developed a variety of measures based on occupational or job characteristics to determine the ‘offshorability’ of jobs (Kletzer 2009; Blinder and Krueger 2009). In one example of this approach, survey respondents were directly asked about the difficulty of having their work performed by someone in a remote location (Blinder and Krueger 2009). Based on the worker’s description of his or her job tasks, the researchers decided how ‘offshorable’ each job was by using professional coders to rank the ‘offshorability’ of each occupation. Another example identified a list of US occupations (at the three-digit level) that are ‘potentially affected by offshoring’ based on ‘offshorability attributes’ of occupations, including the use of information and communication technologies, the use of highly codifiable knowledge and the degree of face-to-face contact (van Welsum and Reif 2009).

The most sophisticated attempt to classify jobs according to their vulnerability to trade is the movability index ('M Index') developed by Jensen and Kletzer (2006). The M Index uses the detailed job descriptions in the Occupational Information Network (O*NET) database[9] that describe the degree of face-to-face customer contact, use of codifiable information and appearance of Internet-enabled work processes to characterise work in specific occupations. They assign a value to each six-digit occupational code based on an examination of the O*NET job description and researchers' characterization of how movable the occupation is. The M Index is based upon eleven job characteristics divided into two categories: information content (*eg* getting, processing, analysing information; Internet enabled) and job process (*eg* face-to-face contact; performing or working directly with the public; routine nature of work in making decisions and solving problems). A similar concept is behind the literature on 'trade in tasks', which also uses O*NET descriptions to consider which work tasks are vulnerable to relocation (see, for example, Grossman and Rossi-Hansberg 2012).

However, there is a fundamental conceptual flaw in using individual tasks and jobs as a unit of analysis in determining how easy it is to fragment and relocate work in the context of geographically extensive, yet operationally integrated production networks. Qualitative field research on how companies set up GVCs (see, for example, Dossani and Kenney 2003; Berger *et al* 2005) suggests that the processes of outsourcing and offshoring are rarely dominated by the shift of individual jobs to distant locations or outside suppliers. Although it is certainly possible,[10] this is even less likely with individual tasks. More common is the outsourcing (and possible offshoring) of larger groups of employees working on a coherent body of activities, such as manufacturing, accounts payable or after-sales service. In other words, it is more likely that *business functions* will be outsourced, rather than individual jobs and tasks. The character (tacitness versus codifiability) of the tasks, jobs and occupations may be far less important than the character of the linkages between domestic and foreign operations, *ie* if instructions and requirements can be easily and clearly transmitted to the remote work site, as well at the ease of transferring the output to the following stage in the value chain. The business function may require the exchange of a great deal of tacit information, but as long as those exchanges occur within the work group and the inbound and outbound information flow can be codified and transported efficiently, the function can be readily outsourced and offshored, all other factors being equal (*eg* there has to be enough competence in the supply base to take on the function, following Gereffi *et al* 2005).

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[9] The O*NET, formerly the Dictionary of Occupational Titles (DOT), is the US Bureau of Labor Statistics' primary source for occupational information. See https://onet.rti.org/.

[10] For example, incoming calls for customer service are sometimes routed to various call centres in different locations, depending on the customer's question or value to the company (Askin *et al* 2007).

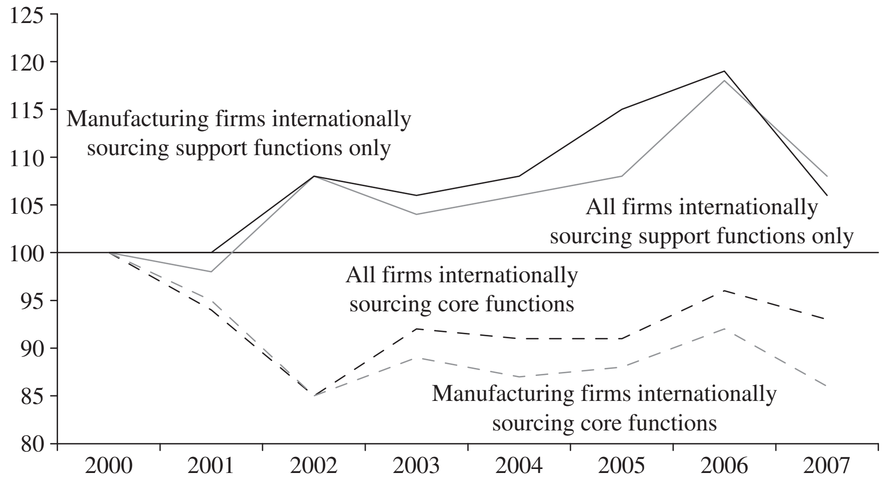


Figure 11.4: *Employment trends by type of function sourced internationally, Denmark, 2000–7.*

Source: Nielsen and Tilewska (2011). Based on median values of full-time equivalent number of employees. Index 2000 = 100.

To be fair, not all of the literature on trade in tasks falls into the trap of equating job characteristics with 'offshorability'. A study by Lanz *et al* (2011) estimates the task content of goods and services by combining information on 41 tasks from the O*NET database with information on employment by occupation and industry for large sets of occupations. This finds the tasks that can be digitised and offshored are often complementary to tasks that cannot.

What is the evidence regarding employment from business function surveys? The 2007 Eurostat International Sourcing Survey found that 20–25% of all surveyed manufacturing enterprises sourced internationally, compared with about 10% of all enterprises in the other sectors of the economy. However, concerns about job loss in Europe due to international sourcing could go beyond the issue of manufacturing job loss to knowledge-intensive job loss as well. The survey shows that around 10–15% of the enterprises that did source internationally in the period 2001–6 sourced R&D functions, as shown by Figure 11.3.

Analysis of firm-level employment patterns in Denmark in the period 2000–7, using an exercise linking data at enterprise level from the 2007 Eurostat International Sourcing Survey to the Danish structural business statistics register, found differences between enterprises sourcing only their core function internationally, and those enterprises sourcing only support functions internationally (see Figure 11.4). This exercise shows that enterprises sourcing their core function internationally had a considerable decline in their employment— down to an index of 93 in 2007—compared with the enterprises only sourcing support functions internationally, which increased employment to an index 108. Enterprises with no international sourcing at all increased employment even faster, to an index of 125. When manufacturing enterprises were analysed separately, this pattern was even more pronounced. Manufacturing enterprises internationally sourcing only core activities lost the most employees, down to an index of 86 in 2007.

3.4 Quantifying Value Added with Business Function Surveys: The 2011 National Organizations Survey

Both economic theory and research based on extensive field interviews suggest that managers often experiment with a variety of 'make' or 'buy' choices and on- or offshore sourcing (Bradach and Eccles 1989; Berger *et al* 2005). Quantifying internal and external sourcing costs is important because firms can, and often do, combine internal and external sourcing of specific business functions. For example, the primary business function (*eg* component manufacturing or assembly) may be outsourced, but only when internal capacity is fully utilised. Or firms might combine internal and external sourcing for strategic reasons, such as pitting in-house operations against external sources for competition in the realms of cost, quality or responsiveness (Bradach and Eccles 1989). Combinations of internal and external sourcing might show a transitional phase of outsourcing, bringing work back in-house (sometimes referred to as insourcing), or building up new in-house functions, and quantitative data collected over time can capture these trends.

The same can be said of location. Managers can decide to locate business functions in proximate or distant locations, in high or low cost locations, near customers, suppliers, specialised labour markets, and so on, and sometimes they combine these approaches and motives. Figure 11.4 captures the four choices managers have in regard to combining the organisational and geographic location of work:

1. domestic in-house ('domestic insourced' in EU terminology);
2. offshore in-house or foreign affiliate ('international insourced' in EU terminology);
3. domestic outsourced; and
4. offshore outsourced ('international outsourced' in EU terminology).

The central question in GVC research, then, is not which of these four choices managers make, but how they combine them.

