DEVELOPMENT OF GLOBAL INTER-COUNTRY INTER-INDUSTRY SYSTEM FOR VARIOUS POLICY PERSPECTIVES

BY

NORIHIKO YAMANO

DISSERTATION

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Doctoral Committee:

Professor Geoffrey Hewings, Chair
Professor Brian Deal
Professor Edward Feser, Oregon State University
Professor Erik Dietzenbacher, University of Groningen

ABSTRACT

Globalization and international economic integration are not new phenomena. However, the recent evolution of global supply and procurement networks has significantly changed foreign dependencies both for inputs (imports) and outputs (exports). These important changes in global production systems challenge conventional statistics and databases provided by national statistics offices since these are no longer sufficient to provide adequate insights into policy discussions. The notable specification features of the global interindustry model developed in this thesis are summarized as follows:

1) Covers approximately 90% to 95% of global value added, exports, imports and production are available in the system for individual countries for time series between 1995 and 2011.

2) It is harmonized with the System of National Accounts, an international comparable accounting framework of economic statistics. Therefore, GDP, trade balances and final expenditures in the model of this thesis match the numbers officially published by national statistics agencies.

3) The direct purchases by non-residents and international transportation and trade margin structures are estimated at the sectoral level. To author's knowledge, this is a unique methodology to link the statistical sources in purchases' and basic prices. Without this methodological specification, a large part of the trade in services particularly for wholesale, water and air transportation and tourism expenditures on hotels and

restaurants industries would be misallocated as is the case in many earlier inter-country (multi-regional) models.

4) The model is specifically designed to analyze the globalization impacts for different policy areas with important extensions to account for regional dimension (Chapter 3) and the role of firm heterogeneity on trade intensity (Chapter 4).

The subsequent chapters of this dissertation detail the methodology for the compilation techniques used to develop the various types of international input-output (IIO) models to analyze the different policy areas described in Chapter 1. The second chapter describes the estimation procedure for developing a spatially extensive IIO model using to the maximum possible extent all available statistical data sources. This model is, therefore, capable of analyzing various policy areas discussed earlier. The third chapter is an extension of the model developed in the second chapter in the context of subnational regions. This extension allows regional planners to analyze the economic impact in the context of participation of regional economies in global production networks. The extension of the model in chapter 4 is particularly designed to analyze the Trade in Value Added (TiVA) indicators by introducing firm heterogeneity in the processing trade of manufacturing activities using examples from China and Mexico. This split in processing trade activities greatly enhances the understanding of the role and magnitude of empirical estimates of emerging regions where their primary tasks in production systems are assigned for the assembly of imported intermediate products. The final chapter provides a summary of this thesis and discusses the wide range of additional policy analyses directly conducted by author.

TABLE OF CONTENTS

CHAPTER 1 : POLICY DISCUSSIONS USING INTER-COUNTRY INPUT-OUTPUT SYSTEM: OVERVIEW

1.1 INTRODUCTION

Globalization and international economic integration is not a new phenomenon. However, recent evolutions of global supply and procurement networks have significantly changed foreign dependencies both for inputs (imports) and outputs (exports). These great changes in global production systems and the removal of trade barriers e.g., tariff reductions and decreases in transport and communication costs, have meant that conventional economic and policy analyses based on single economy/region may be insufficient to provide adequate insights into policy discussions at national and subnational levels. In particular, environmental and trade policy analysts have supplemented conventional approaches with information concerning the spatial (international) spillover effects generated by economic models within a multi-country/region framework.

The economic and social impacts due to these important changes in foreign dependencies have evolved unevenly in terms of geographical locations and, as a result, development patterns are now very different to those observed in the late 19th century to late 20th century, from example, from the Fordism type development notion of Antonio Gramsci's Prison Notebooks until the 1st unbundling of globalization where decreases in trade costs dominated the increases in the linkages between countries (Baldwin, 2006). Income growth and industrialization were tightly connected until the late 1980s (prior to the internet period).

While the emerging economies in Eastern Asia and Eastern European gradually integrated into the trade networks of developed economies (i.e. OECD after the mid-1990s), the majority of global consumption remained in developed regions. In other words, the geographical locations of production sites and consumption regions become imbalanced. The phenomenon of this widening gap between locations of producers and consumers i.e. fragmentation of production processes (Arndt and Kierzkowski, 2001) has been increasingly discussed in the field of international economics, for example, offshoring phenomenon (Grossman and Rossi-Hansberg, 2006), and the 2nd and the 3rd unbundling phenomena (Baldwin, 2006, 2016). In some cases, the geographical reallocations of production activities have generated international frictions leading to trade and currency wars e.g. intentional devaluation of currency exchange rates. The differences in locations of producing and consuming regions has also had an impact on other international social and economic policy agendas such as global environmental issues, modern exploitation by multi-national enterprises, and corporate tax avoidance schemes.

Until recently, key theoretical and methodological tools and corresponding empirical evidence to discuss the effects of the evolution of multinational/regional production networks have been missing mainly due to the limitation of statistical components that allow us to compile inter-country input output tables on a global scale. The only statistics evidences has been suggesting the phenomenon of the fragmentation of production processes across countries, offshoring and unbundling

The main contributions of this dissertation are to identify and develop high-quality international, comparable economic inter-country input-output database based on statistics on international trade, production and expenditure structures at a harmonized sectoral level and to provide a set of

empirical tools for policy analysis regarding the evolution of globalization. The notable specification features of the global interindustry model developed in this thesis are summarized as follows:

1) The model accounts for approximately 90% to 95% of global value added, exports, imports and production are available in the system for individual countries for time series between 1995 and 2011.

2) It is harmonized with the System of National Accounts, an international comparable accounting framework of economic statistics. Therefore, GDP, trade balances and final expenditures in the model of this thesis match the numbers officially published by national statistics agencies.

3) Moreover, the direct purchases by non-residents and international transportation and trade margin structures are estimated at sectoral level. To author's knowledge, this is a unique methodology to link the statistics sources in purchases' and basic prices. Without this methodological specification, a large part of the trade in services particularly for wholesale, water and air transportation and tourism expenditures on hotels and restaurants industries has been misallocated in prior inter-country (multi-regional) models.

4) The model is specifically designed to analyze the globalization impacts in different policy areas. An initial exploration of the role of heterogeneity of industries engaged in trading activities is conducted. Thus, the extensions made for regional dimension in Chapter 3 and firm heterogeneity on trade intensity in Chapter 4 contribute to enrich the understanding of globalization impacts.

1.2 BENEFITS AND LIMITATIONS OF INTER-COUNTRY INPUT-OUTPUT SYSTEMS

National input-output (I-O) tables describe the sales and purchases relationships between producers and consumers within a country providing detail on both final and intermediate outputs. On the other hand, inter-country input-output systems (ICIO) expand the inter-industry relationships to include cross-border transactions by linking national I-Os with trade partner shares of goods and services.

The model can explicitly identify the direct and indirect relationship between multiple agents in the global economy. The international linkage analyses based on ICIO model are able to include four dimensions of countries/regions and four dimensions of industries and products.

- Country (region): value-added source country, exporting country, importing country and final expenditure country
- Industry (product): value-added source industry, products produced in exporting industry, importing industry (sector) and products consumed in final expenditure

Currently, there is no other database or economic model that can handle the highly complex inter-connected system of the global economy. For example, the size of a global-scale ICIO database can easily surpass one million data points, per year, even with relatively small dimensions such as 20 industries, 50 countries, 5 final expenditure components.[1] Linking over a million observations within alternative models, such as macro-econometric models is not possible.

[1] 1,255,000 data points = (50 source country x 20 source industry) x (50 demand country x (20 intermediate industries + 5 final demand components)) + 5 value-added / output components x 50 country x 20 industry

While ICIO databases have proven to be useful for various globalization analyses, there are some statistical and conceptual limitations. The ICIO database relies heavily on various underlying economic statistical sources to compile a database and it may take at least 3-4 years for certain underlying data sources (such as national input-output tables) to become available in most countries. In addition to timeliness issues, the availability of statistics in developing economies can be a limitation that is further exacerbated by issues of coherence between national accounts, balance of payments and input-output tables. Compiling and processing the necessary data require a significant allocation of resources both in terms of money and expertise.

The conceptual issues of I-O based analyses are broadly categorized within the framework of national accounts and the interpretation of multipliers derived from global I-O tables. These can be summarized as follows:

Full implementation of recommended framework of National Accounts

System of National Accounts manuals have been recommending countries to estimate supply and use table at both current prices and constant prices to estimate the main components of National Accounts such as GDP, value added and final expenditures items. However, many countries have not been able to fully integrate the input-output and national accounts data. The GDP figures are mainly estimated from the expenditure side. The quality of national accounts estimates particularly for the first release estimates i.e., quarterly quick estimates are relatively unreliable in the countries where their national accounts are not fully integrated with the SUT framework.

The inter-country comparison analyses of recent years have directly and indirectly contributed to raise the awareness of supply-use and input-output databases as a core database to analyze the various economic and social impacts analyses. For example, many European countries are now able to provide official annual supply, use and input-output tables in an annual series after the completion of several international input-output database projects that have been funded by European Commission such as:

EU KLEMS: Sectoral productivity analysis (http://www.euklems.net).

WIOD: Time series ICIO development for European and major non-EU countries (http://www.wiod.org).

EXIOPOL: Aimed to develop environmental and material flows analysis for significantly details in agricultural and mining sectors (http://www.feem-project.net/exiopol/).

Figaro: Highly disaggregated services sector database with bilateral trade asymmetry solved trade flows (EC Eurostat and Joint Research Center).

In addition, a number of projects focusing on inter-country input-output analysis have also been undertaken or are in progress in Asia–Pacific region (APEC TiVA; NAFTA TiVA; ADB SUT and IOT tables) to support building the national capacities to produce the internationally comparable national accounts and IO/SUT databases.

Interpretation of multipliers

The aim of the framework of national accounts is to record the monetary transactions of inter-industry relationships for accounting purposes and the shares of intermediate inputs to output *i.e.*,

input coefficients do not always represent the technological coefficients of physical processes. In addition, the economic activities of all countries are not recorded in exactly the same manner. For example, due to confidentiality issues and/or to minimize data collection burdens, the unit of measurement for industry statistics (*i.e.*, economic activity dimension) may be closer to enterprises rather than establishment-based economic activity that is recommended by the *Manual for System of National Accounts* (European Commission *et al.*, 2009). Thus an 'industrial activity' may not be easily comparable across countries.

Trade flows in National I-O and ICIO

All trade flows included in national accounts and merchandise trade statistics are not represented in ICIO framework. For example, re-exports reported in the import tables are removed in the ICIO framework, where the trade flows between countries are specified on an origin–final destination concept.

1.3 RELEVANT POLICY AREAS

With its detailed information on international transactions between target countries, the ICIO system developed in this thesis can serve as an important input into a wide range of evidence-based economic and social policy analyses for 61 individual countries and the rest of the global economy. The coverage of 61 individual countries allows also for analysis for economic regions such as the customs unions of the European Union and NAFTA, and economic and political forums such as APEC, ASEAN and OECD. In particular, indicators can be developed to inform discussions in the areas of trade policy, industrial policy, environmental policy, regional development and risk management. These analyses can eventually affect the decisions of policy makers during international negotiations on trade, monetary and environmental issues.

1.3.1 International trade policies using Trade in Value-Added (TiVA) estimates

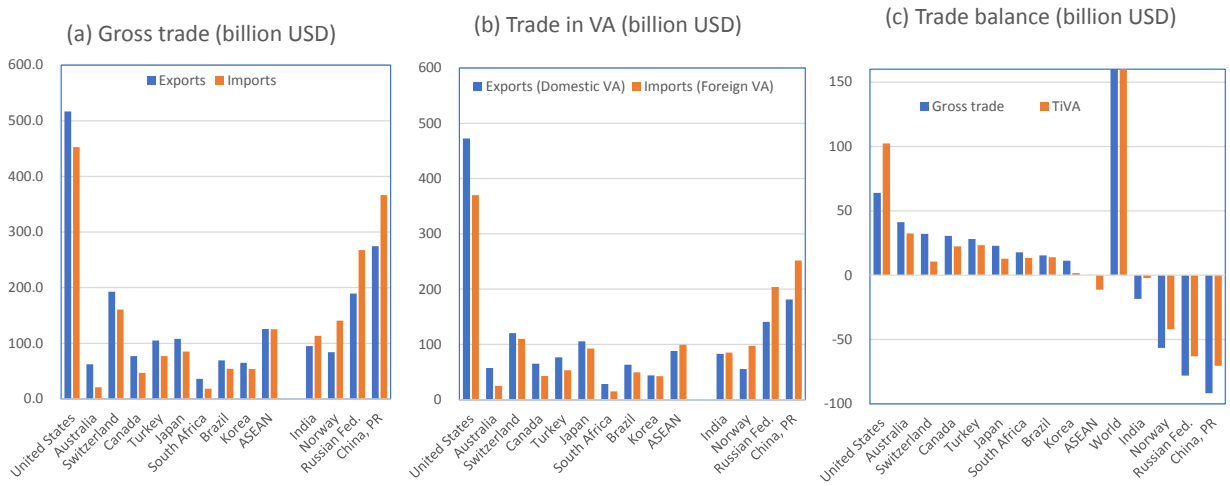
Current manufacturing systems now involve supply chains of specialized operations in multiple locations. In other words, the conventional understanding of beneficial exports and injurious imports has recently changed. Indicators based on an ICIO system can provide both conventional and alternative viewpoints of our understanding of bilateral trade relationships. Due to the significant increase in international trade in intermediate supplies, exported goods and services include the value originally embodied in intermediate imports. As an alternative to a conventional trade measures in "gross" terms, an ICIO system can be used to develop measures of Trade in Value-Added (hereafter, TiVA) (see WTO and IDE JETRO, 2011; OECD and WTO, 2012).

In order to evaluate the trade balances of countries, the ICIO database developed in this thesis are particularly useful for many reasons: 1) The trade balances are consistent with the National Accounts-based figures. Thus, the exports and imports are consistently valued at f.o.b. If the compilation of ICIO begins with the use of the national domestic I-O at basic prices or producers' prices and import tables at c.i.f. purchasers' prices (as most other projects have done), the trade balances are not fully comparable across countries. 2) Secondly, the treatment of direct purchases is not consistent in the official national tables.[2] The direct purchases abroad (imports by domestic resident households) and direct purchases in domestic territories (exports to non-resident households) are explicitly measured in the new system. 3) International wholesale and

[2] Even in the Eurostat harmonized format input-output and supply-use table database, the treatment of direct purchases by non-residents are not consistent.

transportation margins are explicitly allocated to services providers. These two services trade items are the largest trade in services for most countries and they are not endogenized in the ICIO tables of earlier projects e.g. IDE-JETRO and WIOD projects. 4) Extensions of firm heterogeneity in chapter 4 of this thesis have also contributed to avoid overestimating the value added embodied in trade in China and Mexico.

Measurement of this difference between gross exports and value-added based trade indicators impacts on the current framework of recent and ongoing trade negotiations within and between current and proposed free trade zones such as ASEAN, NAFTA, European Union, Transatlantic Trade and Investment Partnership (T-TIP) and Trans-Pacific Partnership (TPP). Figure 1.1 summarizes the trade balances of European Union 28 members in gross exports and final demand value added terms. In 2011, the EU as a region had larger trade deficit with China, Russian Federation, Norway and India and the EU had larger trade surpluses with the United States, Australia, Switzerland and Canada in gross exports term (panel c of Figure 1.1). The net exports figure for the United States widens when it is compared in value added terms because the exported intermediate products and supplies sent to non-US economies are processed to manufacture the final products could be eventually consumed in the US. Similarly, the exported intermediate goods and services to Australia, Switzerland and Canada are also eventually consumed in their neighbor economies when it is processed by the immediate importers. These alternative views of bilateral trade relationship have significant implications on the trade and industrial policies.