Quantitative employment, wage and sourcing information by business function was recently collected in the USA by the 2011 National Organizations

Table 11.4: *Organisation and offshoring: four possibilities.*

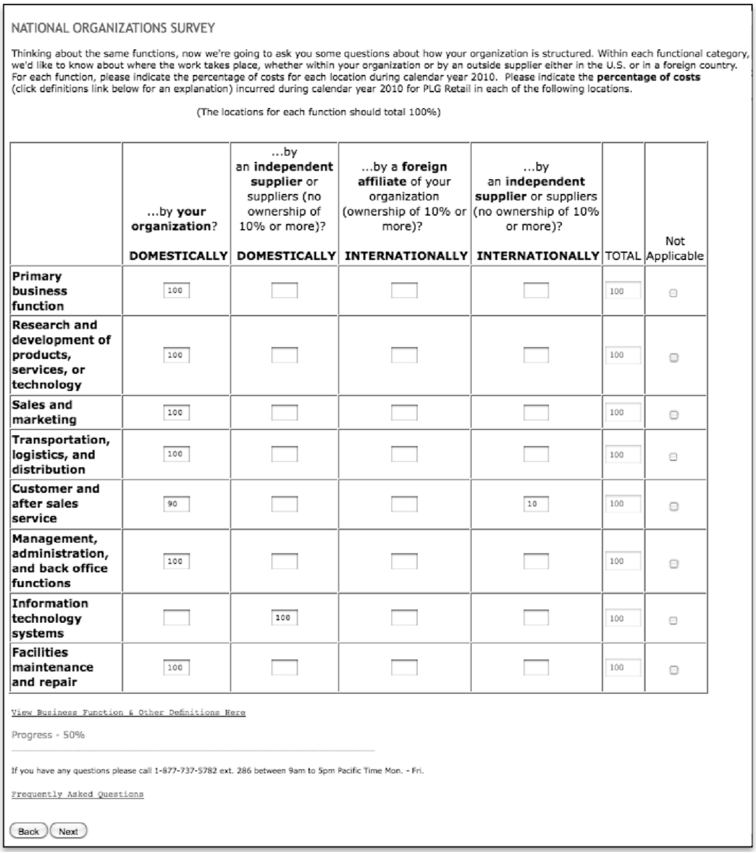
	Location	
Organisation	Domestic	International
Internal: function within the enterprise or enterprise group	EU terminology: domestic insourced US terminology: domestic in-house Function performed within the enterprise or enterprise group within the compiling country	EU terminology: international insourced US terminology: offshore in-house Function performed within the enterprise or enterprise group outside the compiling country (by affiliated enterprises)
External: function outside the enterprise or enterprise group	EU terminology: domestic outsourced US terminology: domestic outsourced Function performed outside the enterprise or enterprise group by non-affiliated enterprises and within the compiling country	EU terminology: international outsourced US terminology: offshore outsourced Production outside the enterprise or group and outside the compiling country (by non-affiliated enterprise, *eg* suppliers, service providers, contractors)

Source: Based on Nielsen (2008).

Survey (NOS), funded by the National Science Foundation.[11] The purpose of the study is to generate direct comparison of domestic employment characteristics with outsourcing and offshoring practices. The 2011 NOS was administered online and by telephone to a representative sample of US businesses, plus a sample of the largest US companies. The survey includes two randomly sampled frames: 900 organisations representative of total US employment linked to the General Social Survey (GSS), and a large firm sample of 975 business segments drawn from the largest companies in the USA (drawn from the 2009 list of 'Fortune 1000' firms),[12] referred to hereafter as the F1K. For these large firms, business segments (also known as divisions or lines of business) are used rather than the firm in its entirely because these sub-units are typically managed with some independence and sometimes make products with very different characteristics than other segments of the same company (*eg* financial products versus manufactured goods). This two-tier sampling incorporated firms/segments of all sizes and also provided a larger sample

[11] See the US Office of Science and Technology Policy website: http://www.scienceofsciencepolicy.net/award/national-survey-organizations-study-globalization-innovation-and-employment.

[12] In addition, the F1K sample was oversampled for firms with high levels of R&D spending because of keen interest in the topic of R&D outsourcing and offshoring.



NATIONAL ORGANIZATIONS SURVEY

Thinking about the same functions, now we're going to ask you some questions about how your organization is structured. Within each functional category, we'd like to know about where the work takes place, whether within your organization or by an outside supplier either in the U.S. or in a foreign country. For each function, please indicate the percentage of costs for each location during calendar year 2010. Please indicate the **percentage of costs** (click definitions link below for an explanation) incurred during calendar year 2010 for PLG Retail in each of the following locations.

(The locations for each function should total 100%)

	...by **your organization**? DOMESTICALLY	...by an **independent supplier** or suppliers (no ownership of 10% or more)? DOMESTICALLY	...by a **foreign affiliate** of your organization (ownership of 10% or more)? INTERNATIONALLY	...by an **independent supplier** or suppliers (no ownership of 10% or more)? INTERNATIONALLY	TOTAL	Not Applicable
Primary business function	100				100	
Research and development of products, services, or technology	100				100	
Sales and marketing	100				100	
Transportation, logistics, and distribution	100				100	
Customer and after sales service	90			10	100	
Management, administration, and back office functions	100				100	
Information technology systems		100			100	
Facilities maintenance and repair	100				100	

View Business Function & Other Definitions Here

Progress - 50%

If you have any questions please call 1-877-737-5782 ext. 286 between 9am to 5pm Pacific Time Mon. - Fri.

Frequently Asked Questions

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Figure 11.5: *Data collection grid for outsourcing and offshoring by business function.*
Source: National Organizations Survey.

of firms (the F1K) likely to be globally engaged. After eliminating duplicates and foreign-owned enterprises, the overall response rate was 30% and was comparable across firms by size.

In the 2011 NOS, questions about business functions were apparently easily understood and answered by senior executives at large and small firms, non-profits and public organisations.[13] Senior executives were able to quantify

[13]'Costs' are defined as follows. For a *manufacturing* business the costs of goods sold (COGS) are materials, labour and factory overhead. For a retail business the COGS is what the company pays to buy the goods that it sells to its customers. For a *service* business, it is the cost of the persons or machines directly applying the service, typically called 'cost of sales' by accountants. For a consulting company, for example, the cost of sales would be the compensation paid to the consultants plus costs of research, photocopying

Table 11.5: *Average share of employment (in percent) by business function and organisation type, December 2011 (US-owned firms' US operations).*

		F1K	For-profit non-F1K	Non-profit	Public sector	All cases
A	Primary business function	49.1	61.3	66.8	68.3	60.1
B	Management, admin and back office	9.6	9.6	14.5	11.4	10.6
C	Sales and marketing	11.9	7.3	2.7	1.3	6.6
D	Customer and after-sales service	8.2	6.5	4.4	2.8	5.8
E	Transportation, logistics, and dist.	6.6	5.2	2.7	4.7	5.2
F	R&D of products, services, or tech.	7.7	4.4	2.1	2.3	4.6
G	Facilities maintenance and repair	2.4	2.9	4.2	5.2	3.5
H	IT systems	4.0	2.4	2.4	3.5	3.1
	Average size (US employment)	15,022	1,616	2,333	4,217	6,272
	Number of cases (n)	99	109	39	85	332

Source: 2011 National Organizations Survey, preliminary, 17 March 2012.

the number of jobs, wage ranges and sourcing locations by business function according to their 'best estimate'. For example, in the 336 completed surveys, only 4.5% (15) respondents indicated 'don't know' to the question about the percentage of total US employment in their organisation according to business function. Of these, 12 were able to supply information about ranges of employment for each function (*eg* 1–10%, 11–30%), leaving only 3 respondents unable to answer the question. The survey also asked for sourcing as a percentage of costs, either the cost of goods sold or the cost of services sold, known as 'cost of sales' (see Figure 11.5). This question was also well received by respondents, again according to their 'best estimate'.

We present some of the study's preliminary findings here. First, Table 11.5 lists the percentage of costs for eight business functions in four types of US organisations where the survey was administered:

1. F1K business segments;
2. for-profit companies (not included in the F1K);
3. non-profit firms and organisations such as religious organisations and hospitals; and
4. public sector organisations, such as local, state, and federal government agencies.

Taken together, samples 2-4 comprise a nationally representative sample of organisations, based on employment.

There are some clear differences in employment allocation (on average) across the four organisational types. Comparing F1K firms with other for-profit firms, we see in Table 11.5 that, on average, F1K firms have fewer

and production of reports and presentations. For a *public* organisation, costs are typically defined in its operating budget.

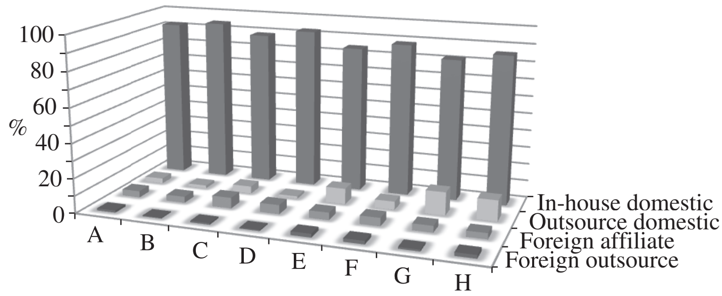

Figure 11.6: *Location of business functions as a percentage of costs of goods or services sold (all cases, n* = 306*).*

Source: National Organizations Survey, preliminary, 17 March 2012. Categories on the horizontal axis refer to those defined in Table 11.5.

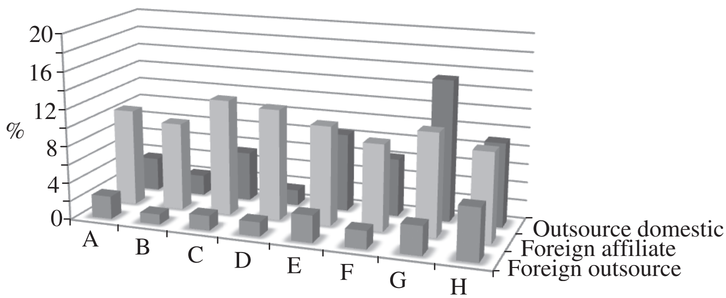

Figure 11.7: *Location of outsourced/offshored business functions as a percentage of costs of goods or services sold: F1K cases, n* = 86*.*

Source: National Organizations Survey, preliminary, 17 March 2012. Categories on the horizontal axis refer to those defined in Table 11.5.

employees working in their primary business function and more working in R&D and sales and marketing.

Figure 11.6 shows the breakdown in costs for each of the eight business functions for the four possible combinations of organisational and geographic location discussed above and shown in Table 11.5 and Figure 11.5. A striking finding of the study is the low levels of international sourcing, on average, across all business functions, with the highest found in sales and marketing (7% of the function's costs from international sourcing) and customer services and after-sales service (6% of the function's costs from international sourcing). In the USA, firms and other organisations tend to source most business functions in-house. Functions with the highest domestic outsourcing, on average, are facilities maintenance (13.5% of the function's costs), IT systems (12%

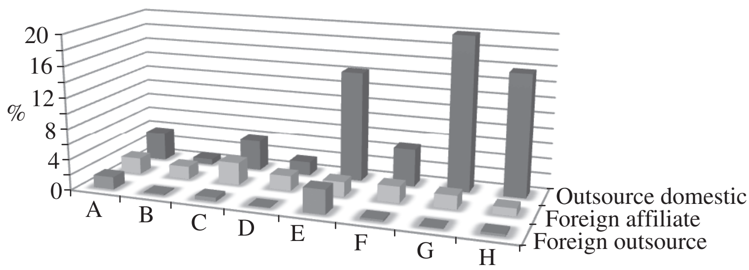

Figure 11.8: *Location of outsourced/offshored business functions as a percentage of costs of goods or services sold: private sector non-F1K cases, n* = 104.

Source: National Organizations Survey, preliminary, 17 March 2012. Categories on the horizontal axis refer to those defined in Table 11.5.

of the function's costs), and transportation and logistics services (9% of the function's costs). On average, all firms in the sample spent only 3% of their primary function's costs on domestic outsourcing and 5% of their primary function's costs on international sourcing.

Global engagement among US firms appears to be roughly comparable to, if slightly more common than among European firms. Recall that the 2007 Eurostat International Sourcing Survey found that 20–25% of all surveyed manufacturing enterprises sourced internationally, compared with about 10% of all enterprises in the other sectors of the economy. The preliminary analysis of NOS data has not yet broken out manufacturing firms for separate analysis, but of the 191 for-profit firms in the NOS study that answered the question, 24% outsourced at least some of their primary function domestically, while 30% sourced some portion of their primary function abroad (26% from foreign affiliates and 15% from offshore suppliers; 11% did both). While more analysis needs to be done to make direct comparisons between the surveys (the 2007 Eurostat International Sourcing Survey did not include firms with fewer than 100 employees, or 50 employees in some countries and covers an earlier time period, 2003–6 as opposed to calendar year 2010), the findings appear to be roughly consistent.

The picture from the USA changes when only the largest firms in the NOS study are considered. When F1K business segments are broken out and compared to the rest of the for-profit cases as in Figures 11.7 and 11.8, F1K cases show a much higher level of international sourcing, especially though foreign affiliates, as expected. Interestingly, non-F1K for-profit companies engaged in average higher levels of domestic outsourcing than F1K companies for three functions: transportation, facilities maintenance and IT services.

Finally, we present preliminary finding from the 58 NOS cases that were engaged in international sourcing (through affiliates, independent suppliers or both) and answered a question about the type of offshore location used:

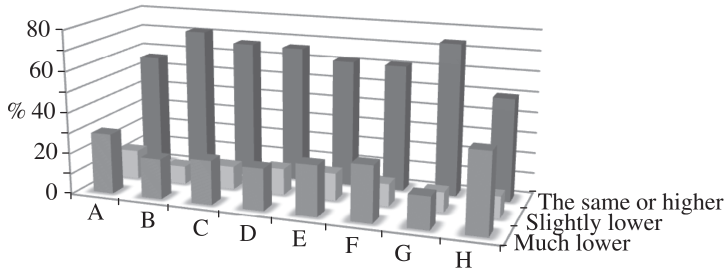

Figure 11.9: *Percentage of international costs by type of location (operating costs in relation to the USA) and business function, 2010, organisations engaged in international sourcing (n = 58).*

Source: National Organizations Survey, preliminary, 17 March 2012. Categories on the horizontal axis refer to those defined in Table 11.5.

those with costs equal to or greater than the USA, slightly lower than the USA or much lower than the USA. The results, presented in Figure 11.9, show that the lion's share of international sourcing is to locations with costs that are equal to or higher than the USA. This suggests that the main motivation for international sourcing is to access skilled labour and advanced county product markets rather than low costs and emerging markets. It may also reflect the long-standing investments sourcing and other business relationships held by firms in the USA, especially with Canada and Western Europe. Next in importance are countries with costs much lower than the USA. International sourcing in countries with costs slightly lower than the USA is quite low, which might help explain the low level of integration of middle-income countries (*eg* in Latin America versus East Asia) in GVCs, contributing to the 'middle-income trap' experience of some developing countries (Giuliani *et al* 2005; Rodrik 2007).

These preliminary findings indicate that, despite the concerns voiced in academic literature and in media coverage about economic globalisation, GVCs and the outsourcing and offshoring of service work, these practices are in fact far from pervasive among US organisations. While GVCs are real and growing, they might be said to be in their infancy. Identification of trends will only come with follow-up surveys using the same framework.

4 CONCLUSIONS

Scalable, comparable data are sorely needed in order to build accurate meso-level portraits of the location of value added and international sourcing patterns. On the one hand, macro-statistics and the IIOs that seek to combine them into larger cross-border matrices are too aggregated to provide reliable, detailed industry-level estimates, and they are difficult to extend into the developing world, where input–output data is less developed or entirely missing. On the other hand, it is not feasible to collect product-level GVC data in large-scale surveys with the purpose of producing aggregated data at industry or country levels, mainly because it places too high a burden on respondents and data agencies, a problem exacerbated by the strategically sensitive nature of the data. Business function surveys can help fill this void.

The importance of developing international standards in connection with new business surveys cannot be overstated. Global integration is first and foremost a cross-border phenomenon, and understanding it fully will require the collection of compatible, if not identical, data. A coordinated, sustained and iterative effort is needed. The inclusion of developing countries in these efforts is essential.

At the same time, current data-collection programmes need to be evaluated on a constant basis in order to make negative priorities (*eg* reduce the number of collected variables, change the frequency of or abandon surveys) in order to make room for new surveys on emerging issues without increasing the overall respondent burden. Currently, official business statistics are under considerable pressure, partly to achieve reductions in respondent burden, and partly because of budget constraints. Even under these conditions, it is important to identify new emerging topics of vital importance for understanding the current structure and dynamics of economic development for which no official statistical evidence is available. Such evidence can partly be established by methods that create no additional burden on enterprises, such as the linking of micro data and the construction of IIOs, but new surveys designed with minimal respondent burden in mind, such as business function surveys, must also be systematically deployed. Ideally, a global data-collection effort can come to rely on automated reporting systems that reduce the burden on organisations while increasing accuracy. While these goals will take time and be difficult to achieve, a concerted and well-coordinated effort is needed now.