Source: OECD-WTO Trade in Value Added Database 2016

Figure 1.1: Trade balances in gross trade and Trade in Value Added between (European Union 28, 2011)

1.3.2 Energy and transportation infrastructure policies

One of the key advantages of I-O analyses is to estimate the derived demand for products such as utility and transportation services. In general, industries and consumers do not gain profits, benefits and utilities by just consuming the utility and transportation services except for few cases such as holiday flights, pleasure driving, etc. The demand for these activities often occurs as a result of demand for other consumption activities e.g. tourism, commuting and housing. The ICIO system allows us to overcome the limitation of single country framework and the derived demands of another country can be explicitly introduced (Wood *et al.*, 2015; Owen *et al.*, 2017). In terms of planning perspectives in a region or country, it is important to know the structure of demand propagation of their own utility and transportation services, because development of these infrastructures usually takes many years of preparation, and negotiations to build the facilities and the costs of construction and maintenance are enormous. The model developed in

this thesis explicitly estimates the international trade and transport margins embodied in goods trade. Thus, the trade figures published in official statistics (national accounts, balance of payments and merchandise customs statistics) in purchases prices have been consistently adjusted.

1.3.3 Global environmental policies

ICIO models, often referred to as multi-regional I-O (MRIO) or interregional I-O (IRIO) models, initially gained most attention from global environmental analysts because most of these greenhouse gasses (GHGs) are related to energy, transport and extraction of energy related mining products that are usually indirectly consumed by households and importers. Various types of globally linked I-O tables have been developed by different type of ecological footprint analyses (see Lenzen *et al*., 2004; Minx *et al*., 2009; Peters *et al*., 2011; Lenzen *et al*., 2012; Wiebe and Yamano, 2016). Changes in consumption and production locations have significantly altered the global patterns of consumption-based and production-based ecological impacts. Compared to a single country linked model (e.g. Ahmad and Wyckoff, 2003; Nakano *et al.*, 2009), the global input-output models provide a more consistent basis for the analysis of consumption-based greenhouse gases (GHGs). These estimates of emissions embodied in final demand and in international trade contribute to a better understanding of how CO_2 emissions around the world are driven by global consumption patterns. The time series tables developed in this thesis are particularly important for the discussion of this policy area because the CO_2 gasses tend to stay in the atmosphere for decades and the accumulated stock measures are as important as snapshot discrete-year analysis.

1.3.4 Risk management

Recent unexpected and devastating events such as 2011 Tohoku earthquake, tsunami and nuclear accident in Japan (Arto *et al.*, 2015; Yonemoto, 2016) and 2011 Bangkok flooding in Thailand (Isono and Kumagai, 2014) that took place in the Asian manufacturing networks raised some understandable concerns over global supply chains. The sensitivity of national economies to external shocks in other parts of the world is significantly increased by the participation in global production networks. The inter-country/interregional input-output system can contribute to a better understanding of direct and indirect vulnerability to economic shocks and to inform countries about possible pre-emptive actions to minimize impacts. First, the regional extended model developed in Chapter 3 of this thesis directly contributes to this policy area. Since the disruptions of production infrastructures by natural disasters usually are made in relatively small geographical areas. Secondly, the annual firm heterogeneity-extended ICIO developed in Chapter 4 also provides useful information to analyze the short time structural changes of dispersion of economic crisis (e.g., Hashiguchi *et al*., 2017a, b).

1.3.5 Jobs and skills

Employment embodied in domestic and foreign final demand expenditures can be estimated in a similar manner to that of TiVA indicator value added embodied in foreign final demand using the ICIO system. The labor inputs per unit of production and labor productivity differ widely across countries and industries. The estimates of domestic employment embodied in foreign final demand attempt to capture the share of jobs used in production to satisfy foreign demand for final goods and services. The model developed in this thesis has been chosen to estimate the OECD Trade in Employment indicators (OECD 2016, http://oe.cd/io-emp) because the sectoral value added and output are consistent with national accounts figures. Thus, the sectoral labor productivity used to calculate the indicators fits consistently in the framework of national accounts for each country. If the ICIO system is built in a product-by-product format (e.g, IDE-JETRO's AIO), it requires additional efforts to develop the employment figures by product rather than industry. Another reason for a benefit of using the model developed in this thesis is that the model allows inclusion of the labor input intensity for processing firms and the non-processing firms. It is obvious that the labor-intensive assembly oriented firms require more employment per monetary unit of production.

As the fragmentation of manufacturing processes within a same industry group becomes evident, the separation of tasks is observed in the allocation of employment characteristics by educational and occupational skills, gender and age groups. A global ICIO system facilitates the detailed identification of the international division of labor.

1.4 SUMMARY

The subsequent chapters of this dissertation detail the methodology for the compilation techniques used to develop the various types of ICIO models to analyze the different policy areas. The second chapter describes the estimation procedure of developing a spatially extensive international input-output model using to the maximum possible extent all available statistical data sources. This model is, therefore, capable of analyzing various policy areas discussed earlier. The third chapter is an extension of the model developed in the second chapter in the context of subnational regions. This extension allows regional planners to analyze the economic impact in the context of participation of regional economies in global production networks. The extension model in chapter 4 is particularly designed to analyze the Trade in Value Added (TiVA) indicators by introducing firm heterogeneity in the processing trade of manufacturing activities in China and Mexico. This split of processing trade activities greatly enhance the understanding of the role and magnitude of empirical estimates of emerging regions where their tasks of production are assigned for the assembly of imported intermediate products. The final chapter provides the summary of this thesis and discusses the wide range of additional policy analyses conducted by the author.

CHAPTER 2 : DEVELOPMENT OF THE INTER-COUNTRY INPUT-OUTPUT DATABASE

2.1 INTRODUCTION

Input-Output tables published from statistical agencies have been widely used by economic and development planners as effective tools for analyzing various economic, social and environmental issues in their target regions and national economies. However, conventional approaches based on a single country/region perspective databases have become less effective in recent years due to increased dependencies on foreign intermediate resources (imports) and external demand (exports).

More importantly, many of the notable changes in the production networks have been generated by the international fragmentation of production processes. Many manufacturing products, notably textiles, electronics and motor vehicles, are increasingly fragmented across countries. The evidence from merchandise trade statistics (UN Comtrade-based OECD Bilateral Trade Database by Industry and End-use Category, http://oe.cd/btd) indicates that transactions of intermediate parts and components have significantly increased not only between neighboring countries, but also between regional trading blocs (such as European Union, NAFTA and "Factory Asia"). These transitions in global systems of production of manufactured goods are often led by changes in the division of labor coordinated by multinational enterprises with improved availability of business supporting services e.g. network communication, supply chains management, consulting services and logistics infrastructure. Thus, a wide range of industrial data is required to analyze the impacts of global consumption patterns and global production activities on cross-border spillovers and feedback ripple effects.

The field of regional science has been analyzing the interconnectedness of multi-industry production networks since the mid-20th century (Isard, 1951; Chenery, 1953; Moses, 1955; METI 1960-2005, etc.) using observed sub-national regional input-output tables (IO) and national input-output structures. Policy interest in interregional economic impacts has been growing in concert with the degree to which domestic economies have become much more globally integrated especially when compared to earlier periods when there were many barriers at international borders (Hewings, 1977; Anderson and van Wincoop, 2004). The conceptual frameworks of Inter-Regional IO (IRIO) and Multi-Regional IO (MRIO) models have been extended to develop inter-country linked models as well, although at relatively smaller geographical scales (See, for example, Wonnacott (1961) for Canada-USA; IDE-JETRO Asian IO 1980-2005; METI Japan-U.S. Input-Output table 2000-2005).

The main issue that has prevented compilation of inter-country input-output tables on a global scale has been the availability of data from national sources. In particular, statistics at a sufficiently detailed level of industry have not yet been published for many countries. While the main aggregate items in National Income and Product Accounts (NIPA) and trade statistics by product are publicly available for most countries in a harmonized format for the total of all industries, sectoral (industry and product) statistics are less harmonized in databases maintained in a national accounts framework.

"Harmonized" input-output databases on a global scale became available in the mid-2000s for selected reference years (see GTAP; OECD STAN I-O Database; Eurostat harmonized SUTs and IOs). Following increased demand from policy makers for the input-output analyses, even annual tables in a harmonized format started to appear from the mid-2010s (WIOD 2013

for 1995 to 2009; WIOD 2015 for 1995 to 2011; Extended WIOD in ISIC4 format for 2000-2014; OECD 2015 for 1995-2011; EORA 2013 for 1995-2011).

Since both access to appropriate computing resources and the availability of underlying data have improved in recent years, a number of research groups in international organizations and research consortia have initiated projects that have developed inter-country input-output systems for different analytical purposes (Peters *et al*., 2011; Dietzenbacher *et al*., 2013; OECD ICIO 2011, 2013 introduced in Yamano (2012) and Inomata *et al.* (2013); Lenzen *et al*., 2013; Tukker *et al*., 2013; Koopman *et al*., 2008; EU Figaro 2016). There are, however, many remaining challenges regarding methodological and statistical issues. The conventional approaches of MRIO to estimate IRIO, including most of the studies noted earlier, are to prepare domestic and import input-output tables at either producers' prices[3] or basic prices[4] and link them using bilateral trade partner shares for goods and services (Chenery, 1953; Moses, 1955; Isard *et al*., 1998). This approach uses relatively simple procedures to compile the inter-country trade flows by multiplying the import matrices of each country by the import partner shares.[5] However, both bilateral trade in goods statistics (merchandise trade statistics from national customs agencies) and services (balance of payments) are valued at purchasers' prices. In other words, a large part of domestic transportation and wholesale services in the exports of input-output tables and national accounts are embodied in goods exports. Therefore, there are potential inconsistencies between national IOs at basic prices and trade statistics in purchasers' prices.

[3] The producer's price is the amount receivable by the producer from the purchaser. It excludes any distribution margin but includes deductible tax (Glossary of Statistical Terms, OECD).
[4] The basic price is the amount receivable by the producer from the purchaser. It excludes any distribution margin, tax payable and subsidy receivable (Glossary of Statistical Terms, OECD).
[5] There are extended versions of this approach using trade coefficients by end-use category (e.g. intermediate, household consumption and capital goods) and additional sectoral constraints on imports and exports to balance the initial values estimated from import tables and trade coefficients.

The differences between use tables at purchasers' prices and symmetric tables at basic prices from selected European countries (Eurostat SUT / IO Database for 2010 to 2013) indicate that the average share of distribution margins and net taxes embodied in goods products are about 15% and 5% respectively.

The compilation methodology described in the following sections of this chapter follows similar three-stage balancing techniques as those developed by Wang *et al.* (2010).[6] While the conventional approach of developing IRIO using MRIO techniques (Isard *et al*., 1998; Miller and Blair, 2009) is to link the national symmetric import tables by trade partner coefficient matrices, this alternative multi-stage balancing approach allows us to introduce as much officially published statistics on sectoral and bilateral trade flows as possible to explicitly control the sectoral trade flows. In particular, price valuations and global trade constraints are carefully controlled in each step.

Wang *et al.* (2010), Tsigas *et al.* (2012) and Ahmad *et al*. (2013) used the already-harmonized use tables from the GTAP (http://www.gtap.agecon.purdue.edu) and WIOD project (http://www.wiod.org) as a given starting point respectively. Extending these preceding studies, the analysis in this chapter goes further by introducing additional steps for balancing both cross-border trade and direct purchases by non-residents abroad within a national accounts framework because reported bilateral trade in goods and services statistics are not balanced at a global level and the reported national input –output data sources are not necessarily harmonized with the national accounts framework.

[6] See also Tsigas *et al.*(2012) and Ahmad *et al.* (2013) for the three stage balancing technique using different data sources.

Another notable feature of the methodology proposed in this chapter is the explicit measurement of direct purchases by non-residents. The expenditures by non-residents are a relatively high share in their total exports for the countries heavily dependent on international tourism (e.g. Greece and Thailand) or education services to foreign students (e.g. United Kingdom and Australia).

There are four major steps for compiling the ICIO in this chapter (see Figure 2.1 for overall flow chart of ICIO development) as follows:

1) Collection of statistics sources and harmonization

For each country, the following data sources are collected from various national statistics agencies: national accounts (SNA), balance of payment (BOP), tourism satellite account (TSA), household consumption data (HC-COICOP), merchandise trade statistics (Customs) and trade in services (TIS).

2) Estimation of balanced trade flows: total industry, sectoral and bilateral trade

The sectoral bilateral trade data are not balanced in one procedure in order to avoid the increases of uncertainty of the results. The methodology used in this thesis provides room for the inclusion of additional constraints in order maximize the uses of official statistics. Direct purchases by non-residents, re-exports and re-imports are adjusted at the product level at this stage. To the author's knowledge, this is a unique approach compared to existing approaches in the literature.

3) Estimation of National input-output and supply –use tables

The supply table at basic prices and use table at purchasers' prices are estimated under the sectoral constraints and control totals constraints. If the sectoral details are not available for a specific target country, the production structures of other countries' average are used as an initial value to start the balancing procedure.

4) Development of inter-country input-output database

Finally, the inter-country transaction flows are estimated using the international harmonized data sources of national IOs and balanced trade partner shares of previous steps.

The rest of this chapter describes the details of each compilation steps. The next section describes harmonization of national data sources. The methodology for different stages of trade balancing methodology is introduced in the third section. The fourth section describes the compilation methodology of national supply, use and input-output tables. The last stage of trade balancing i.e. inter-country input-output system is finally allocated to end-use industries and final expenditure categories in the 5^{th} section. The last section provides a summary.

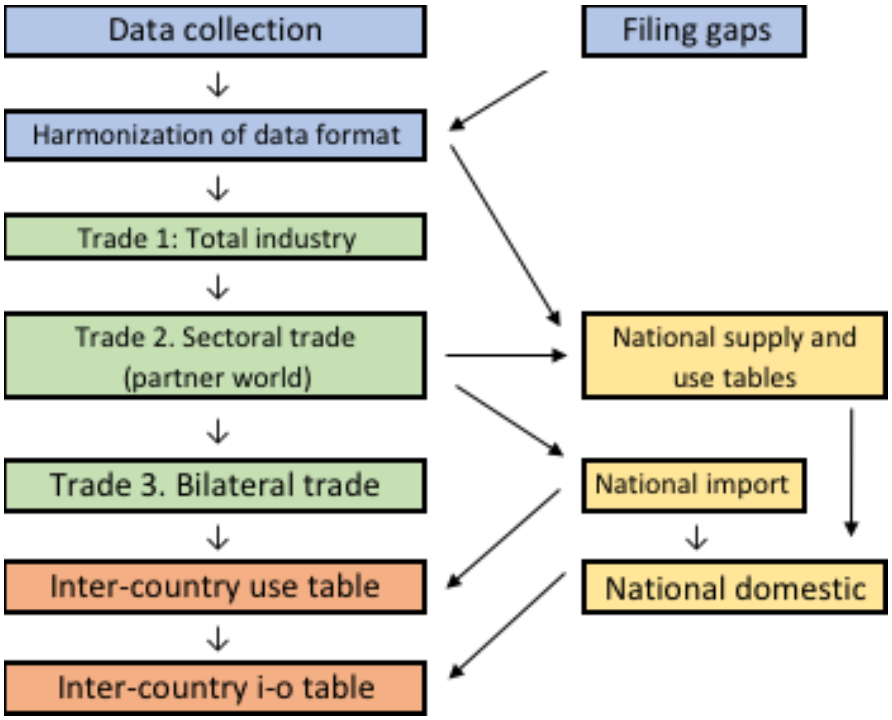


Figure 2.1 : The ICIO compilation procedure

2.2 HARMONIZING NATIONAL DATA SOURCES

National accounts statistics are some of the most reliable sources of information that can be used to compare the economic activities of countries in a common format in both current and constant prices. The primary data sources used in this study are the national accounts detailed tables submitted, in a common format, by national statistical agencies to OECD, Eurostat and United Nations. National accounts databases, with varying coverage, are maintained and regularly updated by these international organizations. If there are gaps in country-reported data, missing data are filled by alternative secondary data sources e.g., long-term main aggregates national accounts database (UN; OECD; World Bank), balance of payments (IMF), tourism satellite accounts (national statistics agencies; OECD) and merchandise trade statistics (UN Comtrade). Table 2.1 summarizes the national accounts variables collected for this study. The items in the left column of the table are generally available in primary national accounts sources, while gaps and jumps (inconsistencies across time) are often observed in the items in the right column.