REFERENCES

Aksin, Z., M. Armony and V. Mehrotra (2007). The Modern Call Center: A Multi-Disciplinary Perspective on Operations Management Research. *Production and Operations Management* **6**, 665–688.

Ali-Yrkkö, J., P. Rouvinen, T. Seppälä and P. Ylä-Anttila (2010). Who Captures Value in Global Supply Chains? Case Nokia N95 Smart Phone. ETLA Discussion Papers 1240, February.

Arndt, S., and H. Kierzkowski (eds) (2001). *Fragmentation: New Production Patterns in the World Economy*. Oxford University Press.

Bair, J. (2009). Global Commodity Chains: Genealogy and Review. In *Frontiers of Commodity Chain Research* (ed. J. Bair). Stanford, CA: Stanford University Press.

Berger, S., and the MIT Industrial Performance Center (2005). *How We Compete*. New York: Doubleday.

Bernard, A. B., J. B. Jensen, and P. K. Schott (2005). 'Importers, Exporters and Multinationals: A Portrait of Firms in the US that Trade Goods', NBER Working Paper 11404.

Bernard, A. B., J. B. Jensen, and P. K. Schott (2006). Survival of the Best Fit: Exposure to Low-Wage Countries and the (Uneven) Growth of US Manufacturing Plants. *Journal of International Economics* **68**, 219–237.

Blinder, A., and A. Krueger (2009). Alternative Measures of Offshorability: A Survey Approach. National Bureau of Economic Research, Working Paper 15287.

Borrus, M., D. Ernst, and S. Haggard (eds) (2000). *International Production Networks in Asia*. London and New York: Routledge.

Bradach, J., and R. Eccles (1989). Price, Authority, and Rust: From Deal Types to Plural Forms, *Annual Review of Sociology* **15**, 97–118.

Brown, C., and T. Sturgeon (forthcoming). The Outsourcing and Offshoring Practices of United States Organizations'. IRLE Working Paper, University of California and Berkeley.

Brown, S. (2008). Business Processes and Business Functions: A New Way of Looking at Employment. *Monthly Labor Review* December, 51–70.

Brülhart, M. (2009). An Account of Global Intra-industry Trade, 1962–2006. *World Economy* **32**(3), 401–459.

Cattaneo, O., G. Gereffi, and C. Staritz (2010). *Global Value Chains in a Postcrisis World: A Development Perspective*. Washington, DC: The World Bank.

Commission of the European Communities (2003). The Competitiveness of Business-Related Services and Their Contribution to the Performance of European Enterprises, COM(2003) 747 final.

Dean, J., K. C. Fung, and Z. Wang (2007). Measuring the Vertical Specialization in Chinese Trade. US International Trade Commission, Office of Economics Working Paper 2007-01-A.

Dedrick, J., K. Kraemer, and G. Linden (2010). Who Profits from Innovation in Global Value Chains? A Study of the iPod and Notebook PCs. *Industrial and Corporate Change* **19**(1), 81–116.

Dixit, A., and G. Grossman (1982). Trade and Protection with Multistage Production. *Review of Economic Studies* **49**(4), 583–594.

Doh, J. (2005). Offshore Outsourcing: Implications for International Business and Strategic Management Theory and Practice. *Journal of Management Studies* **42**(3), 695–704.

Dossani, R., and M. Kenney (2003). Lift and Shift: Moving the Back Office to India. *Information Technologies and International Development* **1**(2), 21–37.

Escaith, H., N. Lindenburg, and S. Miroudot (2010). International Supply Chains and Trade Elasticity in Times of Global Crisis. Report. Economic Research and Statistics Division, World Trade Organization, January 30.

Feenstra, R. (1998). Integration of Trade and Disintegration of Production in the Global Economy. *Journal of Economic Perspectives* **12**(4), 31–50.

Fröbel, F., J. Heinrichs, and O. Kreye (1980). *The New International Division of Labor*. Cambridge University Press.

Gereffi, G. (1994). The Organization of Buyer-Driven Global Commodity Chains: How US Retailers Shape Overseas Production Networks. In *Commodity Chains and Global Capitalism* (ed. G. Gereffi and M. Korzeniewicz), pp. 95–122. Westport, CT: Praeger.

Gereffi, G. (1999). International Trade and Industrial Upgrading in the Apparel Commodity Chain. *Journal of International Economics* **48**(1), 37–70.

Gereffi, G., and M. Korzeniewicz (eds) (1994). *Commodity Chains and Global Capitalism*. Westport, CT: Praeger.

Gereffi, G., J. Humphrey, and T. Sturgeon (2005). The Governance of Global Value Chains. *Review of International Political Economy* **12**(1), 78–104.

Gereffi, G., and K. Fernandez-Stark (2010). The Offshore Services Value Chain: Developing Countries and the Crisis. World Bank Policy Research Working Paper 5262 (April).

Gereffi, G., and K. Fernandez-Stark (2011). *Global Value Chain Analysis: A Primer*. Durham, NC: Center on Globalization, Governance and Competitiveness (CGGC), Duke University.

Giuliani, E., C. Pietrobelli, and R. Rabellotti (2005). Upgrading in Global Value Chains: Lessons from Latin American Clusters. *World Development* **33**(4), 549–573.

Grossman, G., and E. Rossi-Hansberg (2006). The Rise of Offshoring: It's Not Wine for Cloth Anymore. *The New Economic Geography: Effects and Policy Implications*, pp. 59–102. Jackson Hole, WY: Federal Reserve Bank of Kansas City.

Grossman, G. and E. Rossi-Hansberg (2008). Trading Tasks: A Simple Theory of Offshoring. *American Economic Review* **98**(5), 1978–1997.

Grossman, G. and E. Rossi-Hansberg (2012). Task Trade between Similar Countries. *Econometrica* 80(2), 593–629.

Grunwald, J., and K. Flamm (1985). *The Global Factory*. Washington, DC: Brookings Institution.

Henderson, J., P. Dicken, M. Hess, N. Coe, and H. Yeung (2002). Global Production Networks and the Analysis of Economic Development. *Review of International Political Economy* **9**(3), 436–464.

Hesseldahl, A. (2010). The iPad: More than the Sum of Its Parts; $270 More, Actually. *Bloomberg Business Week*, February 22, p. 24.

Houseman, S. (2011). Offshoring and Import Price Measurement. *Survey of Current Business* February, 7–11.

Hummels, D., J. Ishii, and K.-M. Yi (2001). The Nature and Growth of Vertical Specialization in World Trade. *Journal of International Economics* **54**(1), 75–96.

Humphrey, J., and H. Schmitz (2002). How Does Insertion in Global Value Chains Affect Upgrading in Industrial Clusters? *Regional Studies* **36**(9), 1017–1027.

Huws, U., and S. Dahlmann (2004). Outsourcing of ICT and Related Services in the EU: A Status Report. European Foundation for the Improvement of Living and Working Conditions. Luxembourg: Office for Official Publications of the European Communities. URL: http://www.eurofound.europa.eu/emcc/publications/2004/ef04137en.pdf.

Jensen, J. B., and L. Kletzer (2006). Tradable Services: Understanding the Scope and Impact of Services Offshoring'. In *Brookings Trade Forum 2005, Offshoring White-Collar Work* (ed. S. Collins and L. Brainard). Washington, DC: Brookings Institution Press.

Kaplinsky, R. (2005). *Globalization, Poverty and Inequality*. Cambridge, UK: Polity Press.

Kawakami, M. (2011). Inter-Firm Dynamics of Notebook PC Value Chains and the Rise of Taiwanese Original Design Manufacturing Firms. In *The Dynamics of Local Learning in Global Value Chains: Experiences from East Asia* (ed. M. Kawakami and T. J. Sturgeon), Chapter 2. London: Palgrave Macmillan.

Kletzer, L. (2009). Understanding the Domestic Labor Market Impact of Offshore Services Outsourcing: Measurement Issues. In *Measurement Issues Arising from the Growth of Globalization* (ed. W. E. Upjohn). Washington, DC: Institute for Employment Research and the National Academy of Public Administration.

Koopman, R., Z. Wang, and S.-J. Wei (2008). How Much of Chinese Exports is Really Made in China? Assessing Domestic Value-Added When Processing Trade Is Pervasive. NBER Working Paper 14109.

Krugman, P. (1991). Increasing Returns and Economic Geography. *Journal of Political Economy* **99**, 483–499.

Lall, S. (2000). The Technological Structure and Performance of Developing Country Manufactured Exports, 1985–98. *Oxford Development Studies* **28**(3), 337–369.

Lanz, R., S. Miroudot, and H. Nordås (2011). Trade in Tasks. OECD Trade Policy Working Paper 117.

Lewin, A., S. Massini, and C. Peeters (2009). Why Are Companies Offshoring Innovation? The Emerging Global Race for Talent. *Journal of International Business Studies* **40**(6), 901–925.

Linden, G., K. Kraemer, and J. Dedrick (2007). Who Captures Value in a Global Innovation System? The Case of Apple's iPod. Personal Computing Industry Center Working Paper 06-01-2007, University of California Irvine.

Linden, G., K. Kraemer, and J. Dedrick (2009). Who Captures Value in a Global Innovation System? The Case of Apple's iPod. *Communications of the ACM* **52**(3), 140–144.

Linden, G., K. Kraemer, and J. Dedrick (2011). Innovation and Job Creation in a Global Economy: The Case of Apple's iPod. *Journal of International Commerce and Economics* May, pp. 223–240.

Maule, C. (2006). Integrative Trade: Issues for Trade Analysis, Statistics and Policy', Paper prepared for the CTPL Conference on Integrative Trade between Canada and the United States: Policy Implications.

Nielsen, P. B. (ed.) (2008). *International Sourcing: Moving Business Functions Abroad*. Statistics Denmark. URL: http://www.dst.dk/publ/InterSourcing.

Nielsen, B., and Z. Tilewska (2011). Data Linking—Creating New Evidence by Utilising Existing Statistical Registers. Case: International Sourcing. In *Proceedings of the 58th World Statistics Congress of the International Statistical Institute (ISI), Dublin*, pp. 3247–3265.

OECD (2011a). Global Value Chains: Preliminary Evidence and Policy Issues, Directorate for Science, Technology and Industry. Paper presented to the Committee on Industry, Innovation and Entrepreneurship, CIIE meeting, 31 March–1 April 2011.

OECD (2011b). Developments in Measuring Trade In Value Added (and Employment), Statistics Directorate. Paper presented to the Working Party on International Trade in Goods and Trade in Services Statistics, 7–9 November 2011.

Porter, M. (1985). *Competitive Advantage*. New York: Free Press.

Rodrik, D. (2007). *One Economics, Many Recipes. Globalization, Institutions and Economic Growth*. Princeton University Press.

Steinfeld, E. 2004. Chinese Enterprise Development and the Challenge of Global Integration. In *Global Production Networking and Technological Change in East Asia* (ed. S. Yusuf, A. Altaf and K. Nabeshima). Oxford University Press.

Sturgeon, T. (2002). Modular Production Networks. A New American Model of Industrial Organization. *Industrial and Corporate Change* **11**(3), 451–496.

Sturgeon, T. (2003). Exploring the Risks of Value Chain Modularity: Electronics Outsourcing During the Industry Cycle of 2001–2002. MIT IPC Working Paper 03-002, May.

Sturgeon, T., and G. Gereffi (2009). Measuring Success in the Global Economy: International Trade, Industrial Upgrading, and Business Function Outsourcing in Global Value Chains. *Transnational Corporations* **18**(2), 1–35.

Sturgeon, T., and R. Lester (2004). The New Global Supply-base: New Challenges for Local Suppliers in East Asia. In *Global Production Networking and Technological*

Change in East Asia (ed. Y. Shahid, M. A. Altaf and K. Nabeshima), Paper 2. Oxford University Press.

Sturgeon, T., and O. Memedovic (2010). Mapping Global Value Chains: Intermediate Goods Trade and Structural Change in the World Economy. UNIDO Working Paper 05/2012. Vienna: United National Industrial Development Organization.

Sturgeon, T., F. Levy, C. Brown, J. B. Jensen, and D. Weil (2006). Why We Can't Measure the Economic Effects of Services Offshoring: The Data Gaps and How to Fill Them. MIT Industrial Performance Center Working Paper 06-006.

Swedish National Board of Trade (2007). Add Value to the European Economy: How Anti-Dumping Can Damage the Supply of Globalized European Companies. Five Case Studies From The Shoe Industry. Kommerskollegium, Stockholm, Sweden.

Tempest, R. (1996). Barbie and the World Economy. *Los Angeles Times*, September 22.

van Welsum, D., and X. Reif (2009). We Can Work It Out: The Globalization of ICT-Enabled Services. NBER Working Paper 12799.

Winkler, D., and W. Milberg (2009). Errors from the 'Proportionality Assumption' in the Measurement of Offshoring: Application to German Labor Demand. SCEPA Working Paper 2009-12. Schwartz Center for Economic Policy Analysis and Department of Economics New School for Social Research, New York.

Yeats, A. (2001). Just How Big Is Global Production Sharing? In *Fragmentation: New Production Patterns in the World Economy* (ed. S. Arndt and H. Kierzkowski). Oxford University Press.

12

Integrating Value-Added Trade Statistics into the System of National Accounts

A: Perspectives from the World Trade Organization

Andreas Maurer

The meeting's objectives were to identify the state-of-the-art, existing data gaps and the direction of future work for developing 'new measures of cross-border trade'. I wish to highlight the aspect of data gaps and what official statistics can do.

The focus here is on statistics and measures that are developed and used for defining and monitoring trade policy and economic development. Are current statistics useful to gauge trade policy and economic development? The issue is therefore whether current statistics are useful to gauge trade policy and economic development. This is a question taken up in WTO's Public Forum in September 2011, where the objective was geared towards trade policy. The Forum was due to debate how the measure of trade flows in value-added terms affects the way we analyse international economics and conduct trade policy.

However, before we discuss how 'measuring', or better 'estimating', trade in value added impacts on the economic analysis; we have to see how we integrate this 'animal' in official statistics, such as the System of National Accounts, balance of payments and customs-based merchandise trade statistics.

The *System of National Accounts* is a consistent and integrative accounting system. The central question is 'who does what by means of what for what purpose with whom in exchange for what with what changes in stocks?' (see SNA 1993, Paragraph 2.12). The best-known macroeconomic aggregate is gross domestic product (GDP), which equals the sum of gross *value added* of all *resident* producer units.

The *balance of payments* is concerned with transactions between residents and non-residents whereby transactions between the two groups involve a change in economic ownership of the product, be it a good or a service.

Customs-based merchandise trade statistics use the principle of physical crossing for recording international transactions. The recording not only comprises the value, quantity and other data elements; it also assigns to each transaction a country of origin and country of (last known) destination. For the country of origin, rules of origin are used to identify the respective countries.

It is here where *trade in value added* comes into play and where misunderstandings in the interpretation of statistics in the community of users start. In an era of international supply chains and production, where a single product can be made in many countries, the recording of trade flows based on the concept of country of origin may not reflect the way global business is done today or where the resulting income flows will be registered. The questions therefore are whether official statistics produce the right data and whether we (can) draw the right signals out of current statistics.

1 DO WE HAVE THE RIGHT STATISTICS?

International supply chains and trade finance have often been quoted as contributing factors to the steep fall in trade flows in late 2008 and 2009. As pointed out elsewhere in this volume, do official statistics tell us

- 'who produces for whom?' if we analyse the real economy, or
- 'who finances whom?' if we consider the monetary economy?

We face new business models, changes in transportation and communication and mass consumer demand, especially in the West. The latter are met by rising manufacture capacities in Eastern Asia, which makes Asia a global hub of manufacturing (which makes up more than 80% of its exports). The centre of economic gravity seems to have shifted to Asia.

The way in which businesses are run has changed greatly over the last 20 years. We need to have information on the interconnectivity of national economies through linking firm activity (production) with export activity (trade). This will help policymakers base their decisions on economically meaningful data. As a result, governments will better understand that raising trade barriers hurts domestic companies, which are dependent on the availability of competitive inputs for their competitiveness. It will also alleviate some of the misunderstandings resulting from inflated bilateral trade imbalances based on the gross calculation of trade figures rather than on a value-added basis.

2 INTER-AGENCY COOPERATION FROM A WTO PERSPECTIVE

Following an exchange of letters between Director-General Pascal Lamy and Secretary-General Angel Gurría in February 2009, the WTO and OECD have worked together, hosting seminars and conferences involving other key players such as the Japanese Institute of Development Economies (IDE-JETRO), the US International Trade Commission (USITC) and the World Input–Output

Database (WIOD) Project. In parallel, through Eurostat and the UN Statistical Commission, there the WTO had a fruitful dialogue with the community of official statisticians, aimed at strengthening international cooperation.