Table 2.1 : Variables from National Accounts

code*	Variable	code*	Variable
B1_GA	Gross domestic product (output approach)	P31S15	Final consumption expenditure of non-profit institutions serving households
B1G	Gross value added at basic prices, total activity	P61	Exports of goods
D21_D31	Taxes less subsidies on products	P62	Exports of services
B1_GE	Gross domestic product (expenditure approach)	P71	Imports of goods
P3S13	Final consumption expenditure of general government	P72	Imports of services
P31S14	Final consumption expenditure of households	P33	Final consumption expenditure of resident households abroad
P51	Gross fixed capital formation	P34	Final consumption expenditure of non-resident households on the territory
P52_P53	Changes in inventories and acquisitions less disposals of valuables	NFP1R	Output
P6	Exports of goods and services		
P7	Imports of goods and services		

* National Accounts code (OECD, United Nations)

The second step for the compilation of national accounts constraints is to construct cleaned time series figures of each country and world economy under following conditions.[7] The GDP constraints in expenditure and output approaches are respectively defined as:

$$B1\_GE = P31S14 + P31S15 + P3S13 + P51 + P52 + P53 + P61 + P62 - P71 - P72 \quad \textbf{(2.1)}$$

and

$$B1\_GA = B1\_GE = B1G + D21 - D31 \quad \textbf{(2.2)}$$

where the variables are defined as follows:

[7] Note that codes in the parentheses indicate the standard codes used National Accounts data sources at international organizations (UN, OECD and Eurostat).

Table 2.2 : Variables for GDP constraints

B1_GE: GDP expenditure approach	*P61* : exports of goods
B1_GA : GDP output approach	*P62* : exports of services
P31S14: Final consumption expenditure of households	*P71* : imports of goods
P31S15: final consumption expenditure of non-profit institutions serving households	*P72* : imports of services
P3S13: final consumption expenditure of general government	*B1G* : value added at basic prices
P51: gross fixed capital formation	*D21*: taxes on intermediate and final products
P52: changes in inventories	*D31*: subsidies on intermediate and final products
P53: changes in valuables	

The direct purchases of both goods and services in domestic territory by non-residents (*P34*) are included in exports of services (*P62*) and direct purchases abroad by residents (*P33*) are part of household final consumption expenditures (*P31S14*).

National accounts expenditure, gross domestic product (GDP), is used as a reference GDP value for each country. Expenditure GDP figures thus take priority over GDP based on the output and income.[8] The main components of each GDP approach are summarized as follows (OECD Glossary of Statistical Term):

Gross domestic product (output approach) = Gross value added at basic prices +taxes less subsidies on products

Gross domestic product (expenditure approach = Final consumption expenditure +Gross capital formation +Exports -Imports

[8] In principle, all 3 approaches of GDP estimates are equal. However, for many countries, the discrepancy items appear in output and income GDP figures to make the GDP estimates the same for all 3 approaches.

Gross domestic product (income approach = Compensation of employees +Gross operating surplus and gross mixed income +Taxes less subsidies on production and imports

Any statistical discrepancy reported in output GDP (SNA code: *DB1_GA*) and expenditure GDP (SNA code: *DB1_GE*) are merged with taxes less subsidies on products and changes in inventories respectively to meet the above equality condition. This concerns a few, mainly developing, economies.

Sectoral value added and output in a common international classification (e.g. ISIC, NACE) are not available for most non-European countries in the national accounts databases.[9] Also, the level of industry detail available is often not sufficient for the development of the ICIO analysis in general. Thus, value added and output by industry are estimated from combinations of available sectoral data sources such as OECD STAN database (http://oe.cd/stan), UNIDO INDSTAT, Structural Business Statistics from (Eurostat; OECD) and national IOTs and SUTs. The industry level applied in this study is approximately developed at the 2-digit level of international industrial classification (see Table 2.2). There are 2 primary sectors, 16 manufacturing sectors and 14 services sectors. The classification system is based on the third revision edition of International Standard Industrial Classification of all Economic Activities (ISIC Rev. 3).[10] The major revision of international industrial classification has been already implemented (ISIC Rev. 4 of UN, 2008); however, most non-EU countries have published the supply and use tables in ISIC Rev. 3 classification for the period prior to 2005. The value added and output by industry for each country must satisfy following conditions:

[9] Except when submitted, at aggregate level, to UNSD or OECD.
[10] http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=2

National total value added: $B1G = \sum_i VA_i$ **(2.3)**

National total output (NFP1R): $NFP1R = \sum_i X_i = \sum_p D_{ip} X_p$ **(2.4)**

where VA_i is value added by industry i, X_i is output by industry i, X_p is output by product p and D_{ip} is a product p supply ratio by industry i estimated from supply tables. The output data by industry and by product are reviewed again at the later stages of ICIO compilation when supply tables and sectoral exports are finalized with additional conditions described in section 2.4.

2.3 BALANCING INTERNATIONAL TRADE

2.3.1 Trade balance stage I: Goods, services and direct purchases

Total exports must equal total imports at the global level. Both exports and imports are valued at f.o.b. purchasers' prices in the national accounts framework *i.e*., the exporter's domestic transport and trade margins are included in the goods not in the services trade.

The difference between reported exports and imports are adjusted by the figures for the rest of the world. If exchange rates for converting national currencies to United States dollars (USD) are not available in OECD or UNSD National Accounts databases (main aggregate databases), then IMF exchange rates are applied to calculate USD converted figures.

Exports of goods from all countries = Imports of goods by all countries

Exports of cross border services from all countries = Imports of cross border services by all countries

Direct purchases by non-residents at all countries = Direct purchases abroad by residents by all countries

The difference between total trade in goods and services in national accounts and an ICIO table is in the treatment of re-exports and re-imports in addition to the valuation differences in basic prices and purchasers' prices. In an ICIO table, the trade flows involving re-exports (transshipment) and re-imports are subtracted from the national accounts' based exports and imports flows. The relationship between the goods trade figures from national accounts, customs merchandise trade statistics and the ICIO frameworks are summarized in Table 2.3 with an example of USA and Mexican bilateral trade flows. All 7 types of trade flows of this table are part of exports reported by the United States and imports reported by Mexico.

Table 2.3 : Bilateral goods trade in ICIO, merchandise trade and National Accounts statistics: Example of USA exports and Mexico imports

				National Accounts (USA)				Customs			ICIO trade flow		
no	Product origin	Entrepôt transshipment	Final dest.	EXPO goods	EXPO svc	IMPO goods	IMPO svc	Expo USA to MEX	Re-exports	Re-imports	USA to MEX	USA to ROW	ROW to MEX
1	USA	-	MEX	✓				✓			✓		
2	USA	ROW	MEX	✓							✓		
3	USA	MEX	ROW	✓				✓				✓	
4	ROW	USA	MEX	✓		✓		✓	✓				✓
5	USA	MEX	USA	✓		✓		✓		✓			
6	ROW	Purchases at USA	MEX tourists		✓	✓							✓
7	USA	Purchases at USA	MEX tourists		✓						✓		

USA: United States, MEX: Mexico and ROW: Rest of the world

Key:

1: Direct trade flows from USA to Mexico

2: US products exported to Mexico via third country e.g. Canada

3: US products exported to rest of the world via Mexico

4: Rest of the world products re-exported by USA to Mexico

5: US products re-imported (returned) via Mexico

6: Rest of the world products consumed by tourists from Mexico in the US territory

7: US products consumed by tourists from Mexico in the US territory

Exports of goods and services from national accounts are collected for as many countries as possible (198 countries for years around 2010) to determine the size of world economy. The world total is defined as the larger value of either the sum of reported exports or the sum of reported imports and the difference between the two estimates is considered as a discrepancy that is added to one or the other in the trade flows of the rest of the world group. After the trade estimates of target 61 countries and rest of the world are fixed, the trade flows among the rest of the world group countries are removed from the exports and imports of rest of the world based

on the bilateral shares observed in available merchandise trade (UN Comtrade) statistics of approximately 160 countries.

2.3.2 Trade balance stage II: Sectoral trade flows

In the previous section, balanced trade is estimated for goods and services at the world level. The next step for trade flows balancing is to estimate sectoral exports and imports for each target country. The target ICIO table of this study is an industry-by-industry format at basic prices, but the trade flows of each country are first balanced at f.o.b. purchasers' prices. In other words, the goods sector trade flows still include the distribution margins embodied in product of origin countries.

The initial values of sectoral exports and imports for each country are estimated using various sources of trade-related statistics with national accounts trade figures from the previous section as control constraints. The set of constraints for different type trade components is described as follows.

National accounts constraints for each country

$$EXP(P6) = EXP.SNA.GDS(P61) + EXP.SNA.SVC(P62) \quad \textbf{(2.5)}$$
$$= EXP.CB.GDS(P61) + EXP.CB.SVC(P62 - P34) + EXP.DP(P34)$$

$$IMP(P7) = IMP.SNA.GDS(P71) + IMP.SNA.SV \quad (P72) \quad \textbf{(2.6)}$$
$$= IMP.CB.GDS(P71) + IMP.CB.SVC(P72 - P33) + IMP.DP(P33)$$

$$EXP.CB.GDS = \sum_i EXP.CB.GDS_i \quad \textbf{(2.7)}$$

$$EXP.C \quad .SVC = \sum_i EXP.CB.SVC_i \quad \textbf{(2.8)}$$

$$EXP.CB.DP = \sum_i EXP.CB.DP_i \quad \textbf{(2.9)}$$

$$IMP.CB.GDS = \sum_i IMP.CB.GDS_i \quad \textbf{(2.10)}$$

$$IMP.CB.SVC = \sum_i IMP.CB.SVC_i \quad \textbf{(2.11)}$$

$$IMP.CB.DP = \sum_i IMP.CB.DP_i \quad \textbf{(2.12)}$$

World trade constraints

$\sum_c EXP.CB.GDS_{ic} = \sum_c IMP.CB.GDS_{ic}$, for each industry i **(2.13)**

$\sum_c EXP.CB.SVC_{ic} = \sum_c IMP.CB.SVC_{ic}$, for each industry i **(2.14)**

$\sum_c EXP.CB.DP_{ic} = \sum_c IMP.CB.DP_{ic}$, for each industry i **(2.15)**

where *c* and *i* indicate country and industry respectively. The variables with "*SNA*" code i.e. *EXP.SNA.GDS*, *EXP.SNA.SVC*, *IMP.SNA.GDS* and *IMP.SNA.SVC* are the national accounts-based exports and imports values. *CB* indicates the cross-border trade; *GDS* indicates goods products, *SVC* is services products and *DP* is direct purchases abroad.

Retaining the published statistics information as much as possible, the missing (unreported) variables in each country's national accounts are filled from other trade figures i.e. merchandise trade statistics, trade in services, balance of payment and tourism satellite account. The minor numerical adjustments are finally performed using Linear Programming (LP) approach to make sure above numerical conditions are met for each country.

Specifically, the four LP optimization problems are separately solved using above conditions specified in equations **(2.5)** to **(2.15)** as follows:

Total industry trade **(2.16)**

$$\text{Minimize}\left(\sum_C \frac{\left(EXP.CB.GDS_c - EXP.CB.GDS_c^*\right)}{EXP.CB.GDS_c^*} + \sum_C \frac{\left(EXP.CB.SVC_c - EXP.CB.SVC_c^*\right)}{EXP.CB.SVC_c^*} + \sum_C \frac{\left(EXP.DP_c - EXP.DP_c^*\right)}{EXP.DP_*^c} + \sum_C \frac{\left(IMP.CB.GDS_c - IMP.CB.GDS_c^*\right)}{IMP.CB.GDS_c^*} + \sum_C \frac{\left(IMP.CB.SVC_c - IMP.CB.SVC_c^*\right)}{IMP.CB.SVC_c^*} + \sum_C \frac{\left(IMP.DP_c - IMP.DP_c^*\right)}{IMP.DP_*^c}\right)$$

Cross-border goods trade by industry **(2.17)**

$$\text{Minimize}\left(\sum_c \sum_i \frac{\left(EXP.CB.GDS_{ic} - EXP.CB.GDS_{ic}^*\right)}{EXP.CB.GDS_{ic}^*} + \sum_c \sum_i \frac{\left(IMP.CB.GDS_{ic} - IMP.CB.GDS_{ic}^*\right)}{IMP.CB.GDS_{ic}^*}\right)$$

Cross-border services trade by industry **(2.18)**

$$\text{Minimize}\left(\sum_c \sum_i \frac{\left(EXP.CB.SVC_{ic} - EXP.CB.GDS_{ic}^*\right)}{EXP.CB.GDS_{ic}^*} + \sum_c \sum_i \frac{\left(IMP.CB.SVC_{ic} - IMP.CB.GDS_{ic}^*\right)}{IMP.CB.GDS_{ic}^*}\right)$$

Direct purchases trade by industry **(2.19)**

$$\text{Minimize}\left(\sum_c \sum_i \frac{\left(EXP.DP_{ic} - EXP.DP_{ic}^*\right)}{EXP.DP_{ic}^*} + \sum_c \sum_i \frac{\left(IMP.DP_{ic} - IMP.DP_{ic}^*\right)}{IMP.DP_{ic}^*}\right)$$

Reported imports and exports flows from both national accounts and merchandise trade statistics may include products not produced in the accounting year by the exporting countries. These include imported products manufactured in other countries that are then *re-exported*[11] (without further transformation), exported products that are later *re-imported* (without further transformation) from other countries, withdrawals from inventories during the accounting period

[11] Activities of re-exports are prevalent in the countries have large trading hubs e.g. Belgium, Hong Kong, the Netherlands, Singapore and United States.

of goods produced in previous years, recycled products (e.g. sorted metals embodied in scrapped machinery equipment) and second-hand goods (such as motor vehicles) that were originally recorded as domestic capital formation or household consumption in previous years.

Reported re-exports statistics, when available, do not separately identify any markup fees (by intermediaries) or charges for port service facilities in the re-exporting country i.e., the value of a re-exported product is generally higher than when it was imported. Similarly, the value of a re-imported product may be different than the value reported when originally exported. The share of re-exported products in the total exports varies across countries. In an extreme example, re-exports from Hong Kong account for more than 95% of total merchandise goods exported from this economy. This is mainly due to Hong Kong's role as a major trading hub for China: re-exporting products from RoW to China and re-exporting Chinese products, not only to RoW, but back to China itself (identified as re-imports by China). Merchandise trade statistics from customs information (Hong Kong Customs and Excise Department; General Administration of Customs of the People's Republic of China) show that the share of reported exports from China that returns, re-imported from HK, as final consumption expenditure of Chinese households is particularly high for textile/apparel and electronics manufacturing products.