Both the OECD and WTO feel that further benefits could be gained by developing more formal mechanisms of cooperation that would help to

(i) mainstream existing research and results on trade in value added into the wider policymaker community,
(ii) provide an institutional forum for existing initiatives, be they rooted in national, non-official or academic organisations, and
(iii) motivate and accelerate further developments in this work domain.

Results should focus on clarifying the concept of trade in value added to enable gross trade flows to be decomposed into domestic value-added components and import components through exploring a common understanding on the definitions, methodologies and challenges, based on state-of-the-art methodology.

Further work could include reference to common institutional objectives, such as the development of a joint-branded database on value-added trade flows. Improving the coverage (*eg* to African countries) of such a database will be a priority for both organisations. The WTO has launched the 'Made in the World Initiative' (MIWI), as an effort to bridge the gap between researchers and trade policymakers and to develop a network of interested researchers and industries.

As both OECD and WTO have built strong links with other key players in Asia, Europe and the USA, the two institutions are now in a position to coordinate efforts towards the estimation of trade flows in value-added terms based on official trade statistics and national accounts.

Both organisations have been cooperating very closely with IDE-JETRO. Another key project in this area is the World Input–Output Database (WIOD), which was financed by the EU and aims at producing time-series of inter-country IO tables benchmarked on national accounts for 40 countries. The project produced important results in terms of both data and methodologies in March 2012. The long-term sustainability and mainstreaming of the project after this date needs to be addressed. Another stakeholder, the USITC, has also been developing a methodology for measuring trade in value added.

The OECD is part of the WIOD consortium and has long been in the business of producing and maintaining an IO database. In cooperation with other stakeholders, OECD, with the support of WTO, could build on the WIOD experience to coordinate the efforts and expertise of a large network of experts and institutions, such as IDE-JETRO, to deliver long-term benefits beyond the life-time of WIOD.

The OECD and WTO would also promote a closer dialogue between researcher and official statisticians. As countries move to the new 2008 SNA and *Balance of Payments Manual* recommendations (International Monetary

Fund 2009, henceforth BPM6), as well as new industrial classification systems such as ISIC Rev. 4 and NACE Rev. 2, it will be important to tap into the expertise of national accounts, input–output, business and trade statisticians. Promoting such a dialogue would involve a close cooperation with important stakeholders such as Eurostat, the UN Statistical Commission and all the relevant international agencies. Such a dialogue has been included in a 2020 Vision of an International Trade Information System as agreed upon by four organisations in the Global Forum on Trade Statistics, held in February 2011 in Geneva.

3 TRADE IN VALUE ADDED AMONG INTERNATIONAL ORGANISATIONS

Each organisation could be contributing to this joint OECD/WTO project. MIWI is a hub for discussion and exchange of information of importance to this project (by holding events, *etc*).

For example, in February 2011, WTO hosted a UNSD/Eurostat-organised Global Forum on Trade Statistics. One of the major outcomes was the fostering of trade and business statistics linkages by integrating trade and business registers to explore the database for analysing business processes. Others included the lack of detail in trade in services statistics or information on bilateral trade flows. These subjects are not only important for trade in value added but also for export promotion, and involve not new surveys but the use of administrative sources.

4 DO WE DRAW THE RIGHT SIGNALS OUT OF CURRENT STATISTICS? DO WE BRING UNDERSTANDING TO THE MEASUREMENT?

As previously mentioned, the global division of labour has emerged through an intense inter-industry trade in intermediate goods and services, benefitting from the efficient allocation of tasks across the globe for producing and trading. There is a responsibility for statisticians to explain their statistics in this context. For example, if we look at trade flows, conclusions may be drawn in respect of bilateral imbalances on exchange rate policy, but analysis of international fragmentation of production through estimating imported inputs in domestically produced exports may view these imbalances differently.

5 HOW SHOULD OFFICIAL STATISTICS REACT?

As the 2008 SNA, MSITS 2010 and IMTS 2010[1] are put into place, international organisations have to jointly assist implementation of these concepts

[1] *Manual on Statistics of International Trade in Services 2010* and *International Merchandise Trade Statistics 2010*.

and definitions to develop data sets that are more apt for analysing globalisation. However, in fostering implementation, it has to be ensured that there is no information loss between the different versions of the respective statistical frameworks. Keeping track of the flow of intermediate goods exchanged within global value chains when there is no change of ownership is one of the implementation issues to be addressed.

As all statistical frameworks have undergone revision, no new additional concepts and definitions can be defined. However, instead of devising new concepts, existing statistics on the external sector can be used in a more systemic way. In this vein, a new statistical tool in form of a *satellite account* could be developed to complement national accounts. This tool would bring together a country's foreign activities with respect to trade—goods, services, intellectual property, capital (foreign direct investment) and income flows, labour (movement of workers)—in one integrated presentation, similar to tourism satellite accounts.

B: Perspectives from the United Nations

Ronald Jansen

> Global production has become increasingly fragmented and different stages of production are now regularly performed in different countries. As inputs cross-borders multiple times, traditional statistics on trade values—measured in gross terms—do not reflect economic reality in respect of the value added in any particular country.

This is the opening of the workshop programme and the main theme of the workshop.

Similarly, global production and trade in value added were among the main themes of the Global Forum on Trade Statistics, which was organised in February 2011 by the United Nations Statistics Division (UNSD) together with Eurostat, WTO and UNCTAD. The forum received high-level attention from policymakers and was attended by almost 200 trade statisticians from all around the globe. Pascal Lamy stressed in his presentation the importance of relevant trade statistics in a globalised world, stating that all trade negotiations, in the end, deal with numbers.

A number of issues have been raised explicitly or implicitly in the discussion paper on 'Tracing Value Added in International Trade' (Mattoo *et al* 2011). I wish to clarify these issues from the perspective of official trade statistics and will highlight the ongoing efforts to improve trade statistics, also to the benefit of the research on trade in value added. This chapter should be read in connection with the discussion paper and the documents of the Global Forum.[1]

1 ISSUE 1: COLLECTION OF VALUE-ADDED TRADE DATA

First of all, I want to state that detailed trade statistics by product and partner countries in terms of gross values will remain necessary input for many analytical purposes, including IO research. It is not desirable to collect trade statistics in other than gross values. Aside from the fact that such statistics are necessary for agriculture, energy, environment and transportation statistics, quality assurance frameworks of trade statistics are for a large part based on a consistent relation between the value and the quantity of the traded goods. This will hold true whether data is collected via enterprise surveys or through customs documents. Additional information will need to be collected if we want to decompose the gross values into domestic and foreign content, or further refinements. I shall mention some of those additional elements below. The objective of our workshop discussions is to find ways to publish trade data in value-added terms, but such an objective is not equivalent to collecting trade data in value-added terms.

2 ISSUE 2: CUSTOMS RECORDS OR ENTERPRISE SURVEYS?

We need both sources of data. The most important source of trade data remains the customs data. In fact, trade statisticians should advocate more forcefully the keeping of detailed customs information on importation and exportation documents. The trade community (traders and enterprises) puts pressure on the government to facilitate customs procedures, and has been successful in some ways. We should realise that enterprise surveys can be nowhere near as detailed or as timely as customs records. Enterprise surveys will cover necessarily fewer goods, give less detail on trading partners and will be obtained less frequently. The greatest value of enterprise surveys will be as an addition to customs records. These surveys could then focus on specific questions, such as how much of the manufacturing processes of an enterprise are done under contract on behalf of foreign enterprises.

3 ISSUE 3: LINKING TRADE AND BUSINESS STATISTICS

The main topic of our discussion is the fragmentation of the global production processes. The implication is that we want to know more about the strategies

[1] See http://unstats.un.org/unsd/trade/s_geneva2011/outcome.htm.

of businesses that operate globally in their production. To reiterate a point often made, trade is not done between countries, but between businesses. Session 4 of the Global Forum on Trade Statistics was devoted in full to the issue of global production and outsourcing of business functions[2] with presentations by, among others, Timothy Sturgeon (on 'Measuring Global Value Chains') and by Peter Boegh Nielsen (on international sourcing of business functions). These research projects investigate directly the global business strategies and need of the statistical community for further development of classifications on intermediate products and on business functions. Another related outcome of the Global Forum on Trade Statistics[3] was to better link trade and business statistics by

- developing a common basis across all relevant national institutions to identify enterprises active in international trade, including multinational enterprises and their foreign affiliates,
- developing and maintaining a statistical trade information system at micro-level around the enterprise register, including multinational enterprises and their foreign affiliates, and
- establishing this statistical information system—under observance of relevant confidential rules—by making optimal use of and connecting existing data sources, such as custom-based merchandise trade statistics, trade and business registers, economic census data, existing enterprise surveys, other administrative records and possibly data sources for employment, environment or energy.

4 ISSUE 4: CROSS-BORDER TRADE AND THE CHANGE OF OWNERSHIP PRINCIPLE

The main area of contention between trade statisticians and national accountants has been not valuation but the issue of 'change of ownership'. According to SNA, an international transaction in goods takes place only if there has been a change of ownership between a resident and a non-resident. When a good crosses the border, it does not necessarily mean that there has been a change in ownership. International Merchandise Trade Statistics (IMTS) cover goods which add to or subtract from the stock of material resources of a country by entering (imports) or leaving (exports) its economic territory. This basis differs from the change of ownership between residents and non-residents required for balance of payments[4] and national accounts. This controversy

[2] See http://unstats.un.org/unsd/trade/s_geneva2011/outcome.htm.

[3] See the United Nations Statistics Division, http://unstats.un.org/unsd/trade/s_geneva2011/Global_Forum_on_Trade_Statistics-detailed_vision_statement-15Mar2011.pdf.

[4] See http://www.imf.org/external/pubs/ft/bop/2007/pdf/chap10.pdf.

is the backdrop to the discussion on the international sourcing of production processes, better known as the issue of 'goods for processing abroad' or 'processing trade' (Mattoo *et al* 2011) or 'manufacturing services on physical inputs owned by others' (International Monetary Fund 2009). In the context of Global production and GVCs, this issue is probably the most important one.

5 ISSUE 5: INTERNATIONAL SOURCING OF PRODUCTION PROCESSES

International trade has been at the centre of many recent discussions on globalisation, be it through the offshoring of the production process, operations of multinationals, foreign direct investments or trade negotiations. Production processes of garments, motor vehicles, televisions or computers are now often spread across several countries not only to reduce labour and capital costs but also, for instance, to benefit from investment incentives offered by the host countries. Even though treatment of goods for processing in the statistical sense is by no means a new discussion, it gained a lot of recent attention because of its increasing economic importance, especially for economies like China and Mexico.

My proposal for measuring trade statistics in relation to international sourcing of production processes is as follows.

1. Link detailed merchandise trade statistics to the business register. This matching process may not be perfect, but is essential in deriving results.
2. Conduct a survey among exporting enterprises of the manufacturing industries and determine the percentage of processing done under contract by enterprise and industry.
3. Link the enterprise survey to the merchandise trade statistics via the business register, and determine the volume and kind of imported and exported goods that are associated with 'processing under contract'.

The end result will be trade statistics broken down by product, industry and partner country, with a separate breakdown of processing under contract. Balance of payment compilers could then use this information to adjust the trade in services and trade in goods statistics.

Such survey could be validated and complemented by an economic census, which is ideally done at five-year intervals. (For instance, Malaysia conducted an economic census in 2011 and included questions on processing under contract.) This approach produces official statistics on intermediate goods processing by industry and product. Note that change of ownership always needs checking, since even within multinationals it is possible that inputs in the production process are actually acquired by the foreign affiliate. The Bank of Thailand conducted a survey which showed that the top three electronics manufacturers in Thailand buy the inputs into their production from their mother companies. This raises the issue of transfer pricing, which I shall not discuss here.

The international recommendations for IMTS were revised in 2010 (IMTS 2010) and contain new recommendations for a number of additional data elements useful in the analysis of the globalisation issues, namely

1. additional valuation of FOB for imports,
2. country of consignment for imports and exports, which will facilitate tracing the routes the goods take,
3. indication of customs procedures for inward and outward processing, and
4. mode of transport.

IMTS 2010 also recommends linking trade to business statistics; this recommendation has been emphasised in recent months.

6 ISSUE 6: UNSD AND IO TABLES

Paul Cheung, Director of the United Nations Statistics Division, spoke at the 19th International Input–Output Conference in Alexandria, VA on the relation between official statistics and IO analysis (Cheung 2011). One of the points he made is that if a country does not have the source data or the resource capacity and expertise to provide value added by industry, gross domestic product by expenditures in current and constant prices, and gross national income, then the country will not be in a position to produce a fully articulate IO table. In this regard, it will be useful to update the *UN Input–Output Handbook* to reflect all relevant changes introduced with the 2008 SNA, keeping in view that the handbook should be a practical compilation guide for countries at varying levels of statistical development.

In conclusion, I am advocating two parallel and mutual supportive developments: on one hand, to improve official trade statistics by linking them to business statistics, and on the other hand to improve the compilation of IO tables with support of, for instance, an updated handbook on input–output tables.

C: Perspectives from the Organisation of Economic Cooperation and Development

Nadim Ahmad

The OECD is strongly in favour of an internationally coordinated approach to the development of value-added trade estimates and supports the idea that this could best be achieved with an inter-Secretariat approach that brings together a number of international agencies which are able to tap into their existing institutional networks of official statistics. The ultimate goal is of course a global IO table, which will in practice require agreement on the optimal level of industry or product detail across the different agencies responsible for the collection and harmonisation of national IO tables. We feel that it is perhaps premature and ambitious to encourage official statistics offices to produce national input–output (IO) or supply–use (SU) tables that differentiate imports by IO industries and final demand on the basis of the source industry and country which the import came from, but certainly we feel that statistics institutes could be encouraged to provide more detailed information on imports made by IO industries; this would significantly improve the quality of value-added trade estimates, as for many countries these are created using a simplistic proportionality assumption. Many developed economies could be encouraged to do this by tapping into firm-level data, in particular firm-level data that links business and trade registers. Developing countries should be encouraged to develop similar capacities, such that IO tables are able to reflect industry or product classifications in as homogeneous a way as is possible. Particular attention in this regard should be made to classifications that are able to differentiate between ‘ownership’, *ie* foreign or domestic, and import–export intensities. In this context we should also retain some scope for differentiating between ‘processors’ and conventional producers, noting in particular the changes in the 2008 SNA: improvements and indeed potential data sources have been identified in the deliberations of a Eurostat-led task force looking at goods for processing.[1] The value-added trade indicators we produce should be as detailed and useful as possible. In that sense the objective should be to produce estimates that reflect the whole economy and industries, broken down by factors of value added, *ie* labour and capital or operating surplus.

Many major economies already produce annual SU tables but not all. Clearly, the construction of internationally recognised estimates of value-added trade could serve as an important catalyst to motivate the development of more timely annual SU tables. In this regard it is useful to note that the OECD is currently engaged in a project with the Chinese National Bureau of Statistics to produce SU tables. The OECD, along with its partner agencies in the Inter-Secretariat Working Group on the National Accounts, will continue to encourage countries, including developing economies to implement the SNA, which recommends and included annual SU tables.

Certainly more work is needed on the allocation of trade to industries especially services. In the meantime, however, it will remain necessary for some

[1] See http://search.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=STD/TBS/WPTGS%282012%2910&docLanguage=En.

estimation, even if crude, to be done, although clearly there will be merit in providing ranges for the estimates that reflect changes in the assumptions used to allocate imports. This will also help in determining the level of detail at which value-added trade estimates could and should be presented, noting that the level of detail in IO tables is probably likely to be greater than the level of detail published.

A great deal of work remains to be done. But the importance of having some measure of value-added trade now means that we cannot wait for improvements in the underlying data to come first. Indeed, it is hoped that by demonstrating a credible need for these improvements by the production of value-added estimates we will be able to accelerate matters and motivate official statistics offices to allocate resources to improving the underlying data.

D: Perspectives from the US Bureau of Economic Analysis

Robert E. Yuskavage

One of the key features of globalisation has been the international fragmentation of goods production as firms take a global approach to reducing costs and expanding markets. This fragmentation has manifested itself in the development of global value chains characterized by rapid growth in the trade of intermediate products across borders. For some products, inputs cross borders multiple times before a final product is completed. Conventional foreign trade statistics that are based on these cross-border gross flows assign the full value of imports and exports to countries of origin and destination.