Due to the conceptual differences in statistical sources for the treatment of re-exports and re-imports, the bilateral partner shares in trade data in consignment-based figures (typical customs exports flows), products origin-based figures (typical customs imports flows) and ICIO figures (re-exports excluded flows) could be significantly different. Re-exports and re-imports by product can be estimated by combining the import matrices from IO tables and merchandise trade statistics. Imported products purchased by non-resident tourists are also considered as re-

exports here. The consumption of imported products by non-residents follows the imported products shares of household final consumption expenditures not the shares estimated from trade statistics. The adjustments made for re-exports and re-imports are respectively provided as follows:

$$EXP.CB^*.GDS_{ic} = EXP.CB.GDS_{ic} - RXRM.GDS_{ic} \quad \textbf{(2.20)}$$

$$EXP.CB^*.SVC_{ic} = EXP.CB.SVC_{ic} - RXRM.SVC_{ic} \quad \textbf{(2.21)}$$

$$EXP.DP^*_{ic} = EXP.DP_{ic} - RXRM.DP_{ic} \quad \textbf{(2.22)}$$

$$IMP\ CB^*.GDS_{ic} = IMP.CB.GDS_{ic} - RXRM.GDS_{ic} \quad \textbf{(2.23)}$$

$$IMP\ CB^*.SVC_{ic} = IMP.CB.SVC_{ic} - RXRM.SVC_{ic} \quad \textbf{(2.24)}$$

$$IMP\ DP^*_{ic} = IMP.DP_{ic} - RXRM.DP_{ic} \quad \textbf{(2.25)}$$

$$EXP\ CB.GDS_{ic} - IMP\ CB.GDS_{ic} = EXP\ CB^*.GDS_{ic} - IMP\ CB^*.GDS_{ic} \quad \textbf{(2.26)}$$

$$EXP\ CB.SVC_{ic} - IMP\ CB.SVC_{ic} = EXP\ CB^*.SVC_{ic} - IMP\ CB^*.SVC_{ic} \quad \textbf{(2.27)}$$

$$EXP\ DP_{ic} - IMP\ DP_{ic} = EXP\ DP^*_{ic} - IMP\ DP^*_{ic} \quad \textbf{(2.28)}$$

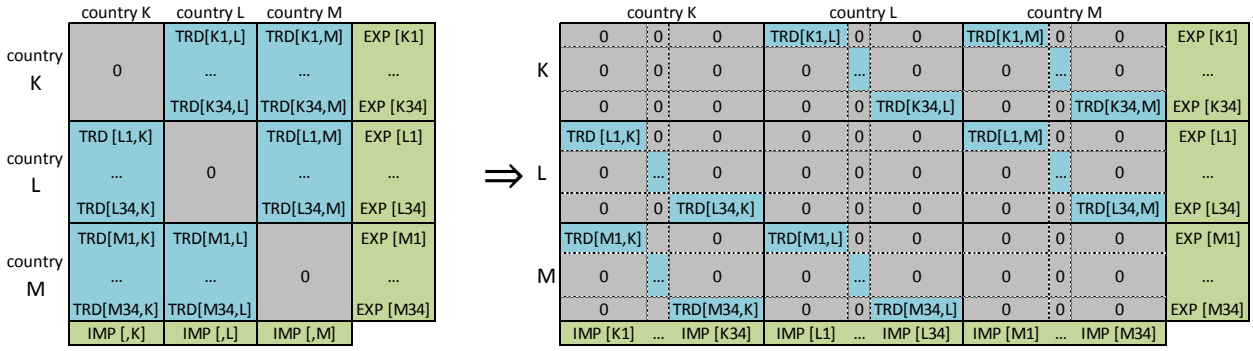
where *EXP.CB**, *EXP.DP**, *IMP.CB** and *IMP.DP** are re-exports/re-imports adjusted trade flows used as trade constraints in harmonized supply and use tables in next section. *RXRM.DP_ic* are direct purchases of product *i* originally exported from country *c* consumed abroad. Note that the same amounts of re-exports adjustments are subtracted from the national account-based exports and imports; thus the net trade balances of each country remain the same

as reported in national accounts (see equations **(2.20)** to **(2.25)**). The economic added value created by re-exporting activities (difference of exports and imports) is separately recorded in output of distribution services.

2.3.3 Trade balance stage III: Bilateral trade flows

The third stage of trade balancing proceeds to estimate bilateral trade flows by country pairs using the sectoral exports and imports that were balanced in the previous step. The row constraints are simply given from the previous section's sectoral exports. However, the sectoral imports cannot be constrained if the initial values of the balancing matrix are given in the conventional format (Panel A of figure 2.2). A unique methodology applied in this thesis is to diagonalize the inter-country trade flow in the format in a diagonalized balancing framework (Panel B of Figure 2.2). This approach allows the analyst to incorporate the additional constraints (sectoral imports) to the inter-country trade flow while retaining a simple two-dimension balancing procedure. In principle, other approaches, such as iterative RAS procedure and linear programming framework, can also achieve the same goal, but the methodology applied in this thesis is the more preferred approach when the dimensions of country and industries are relatively large and the computing power requirements (calculation time and minimum memory) much less than the other methodologies.

When the reasonable bilateral trade flows are not calculated in the first trial, the discrepancy dummy country is added to avoid over-adjusting the trade flows of the largest countries e.g., the US and China. The discrepancy columns can be merged with the RoW final expenditure e.g. changes in inventories rather than allocated to RoW's intermediate transaction in a later stage.



Panel A Panel B

Figure 2.2 : Trade balancing stage III (Bilateral trade flows, 3 countries example)

The initial values for goods and services are separately estimated from the related sectoral bilateral trade shares from OECD BTDIxE and EBTSI (See Zhu *et al*., 2011 and Spinelli and Miroudot, 2015, respectively for previous versions of these databases). Published bilateral trade in goods and services statistics (e.g., UN Comtrade) reveals many asymmetries (i.e. country A's reported exports to country B may be significantly different from country B's reported imports from country A). The identified sources of these "mirror trade" flow issues include transshipment, re-exports and re-imports, and price valuation differences between c.i.f.[12] and f.o.b.[13] prices (see Guo *et al*., 2009).

The definition of export flows is closer to the target figures of national accounts. However, import flows are preferred as a primary data source to estimate trade partner shares to

[12] Cost, insurance and freight price. http://stats.oecd.org/ glossary/detail.asp?ID=332
[13] Free on board price. http://stats.oecd.org/glossary/detail.asp?id=1009

avoid transshipment/ re-export issues, because the destination country in reported exports flows is likely to be the (next) country of consignment rather than the final destination as this may not be known by the exporter (Guo *et al.*, 2009). Ideally, the difference between c.i.f. and f.o.b. valuations in merchandise trade statistics, i.e., international distribution costs, should be adjusted by additional information on transportation mode, physical distances and economic distances. A limited number of countries currently provide import flows in both c.i.f. and f.o.b. valuations (Miao and Fortanier, 2017). Empirical experience with this issue has been previously also discussed by IDE-JETRO's Asian International IO, Hummels and Volodymyr (2006) and CEPII's BACI database (Gaulier *et al.*, 2008).

The product classifications applied by countries follow the Harmonized System (HS). In general, the data are compiled according to HS1988 for years between 1988 and 1995, HS Rev.1 for 1996-2001, HS Rev. 2 (2002) for 2002-2006 and HS Rev.3 (2007) from 2007-2011, HS Rev.4 (2012) from 2012 onwards. The special administrative regions (SAR) of China are treated as separate economies in customs-based statistics. In general, merchandise imports are reported with c.i.f. valuation and by country of origin, while merchandise exports flows are generally recorded on an f.o.b. basis (i.e. excluding international transport costs) and by last known destination.

International transactions of electricity are reported in customs merchandise trade statistics; however, the reported figures are often not consistent with exports and imports values in SUT/IO tables for most countries. The trade partner shares for utility sectors are therefore estimated based on the cross-border electricity transfer database (IEA Electricity Statistics) rather than customs trade statistics. Some other products are also excluded from the calculations

of bilateral goods trade. For example, products that are not directly related to the production activities such as monetary gold, diamonds, luxury antiques, recycled and used products.

Bilateral trades in cross border services are increasingly available for recent years; in many cases, the product details of published statistics and input-output or use tables do not match for most countries. Thus, some more assumptions need to be made to fill the issues of classification mismatches. Examples are provided below.

- No cross-border trade products allocated to education and health services.
- The construction industry is not considered as part of services economic activity but the characteristics of its trade are categorized as services.

All goods and services products purchased by non-residents are assumed to have similar expenditure patterns for visitors from all origins due to the limited availability of statistics concerning expenditure patterns by the origin countries of tourists. Also, for certain destinations, tourists may not be exempted from paying the taxes on merchandise gifts purchased (e.g. expenditures in EU countries by the residents of other EU countries), but this is not explicitly estimated in the database.

2.4 COMPILATION OF HARMONIZED NATIONAL SUPPLY, USE AND INPUT-OUTPUT TABLES

Using the sectoral constraints for gross output (production), value added and trade flows of previous sections, national accounts-benchmarked supply, use and IO tables are estimated. The estimation methods applied to estimate these tables vary depending on the national data source availability. The list of data sources availability for SUTs and I-O tables from national and international statistical agencies are summarized in Table 2.4 and Table 2.5. This list includes the data extracted from organizations that publish statistics submitted by national statistics agencies in a common format (e.g. Eurostat, OECD and Asian Development Bank). The SUTs (Table 2.4) or I-Os (Table 2.5) are available for approximately 40 economies for years between 1995 and 2005 covering, for each year, about 95% of global GDP and 60% of world population. However, the price valuations (basic prices, purchasers' prices), format and industry classification of each IO table are not harmonized particularly for non-European countries. The available published tables need to be converted to a common format for all countries.

Table 2.4 : Data availability* Supply and Use Tables

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
AUS	..	..	..	..	..	..	ps	..	..	pm	pm	pm	pm	pm	pm	..	..
AUT	p	..	p	..	p	p	p	p	p	p	p	p	p	p	p	p	..
BEL	p	..	p	..	p	p	p	p	p	p	p	p	p	p	p	p	..
CAN	..	..	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
CHL	..	ps	..	..	..	..	..	..	ps	..	..	..	..	p	p	p	..
CZE	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	..	..
DNK	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	..	..
EST	..	..	p	..	..	p	p	p	p	p	p	p	p	p	p	p	..
FIN	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	..
FRA	p	..	p	..	p	p	p	p	p	p	p	p	p	p	p	p	..
DEU	p	..	p	..	p	p	p	p	p	p	p	p	p	p	p	p	..
GRC	..	..	..	..	..	p	p	p	p	p	p	p	p	p	p	p	p
HUN	..	..	..	p	p	p	p	p	p	p	p	p	p	p	p	p	..
ISL	..	..	..	..	..	..	..	..	ps	..	..	..	..	..	..	..	..
IRL	..	..	..	ps	..	ps	p	p	p	p	p	p	p	p	p	p	..
ISR	p	..	..	..	..	..	..	..	..	ps	..	pb	..	..	..	..	..
ITA	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	..
JPN	r	..	..	..	..	r	..	..	..	..	r	..	..	..	..	..	..
KOR	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	bs	bs
LUX	ps	ps	ps	ps	ps	ps	ps	ps	ps	ps	ps	ps	ps	ps	ps	ps	ps
MEX	..	..	..	..	..	..	..	..	ps	..	..	..	..	ps	..	..	..
NLD	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	..
NZL	..	..	..	..	..	..	..	..	..	..	..	..	ps	..	..	..	..
NOR	..	..	..	..	..	..	p	ps	ps	ps	ps	ps	ps	..	ps	ps	ps
POL	..	..	..	..	..	p	p	p	p	p	p	p	p	p	p	p	..
PRT	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	..
SVK	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	..
SVN	..	p	..	..	..	p	p	p	p	p	p	p	p	p	p	p	..
ESP	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	..	..
SWE	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	..
CHE	..	..	..	..	..	..	ps	..	..	..	p	..	..	ps	..	..	..
TUR	..	p	..	p	..	..	..	p	..	..	..	..	..	..	..	..	..
GBR	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
USA	r	..	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
ARG	..	..	p	..	..	..	..	..	..	p	..	..	..	..	..	..	..
BGR	..	..	..	..	..	p	p	p	p	p	p	..	..	p	p	p	..
BRA	ps	ps	ps	ps	ps	ps	ps	ps	ps	ps	ps	ps	ps	..	..	..	..
BRN	..	..	..	..	..	..	..	..	..	..	ps	..	..	..	..	..	..
CHN	..	..	ps	..	..	..	..	ps	..	..	..	..	ps	..	..	..	..
COL	p	p	p	p	p	p	p	p	p	p	p	..	..	..	..	..	..
CRI	..	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
CYP	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	..	..
HKG	..	..	..	..	..	..	..	..	..	..	r	..	..	..	..	..	..
HRV	..	..	..	..	..	..	..	..	..	p	p	..	..	..	..	..	..
IDN	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
IND	..	..	..	ps	..	..	..	..	p	..	..	p	p	..	..	..	..
KHM	..	..	..	..	..	..	..	..	..	..	ps	..	..	..	..	..	..
LTU	..	..	..	..	..	ps	ps	ps	ps	ps	ps	ps	ps	ps	ps	ps	..
LVA	..	p	..	p	..	..	..	..	..	p	..	..	p	p	p	p	..
MLT	..	..	..	..	..	p	p	..	..	p	..	..	..	p	..	..	..
MYS	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	pm	..
PHL	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
ROU	..	..	..	..	..	p	..	..	p	p	p	p	p	p	p	p	..
RUS	ps	..	..	ps	ps	ps	ps	..	ps	ps	..	ps	..	..	..	..	..
SAU	..	..	..	..	..	..	..	..	pm	pm	pm	pm	pm	..	..	..	..
SGP	..	..	..	..	..	..	..	..	..	..	pm	..	pm	..	..	pm	..
THA	r	..	..	rm	..	r	..	..	..	..	r	..	..	..	..	..	..
TUN	..	..	..	..	..	..	..	..	..	..	..	..	..	..	p	p	..
TWN	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
VNM	..	..	..	..	..	..	..	..	..	..	..	..	ps	..	..	..	..
ZAF	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

p use table at purchasers' prices
b use table at basic price
r use table at producers' prices
.. not available
s insufficient sectoral detail or confidential entries for IND34 list
m import table is available