Because these conventional trade measures have major limitations for assessing inter-country linkages and bilateral trade balances, the Bureau of Economic Analysis (BEA) supports further research designed to develop accurate value-added trade statistics that could ultimately be included as supplementary measures in the System of National Accounts (SNA). However, BEA strongly believes that the conventional gross flows should remain as the featured measures of cross-border trade because of their important role in calculating the net exports component of gross domestic product and in providing high-frequency bilateral trade balances that are very timely and highly detailed.

Gross flows attribute the full value of imports entirely to the country where the final product is produced regardless of how much value was added by other countries upstream in the supply chain. Although economists have long minimised the importance of bilateral balances, these balances continue to receive considerable attention among policymakers and play important roles in discussions about trade policy and exchange rate management. However, large merchandise trade surpluses or deficits can be misleading for policy purposes when the domestic factor content of imports is high or the foreign factor content of exports is high.

A recent *Wall Street Journal* article (Batson 2010) about the global value chain for the Apple iPhone underscores this point. The iPhone is imported from China and included in the US import statistics at its wholesale value even though that value consists largely of intermediate goods and services produced in other countries, including the USA. The cost of assembly in China contributes only a small portion to the wholesale cost. Many of the papers presented at this workshop propose alternative approaches to measuring bilateral trade flows that focus on the value added to the final product by each country in the value chain. In the iPhone example, the overall US trade deficit would remain the same but the deficit with China would be considerably smaller and the deficits with other countries that supply parts, components, and services would be larger.

1 THE BUREAU'S APPROACH

For its economic accounts, the BEA closely follows international guidelines that are designed to increase the comparability of economic statistics across countries. The current approach followed by the USA and other countries is based on guidelines issued by the International Monetary Fund (IMF) in various editions of the Balance of Payments Manual. In 2009, the IMF released the sixth edition of the *Balance of Payments and International Investment Position Manual* (BPM6). This update, the first since 1993, was coordinated with an update in 2008 of the *System of National Accounts* (2008 SNA) in order to maximise the overall consistency between these two key sets of international guidelines for economic accounts. Several of the provisions in the most recent updates of these new international statistical standards were designed to at least partly address concerns about the impact of global production and global value chains on economic statistics. These provisions are described briefly later in this section.

It is important to recognise that the value-added approach has no impact on a country's overall trade balance and therefore no impact on gross domestic product (GDP) calculated as the sum of final expenditures. In effect, it reallocates a country's overall trade balance among its trading partners and expands the set of trading partners to include other countries in the global value chain. For GDP, net exports are calculated as gross exports minus gross imports. In the value-added approach, measures of gross exports and gross imports would each be smaller, but net exports overall would be the same.

2 THE VALUE-ADDED APPROACH

Value-added-based trade measures have been proposed as an alternative that better reveals the primary resources provided by countries to produce final products. Arguments for this approach have been made in the past in the context of measuring the factor content of international trade and identifying the export content of imports and the import content of exports. However, direct measurement of value-added trade is extremely difficult, if not impossible. A 2006 National Academy of Sciences (NAS) study concluded that meaningful value-added trade measures could not be developed primarily because the information was not available in business record-keeping systems.[1]

In general, US business firms do not maintain information in their accounting systems that would allow them to readily identify whether their material inputs are from domestic or foreign sources. Firms typically obtain their material inputs from wholesale suppliers and distributors and are not necessarily concerned about the country of origin for these materials. In addition, for foreign source materials, the country of origin may change frequently, depending on relative prices and other market factors. However, information developed by firms for supply chain management could prove helpful in this endeavour.

3 INPUT–OUTPUT METHODS

As a result, perhaps the most promising approach to developing comprehensive and consistent value-added trade measures that go beyond case studies of individual high-profile products involves the use of world IO tables. Even the NAS study acknowledged that the IO approach might prove viable for this effort but raised serious concerns about data quality and the assumptions required to obtain results. At that time, the largest reservation concerned the lack of a consistent time series of supply and use tables that could be linked across trading partner countries. These linkages are critical to deriving measures that take into account not only the countries of origin and destination for traded goods throughout the value chain but also the production technology that is employed in the countries that provide inputs both directly and indirectly.

Previous chapters in this volume provide a strong testament to the impressive advances that have taken place in the last few years in the development of consistent and comparable linked regional supply and use tables. As a result of these advances, the reliability of value-added trade measures based on the IO approach has increased significantly, for both the measures for individual countries and the related bilateral trade balances between trading partner countries. Of course, significant further work is required before a consistent

[1] See National Research Council and National Academy of Sciences (2006).

set of reliable measures can be developed on a time-series basis for a wide range of countries on a timely basis.

One area in particular that requires further work is the development of the import use tables that play a key role in generating the estimates of bilateral supply and use of imported intermediate inputs. For the reasons described above, direct measures of the use of imported intermediate inputs by industry are not available, and existing import use tables rely heavily on the import comparability assumption. BEA has conducted research evaluating the reliability of this assumption and has found that while it works well for some industries at aggregate levels it is not as accurate for the more detailed industries that are critical for understanding the use of imported inputs for products involved in cross-border trade. Other research based on Census Bureau micro data holds promise for future improvements in import use tables.

4 NEW INTERNATIONAL GUIDELINES

Two provisions that were introduced in SNA 2008 and BPM6 that are directly related to the impact of global manufacturing are a new treatment of goods sent abroad for processing without a change in ownership (goods for processing) and the purchase and subsequent resale of goods abroad without substantial transformation and without the goods entering or exiting the country (merchanting). Under the treatment of goods for processing, no change in ownership is imputed, the goods are excluded from merchandise trade gross flows for both exports and imports and the value of the service provided by the contract manufacturer is recorded as trade in services. This treatment has no impact on the overall trade balance, but it shifts the composition of the balance between goods and services. If intermediate materials were acquired from other countries, in principle those goods would be counted as imports from those countries rather than from the country of final assembly. The new treatment of goods for processing in particular has the potential to significantly reduce the distortions associated with the traditional measures based on gross trade flows. Some global manufacturing activities may also qualify for the new merchanting treatment, but this treatment would not necessarily address the issue of bilateral balances.

5 CONCLUSION

BEA encourages further research to develop IO based value-added measures of foreign trade in order to more clearly articulate the nature of bilateral trade flows and balances. However, BEA does not believe that value-added measures should supplant conventional gross flow trade statistics as the featured measures of cross-border trade and for calculating GDP. The existing bilateral gross trade flow statistics are timely, long-standing, useful for a wide range of statistical and analytical purposes, well reported by countries around the world and consistent across countries. BEA will support the development of value-added measures by continuing to improve the accuracy and timeliness of its input–output accounts for the USA. However, for IO-based measures to be useful for calculating bilateral trade balances, a coordinated approach across countries would be required. Practical problems would arise if each country were responsible for compiling its own value-added trade statistics. Issues of frequency, timeliness and consistency would also need to be addressed.

Finally, it is important to point out that the new international standards introduced in SNA 2008 and BPM6 related to goods for processing in principle at least partly address some of the concerns raised in this volume. However, national statistical agencies face major challenges in implementing these new standards because of limited source data and resources. For statistical agencies, implementing the new standards should be a higher priority than developing new analytical measures. Researchers should work closely with the statistical agencies to help implement these important new standards while continuing to advance the state of the art for world IO tables.

REFERENCES

Batson, A. (2010). Not Really ‘Made in China’, *Wall Street Journal*, 10 December.

Cheung, P. (2011). Input–Output Analysis in Contemporary Official Statistics. Paper presented to 19th International Input–Output Conference, Alexandria, VA, 13–17 June 2011. URL: http://www.iioa.org/Conference/19th/keynote.html.

International Monetary Fund (2009). *Balance of Payments Manual* (6th edition). URL: http://www.imf.org/external/pubs/ft/bop/2007/pdf/bpm6.pdf.

Mattoo, A., Z. Wang and S.-J. Wei (2011). Tracing Value-Added in International Trade: An Overview of Issues and a Proposal. Discussion Paper presented at World Bank Trade Workshop. URL: http://go.worldbank.org/R156ABXQQ0.

National Research Council and National Academy of Sciences (2006). *Analyzing the US Content of Imports and the Foreign Content of Exports*. Washington, DC: National Academies Press.

SNA (1993). System of National Accounts. United Nations Statistics Division. URL: http://unstats.un.org/unsd/nationalaccount/sna1993.asp.