* country codes: ISO 3166-1 alpha 3

Table 2.5 : Data availability* Input-Output Tables

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
AUS	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
AUT	bm	..	..	..	..	bm	..	..	..	..	bm	..	..	bm	bm	bm	..
BEL	bm	..	..	..	..	bm	..	..	..	..	bm	..	..	..	..	bm	..
CAN	b	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
CHL	..	..	..	..	..	..	..	..	..	..	..	..	..	bm	bm	bm	b
CZE	bm	..	..	..	..	b	..	..	..	..	bm	..	b	..	bm	bm	..
DNK	bm	..	..	..	..	bm	bm	bm	bm	bm	bm	bm	bm	..	..	..	..
EST	..	..	bm	..	..	bm	..	..	..	..	bm	..	..	..	..	bm	..
FIN	bm	bm	bm	bm	bm	bm	bm	bm	bm	bm	bm	bm	bm	bm	bm	bm	bm
FRA	bm	..	bm	..	bm	bm	bm	bm	bm	bm	bm	bm	bm	bm	bm	bm	..
DEU	bm	..	..	..	..	bm	bm	bm	bm	bm	bm	bm	bm	bm	bm	bm	..
GRC	b	..	..	..	b	bm	..	..	..	..	bm	..	..	b	b	bm	..
HUN	..	..	..	bm	..	bm	..	..	..	..	bm	..	..	b	..	bm	..
ISL	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
IRL	..	..	..	bm	..	bm	..	..	..	..	bm	..	..	..	..	bm	..
ISR	bm	..	..	..	..	..	..	..	..	..	..	bm	..	..	..	..	..
ITA	bm	..	..	..	..	bm	..	..	..	..	bm	..	..	..	..	bm	..
JPN	rm	r	r	r	r	rm	r	r	r	r	rm	r	r	r	r	r	r
KOR	r	..	..	r	..	r	..	..	b	..	rm	r	..	bm	bm	rm	rm
LUX	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	..	..
MEX	..	..	..	..	..	..	..	..	b	..	..	..	..	b	..	..	..
NLD	bm	bm	bm	bm	bm	bm	bm	bm	..	bm	bm	bm	bm	bm	bm	bm	..
NZL	r	..	..	..	..	..	..	r	..	..	..	..	..	..	..	..	..
NOR	b	..	..	..	..	bm	bm	bm	bm	bm	bm	bm	bm	..	bm	bm	bm
POL	b	..	..	..	..	bm	..	..	..	..	bm	..	..	..	..	..	..
PRT	b	..	..	..	bm	..	..	..	..	..	bm	..	..	bm	..	..	..
SVK	..	..	..	..	..	bm	..	..	..	..	bm	..	..	..	..	bm	..
SVN	..	bm	..	..	..	bm	bm	..	..	..	bm	..	..	..	bm	bm	..
ESP	bm	..	..	..	..	bm	..	..	..	..	bm	..	..	..	..	..	..
SWE	bm	..	..	..	..	bm	..	..	..	..	bm	..	..	..	..	bm	..
CHE	..	..	..	..	..	..	b	..	..	..	b	..	..	b	..	..	..
TUR	..	..	..	b	..	..	..	b	..	..	..	..	..	..	..	..	..
GBR	bm	..	..	..	..	..	..	..	..	..	bm	..	..	..	..	bm	..
USA	..	..	rm	..	..	..	..	rm	..	..	..	..	rm	..	..	..	..
ARG	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
BGR	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	b	..
BRA	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
BRN	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
CHN	r	..	r	..	..	r	..	r	..	..	r	..	r	..	..	r	..
COL	..	..	..	..	..	..	..	..	..	..	b	..	..	..	..	b	..
CRI	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
CYP	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
HKG	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
HRV	..	..	..	..	..	..	..	..	..	bm	..	..	..	..	..	..	..
IDN	b	..	..	..	..	b	..	..	..	..	b	..	..	..	..	..	..
IND	..	..	..	b	..	..	..	..	..	..	..	..	b	..	..	..	..
KHM	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
LTU	..	..	..	..	..	bm	..	..	..	..	bm	..	..	..	..	bm	..
LVA	..	bm	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
MLT	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
MYS	r	..	..	..	..	b	..	..	..	..	..	..	..	..	..	..	..
PHL	b	..	..	..	..	r	..	..	..	..	b	..	..	..	..	..	..
ROU	..	..	..	..	..	b	..	..	b	b	b	b	..	b	..	b	..
RUS	r	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
SAU	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
SGP	b	..	..	..	..	b	..	..	..	..	bm	..	..	..	..	..	..
THA	rm	..	..	..	..	rm	..	..	..	..	rm	..	..	..	..	..	..
TUN	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
TWN	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
VNM	..	..	..	..	..	r	..	..	..	..	..	..	..	..	..	..	..
ZAF	..	..	..	b	..	b	..	b	..	..	b	..	..	..	b	b	b

b IO table at basic price
r IO table at producers' prices
m import table is available
s insufficient sectoral detail or confidential entries for IND34 list
.. not available

* country codes: ISO 3166-1 alpha 3

2.4.1 Supply tables

Supply tables record how supplies of different kinds of goods and services originate from different domestic industries in the form of a matrix table (OECD Glossary of Statistical Term).[14] The tables also record the imports, taxes less subsidies on products and distribution margins by product. The sum of all columns is the total supply of products at purchasers' prices (Figure 2.3). Published supply tables are available for 57 countries for at least for one year in the target period between 1995 and 2011 (Table 2.4).

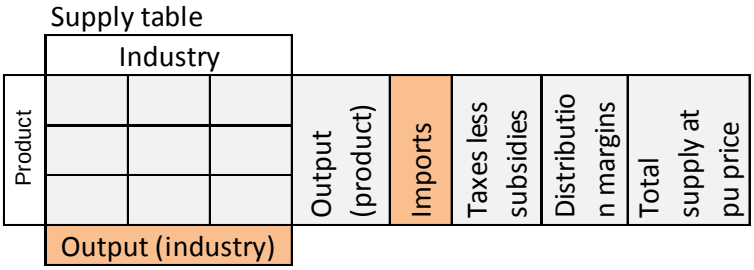


Figure 2.3 : Harmonized Supply table

If a supply table is available for a country in the target period, the product-supply shares, distribution margins to product output shares and taxes less subsidies to output shares are first interpolated for the missing years using the byproducts' production ratio for each industry. If the supply table is not available for all years, it is assumed that product and industry dimensions coincide i.e. a purely diagonal relationship for the product-industry matrix. Using the national accounts constraints and trade constraints estimated in previous sections, the rebalanced output and total supply by product can be estimated as follows.

[14] http://stats.oecd.org/glossary/

The output of product *p* produced by all industries becomes:

$$X_p^* = \sum_i X_i^* \, SX_{pi} \qquad \textbf{(2.29)}$$

where X_p^* is output of product *p*, SX_{pi} is product –supply share for each industry *i*.

The total supply of product *p* is defined by the sum of output, imports, distribution margins and taxes less subsidies on products as:

$$TSp^* = Xp^* + IMp^* + Xp^* \, SDp + Xp^* \, STp \qquad \textbf{(2.30)}$$

where *TSp** is total supply of product *p* at purchasers' prices and *IMp** is imports of product *p* at purchasers' prices, *SDp* is distribution margins to output share and *STp* is taxes less subsidies to output share. The imports column in this rebalanced supply table (*IMp**) comes from the previously estimated imports (re-exports/re-imports excluded) in f.o.b. valuation at purchasers' prices while conventional supply tables show *t* imports with c.i.f. valuation at purchasers' prices (re-exports/re-imports included). The total supply of services is therefore systematically higher than the supply tables in conventional format (because the international distribution margins in imports of goods, the difference between c.i.f. and f.o.b., are allocated to services).

2.4.2 Use tables at purchasers' prices

Use tables record how different kinds of goods and services are used (purchased) by different domestic industries and final expenditure sectors in the form of a matrix table (Figure 2.4). In general, published use tables separate final expenditures into different categories such as household consumption, general government expenditures, gross fixed capital formation (business investment), changes in inventories and valuables and, exports of goods and services. The sum of all columns matches the column of total supply at purchasers' prices in supply tables.

The use tables at purchasers' prices are also rebalanced using national accounts benchmarked sectoral constraints and the vector of total supply by product is estimated for rebalanced supply tables. Therefore, sectoral value added, output and exports in f.o.b. valuation at purchasers' prices are exogenously given before rebalancing. The re-exports and re-imports are also excluded from the exports and columns at this stage. The initial values of intermediate and domestic final expenditures by product are given from the sectoral shares of published IO or use tables.

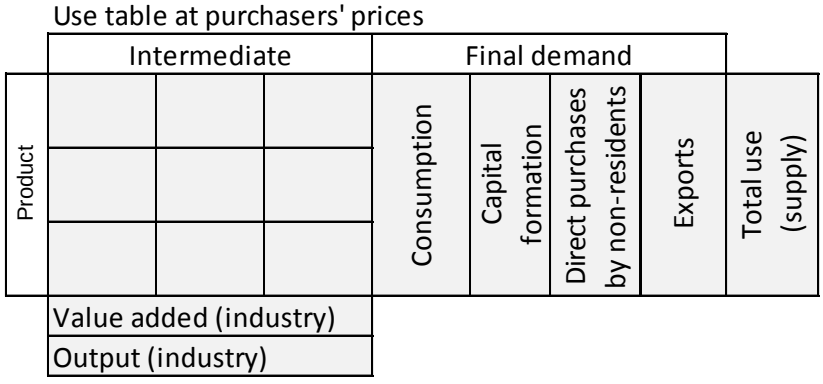


Figure 2.4 : Harmonized use table at purchasers' prices

Seven types of final expenditure components are provided in the database.

1) Household final consumption expenditures (HFCE)

2) Final consumption expenditure by non-profit institutions serving households (NPISHs)

3) General government final consumption expenditures (GGFC)

4) Gross fixed capital formation (GFCF)

5) Changes in inventories and valuables

6) Direct purchases by non-residents

7) Exports

However, not all countries are able to provide such a breakdown particularly for NPISHs that is often included within Household final consumption expenditures. For each expenditure items, the industry totals are controlled by the national accounts data.

The methodology for preparation of the initial values of the use tables at purchasers' prices before balancing varies on the availability of data sources as described below (See Eurostat (2008) for details).

- If use tables at purchasers' prices are available, the initial matrix is simply an aggregation of the products and industry dimensions to the harmonized classification.

- If use tables at producers' prices or basic prices are only available, the initial matrix is estimated by adding the trade, transportation and/or taxes margins from supply tables.

- If symmetric IO tables at producers' prices or basic prices in product-by-product format are only available, the initial matrix is estimated by adding the trade, transportation and/or taxes

margins from supply tables. The intermediate inputs by industry are estimated using input coefficient of symmetric tables and byproduct shares of supply tables.

A few countries, such as Japan and Korea, report negative values for transactions of recycled metal products and paper products in the cells of intermediate, household consumption or gross fixed capital formation while other countries treat recycled products as an imputed industrial activity. In order to harmonize the table format, this study converts the former type of tables to latter format. Negative values are adjusted by transferring a proportion of the value from the changes and inventories column to the other manufacturing industry group following the suggestions in ISIC Rev.3 36 to 37.

If use tables are not published for a specific target year, the structure of input coefficients of the intermediate section are estimated using interpolated numbers from the nearest available years' structures. For the gaps in final consumption shares by product, national accounts household final expenditures according to the international standard Classification of Individual Consumption by Purpose (COICOP, https://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=5) is also used to complement the sectoral shares of household consumption.

Since negative values may appear in the columns of "Changes in inventories and valuables," the use tables for each country are numerically balanced using the Generalized RAS (GRAS) methodology (Junius and Oosterhaven, 2003; Temurshoev *et al*. 2013). The GRAS approach is preferred here because some negative values of initial matrix for use tables prevent the system to converge in conventional RAS approach. Particularly for non-European developing economies, the annual supply and use and IO data sources are relatively limited, thus the methodology applied to estimate for these countries depend on additional assumptions to fill

the gaps to complete initial values. Thus, the GRAS approach described here is eventually become closer to the concept of RAS variant procedures[15] aimed to estimate the annual SUTs with limited control totals.

If, for a given year, use or IO tables are not published, the initial values of changes in inventories are estimated using the investment patterns of capital formation of goods sectors (agriculture, mining and manufacturing sectors). For smaller economies (especially non-OECD) with limited data availability, the levels of exports, imports, re-exports, re-imports and shares and output by product are reviewed at this stage when the initial constraints disrupt the balancing procedures.

2.4.3 Domestic and import use table at basic prices

The national accounts benchmarked use tables at purchasers' prices are now split into domestic and import tables. Unlike use tables at purchasers' prices and IO tables at basic prices, the use tables of domestic and imported products at basic prices are rarely provided by national statistical agencies. Thus, the use tables at basic prices are estimated for all countries using the rebalanced use table at purchasers' prices with the distribution margins i.e., wholesale, retail and transportation margin columns reported in supply tables (Figure 2.5). While the distribution margin tables are not published by many countries, import tables in either product-by-product or product-by-industry format are available for about half of the target 61 countries. If any of the

[15] Examples of annual SUT oriented approaches are SUT-RAS approach by Temurshoev and Timmer (2011) to complement the product output and Euro method by Beutel (2002) to complement the sectoral expenditures by macroeconomic constraints.

margins and import tables are missing for a country, the row proportionality assumption[16] is applied to estimate the margins and imports embodied in the transaction flows at purchasers' prices using supplementary information from imports flows by end-use category (OECD BTDIxE Database).

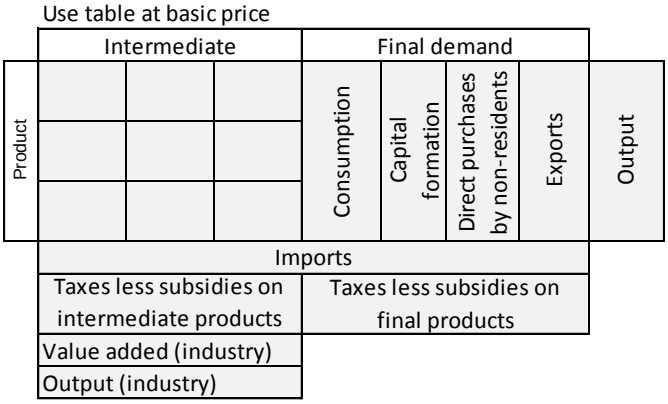


Figure 2.5 : Harmonized domestic use table at basic prices

Often, published import tables are valued at c.i.f. and at purchasers' prices while direct purchases by residents (consumption abroad) may be included within the household consumption columns. In order to harmonize the definitions of import items with the national accounts figures, the published import tables are rebalanced. Note that three types of household consumption related imports are explicitly separated in this database. 1) cross border, 2) imported goods and services consumed by non-resident tourists and 3) direct purchases abroad by residents - particularly for travel-related services e.g. hotels, restaurant and transportation (Figure 2.6).

[16] Row proportionality assumption is a methodology to fill the import matrix by assuming the same import penetration ratio across using industries and final demand sectors. This methodology is widely applied in statistics offices to estimate domestic production multipliers e.g. Cabinet office, Japan and Bureau of Economic Analysis, United States.

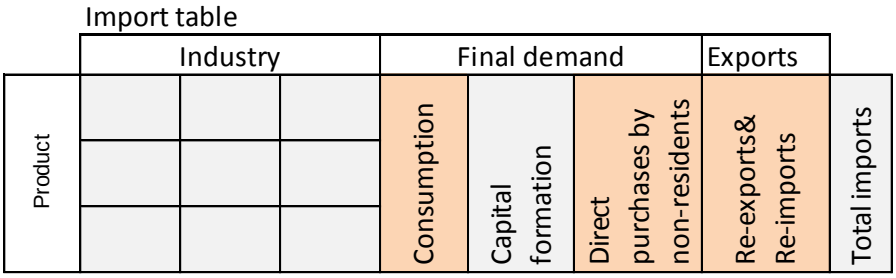


Figure 2.6 : Harmonized import table

Also, the taxes less subsidies on products are eventually rebalanced using the row of taxes less subsidies on intermediate and final products of the IO tables at basic prices. The row and column constraints for balancing taxes less subsidies margin matrices are:

1. Row total = Taxes less subsidies on products column of supply table
2. Column total = [Taxes less subsidies row divided by the total intermediate and final uses at purchasers' prices from Input-Output tables at basic prices] x [total intermediate and final uses in use table at purchasers' prices.]

The differences between exports f.o.b. at purchasers' prices and exports f.o.b. at basic prices from both use tables at purchasers' prices and basic prices are used to convert the purchasers' prices-based inter-country trade by product tables to basic prices at later stage.

2.4.4 Symmetric Input-Output tables

The domestic use tables are transformed to IO tables in an industry-by-industry format using fixed product sales structure (FPSS) assumption often referred to as the industry technology assumption (Chapter 4 Converting Supply and use tables into a symmetric I/O table: treatment of secondary products, United Nations, 1999; Model D of Chapter 11 Transformation of Supply and Use Tables to Symmetric Input-Output Tables, Eurostat, 2008). The methodology is commonly used for non-survey (no additional internal survey information) approach of converting dimensions because no negative numbers are produced during estimation procedure. Compared to a manual balancing procedure often used in product-by-product tables using the product technology assumption, the FPSS methodology is more transparent (Eurostat, 2008). This methodology has been also widely applied in other multi-country IO projects to estimate national symmetric IOs (Yamano and Ahmad, 2006) and Inter-Country I-Os (World Input-Output Database, http:// www.wiod.org; OECD ICIO, http:// oe.cd/icio).

The algebraic formulation of this method is described below:

The basic relationship that describes supply use tables can be shown as:

$$q = Bg + F \qquad \textbf{(2.31)}$$

where, q is the vector of product outputs, g is the vector of industry outputs, Bg is the industry use matrix showing the purchases of goods and services by industries by product (rows) and industry (columns) and F, the vector of final demand by product.

Let M be the matrix of supply of goods and services (rows) produced by industries (columns) so that we can define D as

$$D = M'q^{-1} \quad \textbf{(2.32)}$$

By multiplying both sides of equation **(2.31)** by D, as shown in **(2.32)** above, it follows that

$$Dq = DBg + DF = g \quad \textbf{(2.33)}$$

that

$$(I - DB)g = F \quad \textbf{(2.34)}$$

and

$$g = (I - DB)^{-1}F \quad \textbf{(2.35)}$$

where $(I - DB)^{-1}$ reflecting the Leontief inverse.

It follows that the industry-by-industry use matrix = DBg and DF, the final demand by industry output. Note that this transformation to DBg preserves, exactly, the value-added by industry relationships observed in the original industry use matrix Bg.

2.5 BALANCING INTER-COUNTRY USE TABLE AND ICIO

The inter-country use tables, i.e., the transaction tables with product origins by end-use industry and final expenditure category, are estimated in the final stage of trade balancing (Figure 2.1). The row control total constraints are the sectoral inter-country trade flows estimated in the previous sections while the column sum constraints are the column sums of the use import table of each country (Figure 2.7). Thus, the rightmost columns of Figure 2.7 and Panel A and B of Figure 2.2 are exactly the same.

Note that the inter-country transactions of direct purchases by non-residents are already estimated in the previous stage.

[trade balance stage IV]

Bilateral flows by end-use industry and final expenditure sectors (international use table component)

Intermediate Industry 1 ... Industry34	Final Consumption	Capital formation	
0	0	0	EXP.CB 1 from K to K ... EXP.CB 34 from K to K
TRD.CB[L1,K1] ... TRD.CB[L1,K34] .. .. .. TRD.CB[L34,K1] ... TRD.CB[L34,K34]	TRD.CB[L1, CONS] ... TRD.CB[L34, CONS]	TRD.CB[L1, CAP] ... TRD.CB[L34, CAP]	EXP.CB 1 from L to K ... EXP.CB 34 from L to K
TRD.CB[M1,K1] ... TRD.CB[M1,K34] .. .. .. TRD.CB[M34,K1] ... TRD.CB[M34,K34]	TRD.CB[M1, CONS] ... TRD.CB[M34, CONS]	TRD.CB[M1, CAP] ... TRD.CB[M34, CAP]	EXP.CB 1 from M to K ... EXP.CB 34 from M to K

IMP.CB by K

National use import table

Intermediate Industry 1 ... Industry34	Final Consumption	Capital formation	direct purchases	
USE[1,K1] ... USE[1,K34] .. .. .. USE[34,K1] ... USE[34,K34]	USE[1, CONS] ... USE[34, CONS]	USE[1, CAP] ... USE[34, CAP]	USE[1, DP] ... USE[34, DP]	IMP 1 by K ... IMP 34 by K
IMP.CB by K			IMP.DP by K	

Figure 2.7: Trade balancing stage IV (bilateral use table, 3 countries example)

There is also an additional constraint on the national import tables. When the bilateral use tables are balanced, the sum of ICIO import use table components preferably matches each cell of the national import tables in Figure 2.7.

$$U_i^{mj} = \sum_c \mathrm{U}_{\mathrm{ci}}^{\mathrm{mj}} \qquad \textbf{(2.36)}$$

where U_i^{mj} is the component of national use import table (purchase of product *i* by country *m*'s industry *j* (or final expenditure category *j*). $\mathrm{U}_{\mathrm{ci}}^{\mathrm{mj}}$ is the component of bilateral use table (purchase of country *c*'s product i by country *m*'s industry *j* (or final expenditure category *j*).

The size of inter-country import matrix for each importing country is (62 countries x 34 industry) x (34 industry + 6 final expenditure). The biproportional RAS procedure was applied to balance this matrix with cell-by-cell constraints of (2.36). In order to have the cell-by-cell constraints in the biproportional matrix balancing, the columns of initial value can be diagonalised as shown in Figure 2.8. The RAS procedure is chosen to estimate this balancing procedure because of following advantages: 1) It requires relatively less computing power to estimate 17 years x 62 economies tables (2.2 million cells); 2) it provides a reasonably efficient methodology for sparse matrix (cells with many zero values).

The last condition on national import tables, however, is a strong assumption for ICIO compilation and balanced results may not be achieved. If so, the assumptions are relaxed. The limitations of cell-by-cell constraints on international IO tables are discussed in Meng *et al.* (2016). One of the reasons why balanced results may not be achieved is that the cells in import

tables are usually very scarce for inter-country trade for small economies particularly for the services trade. In that case, the small values e.g. less than 0.1 million USD are manually replaced with zero and/or limit the number of maximum iterations e.g. 5000 loops in the RAS procedures.

Country A's import table (constraint matrix)

		Ind 1	Ind 2	final cons.	Total
Country A	Industry 1	10	30	50	90
	Industry 2	20	40	60	120
	Total	30	70	110	

Country A's bilateral import table constraints (ordinary biproportional setting)

		Ind 1	Ind 2	final cons.	Total
Country A	Industry 1	0	0	0	0
	Industry 2	0	0	0	0
Country B	Industry 1	*	*	*	40
	Industry 2	*	*	*	60
Country C	Industry 1	*	*	*	50
	Industry 2	*	*	*	60
	Total	30	70	110	

* filled with initial value

Country A's bilateral import table constraints (cell-by-cell constraint)

		Ind 1	Ind 1	Ind 2	Ind 2	final cons.	final cons.	Total
Country A	Industry 1	0	0	0	0	0	0	0
	Industry 2	0	0	0	0	0	0	0
Country B	Industry 1	*	0	*	0	*	0	40
	Industry 2	0	*	0	*	0	*	60
Country C	Industry 1	*	0	*	0	*	0	50
	Industry 2	0	*	0	*	0	*	60
	Total	10	20	30	40	50	60	

* filled with initial value

Figure 2.8 : Cell-by-cell import matrix balancing (3 countries 2 industries example)

The initial values before the numerical balancing procedure are estimated based on the row proportionality assumption i.e. the bilateral trade partner shares are equally allocated across industries and final expenditures. Note that this is not the same row proportionality assumption

made to estimate national import tables in section 2.4 for the cases where the import tables are not published by national statistics institutes.

For some merchandise goods products, the end-use category defined in the OECD BTDIxE database (http://oe.cd/btd) is useful to separate the import partner shares by different end-use characteristics namely intermediate, household consumption and capital goods. Each 6 digit-level product in the HS classification system is assigned to a unique industry used in this study and a unique end-use category. The mixed end-use category products (personal computers, mobile phones, passenger cars, agricultural, mining and refinery products, etc.) of household consumption and industry use products are spread according to the consumption and industry use shares of use tables.

The inter-country IO table in a conventional IRIO format (Figure 2.9) for each year is finally estimated by merging the balanced results of the different stages of above sections. However, it is not a necessary step for the analytical purposes. In fact, it is practical to use the already separated objects for intermediate and final demand matrices and vectors of output and value added for a typical IO analysis to calculate the Leontief inverse and value added and environmental footprint multipliers.[17]

[17] For the same reason, separate ICIO components are provided to OECD-WTO Trade in Value-Added project.

Inter-country I-O	Intermediate demand						Final expenditure			Output
	Cou A		Cou B		Cou C		Cou A	Cou B	Cou C	
	Ind 1	Ind 2	Ind 1	Ind 2	Ind 1	Ind 2				
Country A Industry 1	Z(AA11)	Z(AA12)	Z(AB11)	Z(AB12)	Z(AC11)	Z(AC12)	FE(AA1)	FE(AB1)	FE(AC1)	X(A1)
Industry 2	Z(AA21)	Z(AA22)	Z(AB21)	Z(AB22)	Z(AC21)	Z(AC22)	FE(AA2)	FE(AB2)	FE(AC2)	X(A2)
Country B Industry 1	Z(BA11)	Z(BA12)	Z(BB11)	Z(BB12)	Z(BC11)	Z(BC12)	FE(BA1)	FE(BB1)	FE(BC1)	X(B1)
Industry 2	Z(BA21)	Z(BA22)	Z(BB21)	Z(BB22)	Z(BC21)	Z(BC22)	FE(BA2)	FE(BB2)	FE(BC2)	X(B2)
Country C Industry 1	Z(CA11)	Z(CA12)	Z(CB11)	Z(CB12)	Z(CC11)	Z(CC12)	FE(CA1)	FE(CB1)	FE(CC1)	X(C1)
Industry 2	Z(CA21)	Z(CA22)	Z(CB21)	Z(CB22)	Z(CC21)	Z(CC22)	FE(CA2)	FE(CB2)	FE(CC2)	X(C2)
Taxes less subsidies on intermediate and final products	NTZA1	NTZA2	NTZB1	NTZB2	NTZC1	NTZC2	FEA	FEB	FEC	
Value-added	V(A1)	V(A2)	V(B1)	V(B2)	V(C1)	V(C2)				
Output at basic price	X(A1)	X(A2)	X(B1)	X(B2)	X(C1)	X(C2)				

A's exports of intermediate products = Z(AB11)+Z(AB21)+Z(AB12)+Z(AB22)+Z(AC11)+Z(AC21)+Z(AC12)+Z(AC22)
A's exports of final products = FE(AB1)+FE(AB2)+FE(AC1)+FE(AC2)
A's imports of intermediate products = Z(BA11)+Z(BA12)+Z(BA21)+Z(BA22)+Z(CA11)+Z(CA12)+Z(CA21)+Z(CA22)
A's imports of final products = FE(BA1)+FE(BA2)+FE(CA1)+FE(CA2)

Figure 2.9 : Inter-Country Input-Output table (basic prices)

2.6 SUMMARY

The inter-country input-output (ICIO) tables developed in this paper include notable features for consistent globalization analyses. The estimates for each country included in this database tables are basically constrained to national accounts variables. Thus, the trade balance of each country covers both cross border trade flows and direct purchases by non-residents. Therefore, the database is specifically useful for policy analyses that draw on balanced data from conventional statistics. Examples of such analyses include comparison of production-based and consumption-based CO2 emissions (http://oe.cd/io-co2) and estimation of Trade in Value Added indicators (http://oe.cd/tiva).

The quality of this ICIO table and the analytical results from this database can be improved in many ways. Some examples are noted below.

- Methodological enhancement. The balancing the different components of ICIOs can be made at more detailed sector levels. The distribution margins for transport sectors can be balanced at different transportation mode. Import duty can be explicitly separated from the value added and sales taxes of domestic products when the tables at purchasers' prices are converted to basic prices format.

- More countries. The current set of target countries consists of more than 90% of world GDP, however some analyses such as global environmental and sustainable development goals can be improved by including the mining products exporters e.g. Middle Eastern countries and developing economies with larger population such as South Asian and African countries are included.

- Subnational regional split. The integration of subnational economic structure in a country aggregated ICIO can provide additional information for different types of policy agendas e.g. regional innovation policy, natural disaster mitigation, infrastructure and local environmental impact analysis such as atmosphere pollution and fresh water stress analyses.

- Firm heterogeneity split. The integration of industries in global production networks for each country is unequal across all the firms in the same industry group. For example, multinational enterprises and SMEs have different destinations for their product sales and the production structures of exporters and non-exporters in a developing economy could be quite different.

The second and third extensions described above are extensively examined in following two chapters.

CHAPTER 3 : DEVELOPMENT OF REGIONAL EXTENDED INTER-COUNTRY INPUT-OUTPUT DATABASE

3.1 INTRODUCTION

Changes in the international trade environment in recent decades have seen greater integration of production networks among neighboring economies, particularly in the Asian, North American and European regional blocs. Global scale ICIOs can be applied to various policy areas (Chapter 1 of this dissertation) and many studies have recently been published analyzing bilateral and multilateral trade relationships (Koopman *et al*., 2014; OECD-WTO 2013, 2015), global environment (Peters *et al*., 2011; Tukker *et al*., 2013; Wood *et al*., 2015; OECD Green Growth indicator) and other social issues such as biodiversity (Lenzen *et al*., 2012) and decent jobs (Alsamawi *et al*., 2014).

Some researchers, however, have raised concerns about analyses based on existing global ICIOs due to the limited level of disaggregation required for specific policy interests (see, for example, Lenzen, 2011 and Steen-Olsen *et al*., 2014, in the context of carbon emissions and environmental issues). Also, de Koning *et al*. (2015) argue that the effect of reducing the sectoral resolution influences the material footprint results of many countries (Germany 9%, France 9%, the Netherlands 13%, Russian federation 10% and South Africa 9%). Thus, we should not underestimate the impact of using aggregated sectors. In general, the more countries/economies covered, the higher the levels of aggregation of industrial activities (Table 3.1).

Table 3.1 : Number of industries in existing ICIOs

ICIO table (reference year)	Target economies	Number of sectors in symmetric ICIO (Agriculture/Mining/Manufacturing)
IDE-JETRO AIO (2005)	10	76 (7 / 4 / 49)
OECD ICIO 2015ed (1995-2011)	61 countries and RoW	34 (1 / 1/ 16)
WIOD WIOT 2016ed (1995-2014)	44	55 (3/1/19) + 1 special sector
WIOD WIOT 2013ed (1995-2009)	41	35 (1/ 1/ 14)
EXIOBASE2 (2007)	43 countries and 5 RoWs	162 (19 / 15 / 61) + 1 special sector
EORA (1990-2011)	182	24 (2 / 1 / 9) + 2 special sectors
JRC/Eurostat Figaro for 2010 (forthcoming)	29	64 (3 / 1/ 18)

Sources : Timmer *et al*. (2016), Wood *et al*. (2015), OECD (2015), IDE-JETRO (2011), Remond-Tiedrez and Rueda-Cantuche (2016) and Lenzen *et al*. (2013)

In addition to the level of industry aggregation, another consideration could be the level of geographical details. The IO databases have often been used by regional planners as a primary tool to evaluate the economic impacts of various policy interventions (see chapter 3 Input-Output Models at the Regional Level; Miller and Blair, 2009; Wang and vom Hofe, 2007). Regional multiplier analyses are well established and the official regional multipliers are available from national statistics agencies in many countries (e.g. USA: Bureau of Economic Analysis, Japan: Ministry of Economy, Trade and Industry, China: National Bureau of Statistics, and Canada: STATCAN). Regional IO tables are particularly useful for generating the economic impacts for a relatively smaller geographical area such as a metropolitan region or a state for analysis of impacts of natural disasters, local pollution, tourism and sports and exhibition events.

However, the single-regional framework, does not consider the explicit economic linkages of industries and household between external regions and countries. The roles of each regions in a country vary significantly across subnational regions. As merchandise trade statistics (e.g. UN Comtrade) and regional account databases indicate that the intermediate

supplies and product sales destinations are much more dependent on external economies than earlier years, the demand for multiregional analysis has become increasingly important.

Interregional input-output databases have been estimated for different target countries (e.g. China: Okamoto and Zhang (2003) and Okamoto and Ihara (2005); Italy: IRPET (e.g. Casini Benvenuti and Grassi, 1977 and Casini Benvenuti *et al*., 1995); Japan: Miyagi *et al*. (2003), Ishikawa and Miyagi (2004), Hitomi and Pongsun (2008), Hagiwara (2012); Brazil: Guilhoto *et al*, (2010); USA: Polenski (1980); Sonis *et al.*, 2002; Munroe *et al.*, 2007), but most of the interregional trade flows in these databases have been estimated by non-survey approaches (Chenery-Moses or Multiregional IO model (MRIO) approaches) due to the limited availability of statistical sources on end-use industries and household expenditures on imported products. Conventional approaches for compiling bilateral trade flows between domestic regions apply variants of gravity models and regional partner shares based on physical commodity flow surveys. The interregional tables used in this chapter, estimated by the Ministry of Economy Trade and Industry in Japan is one of the few cases that the statistical agencies have conducted special surveys to estimate the official interregional input-output tables.

Recently, there have been a number of initiatives to integrate global ICIO and interregional input tables to analyze the participation of regional economies in global supply chains. The motivations for these studies are similar to those ones for development of inter-regional input-output tables. The manufacturing and services sectors of regional economies have become much dependent on foreign countries resources and markets and the existing inter-regional analytical framework become less effective. The examples of interregional-extended global ICIO includes Inomata and Meng (2013) for three East Asian countries (China, Japan and

South Korea); Dietzenbacher *et al*. (2013) for Brazil; Cherubini and Los (2013) for Italy; and JRC RHOMOLO-v2 (Mercenier *et al*., 2016) using the Nomenclature of Territorial Units for Statistics level 2 regions (NUTS2) of the European Union.

The notable features of the model developed in this chapter are the integration of the regional customs statistics at the HS 6 digit product level with regional input-output tables. While bilateral trade in services are not available at the regional level, the customs regional data will improve the quality of international import matrix of each region both in terms of heterogeneity in imported product dependency in each region and the sources of imported product by origin country. In other words, a Japanese multinational enterprise in one region depends the intermediate supplies from Europe and a firm in different region may depends more on the north American supplies. To the author's knowledge, bilateral trade statistics by regional customs offices i.e., transactions information between foreign economies and domestic regions are not explicitly used to compile these ICIO-IRIO integrated databases.

The aim of this chapter is to develop a general methodology to split aggregated industries in a country-based Inter-Country IO (ICIO) system using existing interregional IO (IRIO) tables and "official" merchandise trade statistics at a regional level. A similar methodology used to split estimates of the "Rest of the world" (RoW) using existing national IOs and Customs data of additional countries - can be applied here (e.g. ADB, 2016 for Bangladesh, Philippines, Malaysia, Thailand and Viet Nam from RoW of WIOT; Bullon *et al*., 2015 for Costa Rica from RoW of WIOT; OECD (2016) for Morocco and Peru from RoW of OECD ICIO 2015). Such a methodology for "splitting" is, in fact, not the preferred approach. The preferred approach would be to build all components of extended ICIOs i.e. SNA harmonized trade statistics and

supply-use at purchasers' prices from the beginning. However, it requires a significant amount of data estimation because no equivalent of national economy statistics is published at the regional level by any country. Therefore, the generalized methodology proposed in this paper is a practical approach to integrate more detail regional IO tables to a global ICIO of a given year.

This chapter proceeds as follows: The next section outlines the methodology to "split" regional inter-industry structures from global ICIOs. The third section describes the procedures of the proposed methodology and the last section gives a summary of this study.

3.2 METHODOLOGY

Approaches to integrate a subnational interregional IO (IRIO) into a global ICIO have been examined by earlier studies targeting different countries (Inomata and Meng, 2013; Dietzenbacher *et al*., 2013; Cherubini and Los, 2013). The methodology of integrating IRIO into the global ICIO system involves procedures of data collection, harmonization of classification and valuation formats, and then splitting the aggregated inter-industry transaction flows to different regions with multi-layered constraints.

3.2.1 Harmonization of national data sources

The main requirements for this analysis are summarized as follows.

1) Global scale ICIO table such as the one estimated in the previous chapter

2) Interregional Input-Output table

3) Regional Customs trade statistics

First, using the target country rows and columns from an ICIO (Figure 3.1) as control totals, the interregional input output table is re-balanced (Figure 3.2 shows a 3-region example). The output, value added, trade flows and domestic expenditure items are rescaled according to country total figures from ICIO table. This rebalancing procedure includes the conversion of price valuation to basic prices, harmonizing to the industry classification of the ICIO system and the expenditure items of final demand. For simplicity, only the total final demand and total value added items are considered here. This can be expanded to as many items as possible depending on data availability. If sectoral international imports by each region are not available, imports by each region are estimated from the sectoral aggregated regional customs statistics. The original imports columns or rows in the national tables are valued at c.i.f. purchasers' prices, but the imports for all regions are eventually rescaled again by the sectoral imports constraints from the ICIO that are valued at f.o.b. basic prices of the products from origin countries. The import matrix of each region is estimated using the national import table given by the global ICIO system.

Inter-country I-O	Intermediate demand			Final expenditure			Output
	Cou A	Cou B	Cou C	Cou A	Cou B	Cou C	
	Ind 1…ns	Ind 1…ns	Ind 1…ns				
Country A Industry 1..ns	Z(AA)	Z(AB)	Z(AC)	FE(AA)	FE(AB)	FE(AC)	X(A)
Country B Industry 1..ns	Z(BA)	Z(BB)	Z(BC)	FE(BA)	FE(BB)	FE(BC)	X(B)
Country C Industry 1..ns	Z(CA)	Z(CB)	Z(CC)	FE(CA)	FE(CB)	FE(CC)	X(C)
Taxes less subsidies on intermediate and final	NTZA	NTZB	NTZC	NTFA	NTFB	NTFC	
Value-added	V(A)	V(B)	V(C)				
Output at basic price	X(A)	X(B)	X(C)				

Figure 3.1: Inter-Country I-O Database (3 countries example)

The exports for country *A* in the IRIO and the ICIO framework of the 3 countries and 2 regions example (Figure 3.2) are summarized in a general format as follows:

Exports of product *i* for country *A*: $\sum_r EXP_i^r = \sum_p Z_i^{Ap} + \sum_p F_i^{Ap}$ **(3.1)**

where EXP_i^r is exports of product *i* from region *r* of country *A*, Z_i^{Ap} is intermediate transaction from country *A* to country *p* and F_i^{Ap} is final expenditure transaction from country *A* to country *p*.

Country A's ICIO benchmarked Inter-regional I-O		Intermediate demand			Final expenditure			Export	Output
		Reg 1	Reg 2	Reg 3	Reg 1	Reg 2	Reg 3		
		Ind 1…ns	Ind 1…ns	Ind 1…ns					
Region 1	Industry 1..ns	Z(11)	Z(12)	Z(13)	FE(11)	FE(12)	FE(13)	EXP(A1)	X(A1)
Region 2	Industry 1..ns	Z(21)	Z(22)	Z(23)	FE(21)	FE(22)	FE(23)	EXP(A2)	X(A2)
Region 3	Industry 1..ns	Z(31)	Z(32)	Z(33)	FE(31)	FE(32)	FE(33)	EXP(A3)	X(A3)
Imports	Industry 1..ns	ZM(A1)	ZM(A2)	ZM(A3)	FM(A1)	FM(A2)	FM(A3)		
Taxes less subsidies on intermediate and final		NTZA1	NTZA2	NTZA3	NTFA1	NTFA2	NTFA3		
Value-added		V(A1)	V(A2)	V(A3)					
Output at basic price		X(A1)	X(A2)	X(A3)					

	IRIO	ICIO
Exports	EXP(1)+EXP(2)+EXP(3)	Z(AB)+Z(AC)+FE(AB)+FE(AC)
Imports	ZM(1)+ZM(2)+ZM(3)	Z(BA)+Z(CA)+FE(BA)+FE(CA)
Output	X(A1)+X(A2)+X(A3)	X(A)
Value added	V(A1)+V(A2)+V(A3)	V(A)
Net taxes on intermediate prod	NTZA1+NTZA2+NTZA3	NTZA
Net taxes on final products	NTFA1+NTFA2+NTFA3	NTFA

Figure 3.2: ICIO benchmarked Interregional IO table (3 regions example)

Region Extended Inter-country I-O		Intermediate demand								Final expenditure				Output
		Cou A Region 1		Cou A Region 2		Cou B		Cou C		Cou A	Cou A	Cou B	Cou C	
		Ind 1	Ind 2	Ind 1	Ind 2	Ind 1	Ind 2	Ind 1	Ind 2	Reg1	Reg2			
Country A (Region 1)	Industry 1	$Z(AiAi^{11})$	$Z(AiAi^{12})$	$Z(AiAii^{11})$	$Z(AiAii^{12})$	$Z(AiB^{11})$	$Z(AiB^{12})$	$Z(AiC^{11})$	$Z(AiC^{12})$	$F(AiAi^{1})$	$F(AiAii^{1})$	$F(AiB^{1})$	$F(AiC^{1})$	X(Ai1)
	Industry 2	$Z(AiAi^{21})$	$Z(AiAi^{22})$	$Z(AiAii^{21})$	$Z(AiAii^{22})$	$Z(AiB^{21})$	$Z(AiB^{22})$	$Z(AiC^{21})$	$Z(AiC^{22})$	$F(AiAi^{2})$	$F(AiAii^{2})$	$F(AiB^{2})$	$F(AiC^{2})$	X(Ai2)
(Region 2)	Industry 1	$Z(AiiAi^{11})$	$Z(AiiAi^{12})$	$Z(AiiAii^{11})$	$Z(AiiAii^{12})$	$Z(AiiB^{11})$	$Z(AiiB^{12})$	$Z(AiiC^{11})$	$Z(AiiC^{12})$	$F(AiiAi^{1})$	$F(AiiAii^{1})$	$F(AiiB^{1})$	$F(AiiC^{1})$	X(Aii1)
	Industry 2	$Z(AiiAi^{21})$	$Z(AiiAi^{22})$	$Z(AiiAii^{21})$	$Z(AiiAii^{22})$	$Z(AiiB^{21})$	$Z(AiiB^{22})$	$Z(AiiC^{21})$	$Z(AiiC^{22})$	$F(AiiAi^{2})$	$F(AiiAii^{2})$	$F(AiiB^{2})$	$F(AiiC^{2})$	X(Aii2)
Country B	Industry 1	$Z(BAi^{11})$	$Z(BAi^{12})$	$Z(BAii^{11})$	$Z(BAii^{12})$	Z(BB11)	Z(BB12)	Z(BC11)	Z(BC12)	$F(BAi^{1})$	$F(BAii^{1})$	F(BB1)	F(BC1)	X(B1)
	Industry 2	$Z(BAi^{21})$	$Z(BAi^{22})$	$Z(BAii^{21})$	$Z(BAii^{22})$	Z(BB21)	Z(BB22)	Z(BC21)	Z(BC22)	$F(BAi^{2})$	$F(BAii^{2})$	F(BB2)	F(BC2)	X(B2)
Country C	Industry 1	$Z(CAi^{11})$	$Z(CAi^{12})$	$Z(CAii^{11})$	$Z(CAii^{12})$	Z(CB11)	Z(CB12)	Z(CC11)	Z(CC12)	$F(CAi^{1})$	$F(CAii^{1})$	F(CB1)	F(CC1)	X(C1)
	Industry 2	$Z(CAi^{21})$	$Z(CAi^{22})$	$Z(CAii^{21})$	$Z(CAii^{22})$	Z(CB21)	Z(CB22)	Z(CC21)	Z(CC22)	$F(CAi^{2})$	$F(CAii^{2})$	F(CB2)	F(CC2)	X(C2)
Taxes less subsidies on intermediate and final products		NTZAi1	NTZAi2	NTZAii1	NTZAii2	NTZB1	NTZB2	NTZC1	NTZC2	NTFAi	NTFAii	NTFB	NTFC	
Value-added		V(Ai1)	V(Ai2)	V(Aii1)	V(Aii2)	V(B1)	V(B2)	V(C1)	V(C2)					
Output at basic price		X(Ai1)	X(Ai2)	X(Aii1)	X(Aii2)	X(B1)	X(B2)	X(C1)	X(C2)					

Figure 3.3 : Regional extended ICIO (3 countries 2 regions example)

Similarly, the imports variables for country *A* are defined as:

Imports of product i by country A: $\sum_r ZM_i^r + \sum_r FM_i^r = \sum_p Z_i^{pA} + \sum_p F_i^{pA}$ **(3.2)**

where ZM_i^r and FM_i^r are the intermediate and final products imports by region *r* respectively in the IRIO database, and Z_i^{pA} is intermediate imports by country *A* from country *p* and F_i^{pA} is final products imports by country *A* from country *p*.

The sum of regional output and value added are also constrained to national totals as

Output of industry *i* for country *A*: $\mathrm{XA} = \sum_r XA_i^r$ **(3.3)**

Value added of industry *i* for country *A*: $\mathrm{VA} = \sum_r VA_i^r$ **(3.4)**

where XA is output of country *A* in ICIO database, XA_i^r is output of region *r* in country *A*., VA is value added of country *A* and VA_i^r is value added of industry *i* of country *A*'s region *r*.

The re-balancing of the raw IRIO to the ICIO compatible table can be estimated by a RAS variant of the biproportional adjustment methodology (e.g. GRAS by Junius and Oosterhaven, 2003). However, splitting the ICIO requires additional constraints and thus linear programming approaches are more efficient and suitable. The benefit of the linear programming methodology is that inter-industry relationships of national total flows are preserved as much as possible in domestic interregional transactions.

$$\text{Minimize} \left(\sum_r \sum_s \sum_i \sum_j \frac{\left(z_{ij}^{rs} - z_{ij}^{*rs}\right)^2}{z_{ij}^{*rs}} + \sum_r \sum_s \sum_i \sum_k \frac{\left(f_{ik}^{rs} - f_{ik}^{*rs}\right)^2}{f_{ik}^{*rs}} + \sum_i \sum_r \frac{(x_i^r - x_i^{*r})^2}{x_i^{*r}} + \sum_i \sum_r \frac{(v_i^r - v_i^{*r})^2}{v_i^{*r}} + \sum_k \sum_r \frac{\left(y_k^r - y_k^{*r}\right)^2}{y_k^{*r}} \right) \quad \textbf{(3.5)}$$

subject to the conditions of (3.1), (3.2), (3.3) and (3.4), final expenditures and domestic inter-industry intermediate transactions. The variables with "*" indicate initial values, y_k^r is the column-sum of final demand.

The second part of the development of ICIO compatible national data sources is the calculation of bilateral trade flows by region. The bilateral goods import partner shares (product origin countries) are estimated from regional customs trade statistics. Similar to the characteristics of trade statistics at the national level, the regional customs data have benefits and limitations. For most countries, regional customs data are the only source that can identify the bilateral partner information and the product classification is sufficiently detail (over 5000 products) to separate the product characteristics to intermediate and final products. One of the biggest issues of the customs-based data sources are re-exports that are often not separated from the products produced within the region where the international ports are located.

The estimation procedure is basically the same as the calculation methodology for national total import partner shares. Firstly, regional customs data should be aggregated to match the regional groups of IRIO table. Unlike the national trade sources, the re-exports information is not provided in regional customs data source, thus, if the geographical distances between regions are relatively close and connected by high standard land transport networks, the regional customs data should be aggregated with neighbor regions. Then, detailed 6-digit HS trade data can be aggregated to the ICIO target industries and end-use categories. The end-use categories are based on those used OECD's Bilateral Trade by industry and end-use database BTDIxE (Zhu *et al*., 2011 and http://oe.cd/btd), a modified version of the UN's Broad Economic Category[18] (BEC), to match better with the frameworks of National Accounts and Input-Output databases.

Note that the flows of re-imports and re-exports are excluded from the estimated results if these flows are separately provided in the trade statistics of regional customs offices. The import partner share for partner "Rest of the world" is defined by the world total minus the sum of target countries. Since trade in services (balance of payments) statistics are not available at subnational regional level, export and import partner shares of national averages are applied as regional trade partner shares.

The bilateral exports and imports partner shares for intermediate and final products of each region *r* in country *A* for industry *i* are defined as

[18] https://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=10

$TXz(\mathrm{Ar,P,i}) = TRD(Ar,P,i)/\sum_p TRD(Ar,P,i)$; exports share for intermediate goods **(3.6)**

$TXf(\mathrm{Ar,P,i}) = TRD(Ar,P,i)/\sum_p TRD(Ar,P,i)$; exports share for final goods **(3.7)**

$TMz(\mathrm{Ar,P,i}) = TRD(P,Ar,i)/\sum_p TRD(P,Ar,i)$; imports share for intermediate goods **(3.8)**

$TMf(\mathrm{Ar,P,i}) = TRD(P,Ar,i)/\sum_p TRD(P,Ar,i)$; imports share for final goods **(3.9)**

where *TXz(Ar,P,i)* and *TMz(Ar,P,i)* are export and import partner shares respectively for intermediate products. *TXf(Ar,P,i)* is export partner shares for final products, *TRD(Ar,P,i)* is exports of *Ar* to country *P* from regional customs statistics, and *TRD(P,Ar,i)* is imports by *Ar* from country *P*. International cross border transactions of electricity, other utility products and medical services are negligibly small. Most of the transactions can be assumed to be direct purchases by non-residents.

The partner shares for distribution services, i.e. transportation and trade margins, are estimated from the bilateral partner shares of total goods

$TXz(\mathrm{Ar,P,i}) = TRD(\mathrm{Ar,P,i})/\sum_p TRD(Ar,P,i)$; *i* is distribution services **(3.10)**

$TXf(\mathrm{Ar,P,i}) = TRD(\mathrm{Ar,P,i})/\sum_p TRD(Ar,P,i)$; i is distribution services **(3.11)**

$TMz(\mathrm{Ar,P,i}) = TRD(\mathrm{P,Ar,i})/\sum_p TRD(P,Ar,i)$; i is distribution services **(3.12)**

$TMf(\mathrm{Ar,P,i}) = TRD(\mathrm{P,Ar,i})/\sum_p TRD(P,Ar,i)$; i is distribution services **(3.13)**

For other services sectors, there is no reference bilateral partner country information for all regions, therefore the partner shares are given from the national average figures from the ICIO table.

$TXz(\mathrm{Ar,P,i}) = Z(\mathrm{A,P,i})/\sum_p Z(A,P,i)$; i = other services **(3.14)**

$TXf(\mathrm{Ar,P,i}) = F(\mathrm{A,P,i})/\sum_p F(A,P,i)$; i = other services **(3.15)**

$TMz(\mathrm{Ar,P,i}) = Z(\mathrm{P,A,i})/\sum_p Z(P,A,i)$; i = other services **(3.16)**

$TMf(\mathrm{Ar,P,i}) = F(\mathrm{P,A,i})/\sum_p F(P,A,i)$; i = other services **(3.17)**

where *Z(A,P,i)* is intermediate flow of services product *i* from country *A* to country *P*, *Z(P,A,i)* is intermediate flow of services product *i* from country *P* to country *A*, *F(A,P,i)* is final expenditure flow of services product *i* from country *A* to country *P* and *Z(P,A,i)* is final expenditure product flow of services product *i* from country *P* to country *A*.

3.2.2 Initial values of international trade flows by region

The initial values for the inter-country part of region extended ICIO are calculated by multiplying the national intermediate exports flow and bilateral trade partner shares. The exports of intermediate and final products for country A's region *r* are respectively calculated as

$$Z_{ij}^{Ar,P} = Z_{ij}^{A,P} * BTDz_i^{Ar,P} \quad \textbf{(3.18)}$$

$$F_{ij}^{Ar,P} = F_{ij}^{A,P} * BTDf_i^{Ar,P} \quad \textbf{(3.19)}$$

The imports of intermediate and final products for region *r* are also given similarly as

$$Z_{ij}^{P,Ar} = ZM_{ij}^{P,Ar} * BTDz_i^{P,Ar} \quad \textbf{(3.20)}$$

$$F_{ij}^{P,Ar} = FM_{ij}^{P,Ar} * BTDf_i^{P,Ar} \quad \textbf{(3.21)}$$

where $Z_{ij}^{Ar,P}$ is intermediate exports from industry *i* country *A*'s region *r* to industry *j* of country *P*, $ZM_{ij}^{P,Ar}$ is intermediate import matrix of country *A*'s region *r*, $BTDz_i^{Ar,P}$ and $BTDf_i^{Ar,P}$ are bilateral trade partner shares between country *A'*s region *r* to country *P* for intermediate and final products respectively.

Note that the intermediate and final product transaction of domestic transactions, output and value added parts are already made available from earlier estimation step for the ICIO compatible national IRIO.

3.2.3 Balancing inter-country/interregional flows

The international parts of integrated ICIO are separately estimated for exports and imports blocks (Figure 3.4). For each block, the bilateral intermediate and final demand components must satisfy the constraints from national totals from ICIO. The conditions of exports of intermediate by end-use industry (*j*) and final demand sectors (*k*) between country *A* to country *p* are respectively defined by the sum of regional figures as:

$\sum_p \sum_j Z(A,p,i,j) = \sum_r \sum_p \sum_j ZR(r,p,i,j)$, *p* is not equal to *A*, **(3.22)**

$Z(A,p,i,j) = \sum_r ZR(r,p,i,j)$, *p* is not equal to *A*, **(3.23)**

$\sum_p \sum_k F(A,p,i,k) = \sum_r \sum_p \sum_j FR(r,p,i,k)$, *p* is not equal to *A*, **(3.24)**

and

$F(A,p,i,k) = \sum_r FR(r,p,i,k)$, *p* is not equal to *A*. **(3.25)**

where *Z* is the intermediate of product *i* of country *A*, *ZR* is subnational region's intermediate exports of country *A*, *F* is exports of intermediate product *i* from country *A*, *FR* is subnational region's final products from country *A*.

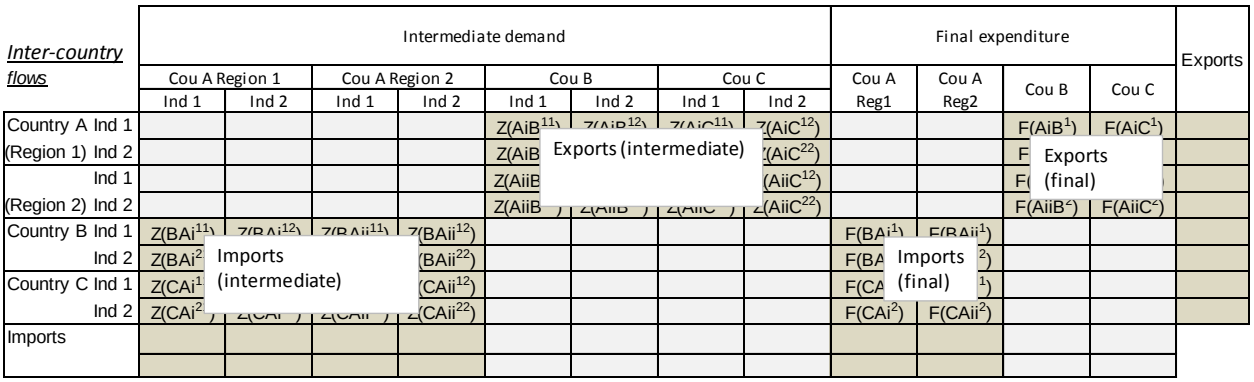


Figure 3.4 : Balancing inter-country flows (3 countries 2 regions example)

While intra-country domestic transactions are based on published input-output and supply-use data sources, the inter-country parts of ICIO are usually computed by non-survey methods with many assumptions on trade coefficients. Thus, the cell-by-cell constraints on end-use intermediate industries (i.e. importing industries) and final demand categories of equations **(3.23**) and **(3.25**) can be relaxed when the system cannot fully balance the inter-country part of ICIO as follows:

$\sum_j Z(A,p,i,j) = \sum_r \sum_j ZR(r,p,i,j)$, p is not equal to A and j is importing industries **(3.26)**

and

$\sum_k F(A,p,i,k) = \sum_r \sum_k FR(r,p,i,k)$, p is not equal to A and k is final demand categories. **(3.27)**

Again, the linear programming approach is an efficient numerical approach to balance the inter-industry transaction system with multiple layers of conditions of ICIO and IRIO with the

country totals of sectoral exports, the bilateral exports by product and national import by end use category (import use or symmetric import tables) are estimated by following model.

$$\text{Minimize}\left(\sum_r\sum_s\sum_i\sum_j\frac{\left(z_{ij}^{rs}-z_{ij}^{*rs}\right)^2}{z_{ij}^{*rs}}+\sum_r\sum_s\sum_i\sum_k\frac{\left(f_{ik}^{rs}-f_{ik}^{*rs}\right)^2}{f_{ik}^{*rs}}\right) \quad \textbf{(3.28)}$$

subject to the exports constraints of equations **(3.22**), **(3.23**), **(3.24**) and **(3.25**). If the system cannot fully balance, **(3.23**) and **(3.25**) can be respectively relaxed to **(3.26**) and **(3.27**).

Similarly, the import conditions are given as follows:

$$\text{Minimize}\left(\sum_r\sum_s\sum_i\sum_j\frac{\left(z_{ij}^{rs}-z_{ij}^{*rs}\right)^2}{z_{ij}^{*rs}}+\sum_r\sum_s\sum_i\sum_k\frac{\left(f_{ik}^{rs}-f_{ik}^{*rs}\right)^2}{f_{ik}^{*rs}}\right) \quad \textbf{(3.29)}$$

subject to the conditions of imports constraints of:

$$\boldsymbol{Z(A,p,i,j)=\sum_r\ ZR(r,p,i,j)}\text{, p is not equal to A} \quad \textbf{(3.30)}$$

and

$$F(A,p,i,j)=\sum_r\ FR(r,p,i,j)\text{, p is not equal to A.} \quad \textbf{(3.31)}$$

Note that the imported product by end-use industry and final demand sector are not included because it is assumed the ICIO system is built from the estimated import tables for all countries and the import matrix can identify the consumption industries and final expenditure items in principle.

The relaxed conditions of end-use industries and final demand items in imports constraints are also given as:

$$\sum_j Z(A,p,i,j) = \sum_r \sum_j Z(r,p,i,j) \quad \textbf{(3.32)}$$

and

$$\sum_k F(A,p,i,k) = \sum_r \sum_k FR(r,p,i,k), \quad \textbf{(3.33)}$$

where p is not equal to A, j is importing industry and k is final demand categories.

3.3 THE JAPANESE CASE: INTEGRATION OF IRIO AND GLOBAL ICIO

Japan consists of four main islands and many inhabited smaller islands (Figure 3.5). The distance between capital cities in the north-easternmost prefecture (Sapporo in Hokkaido) and the south-westernmost (Naha in Okinawa) is approximately 2250km. Most industrial activities are highly concentrated in the central regions in Japan.

Economic size, industry structures and export dependency vary across regions. While the differences in growth rates of output and per capita income across Japan's regions are marginal (Table 3.2 and Figure 3.6), export dependency ratios (exports per regional output) have significantly increased for many regions e.g. Chubu (3.2%), Chugoku (2.9%) and Kyushu (3.3%). Also, the import to output ratios for all regions except for Okinawa region have increased and the economies have become more dependent on imported intermediate and final products from abroad. The national average import penetration rate increased from 3.1% to 5.0% between 1995 and 2005. The interconnectedness analysis of regional industries in a context of global production networks has become more important.

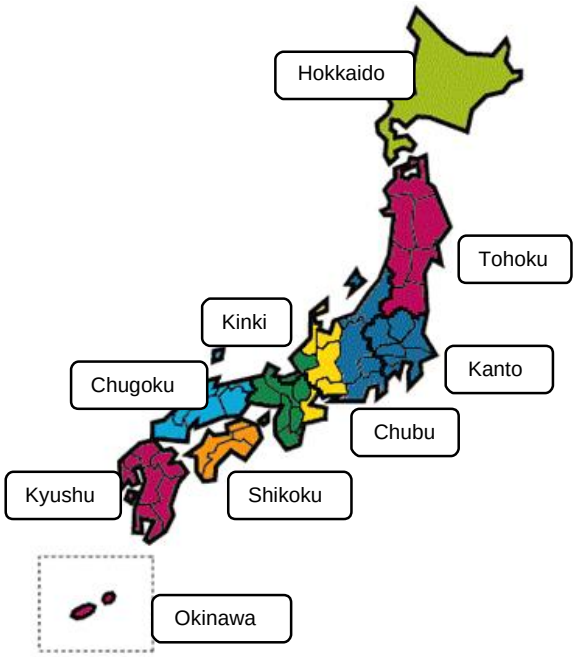
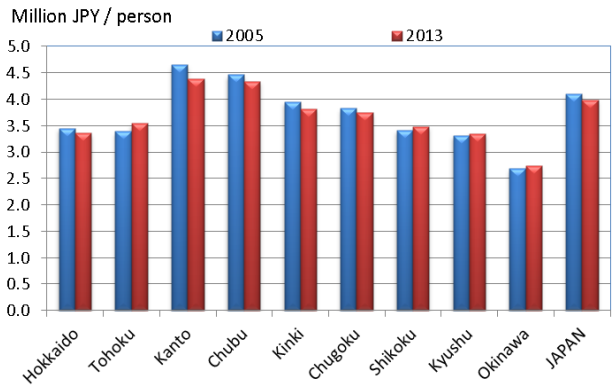


Figure 3.5: Japanese regions

Table 3.2: Regional output, exports and imports

Billion JPY	Exports		Imports		Output		Exports/ Output		Imports/ Output		Growth rate , 1995-2005 % per year		
	1995	2005	1995	2005	1995	2005	1995	2005	1995	2005	Exports	Imports	Output
Hokkaido	255	374	1,474	2,474	53,791	52,571	0.5%	0.7%	2.7%	4.7%	3.9%	5.3%	-0.2%
Tohoku	1,607	3,325	2,606	4,004	92,769	87,218	1.7%	3.8%	2.8%	4.6%	7.5%	4.4%	-0.6%
Kanto	20,642	28,212	18,776	31,010	610,679	627,446	3.4%	4.5%	3.1%	4.9%	3.2%	5.1%	0.3%
Chubu	8,992	15,146	5,104	9,694	171,917	179,691	5.2%	8.4%	3.0%	5.4%	5.4%	6.6%	0.4%
Kinki	7,572	11,463	7,629	11,054	247,606	233,482	3.1%	4.9%	3.1%	4.7%	4.2%	3.8%	-0.6%
Chugoku	3,241	6,007	2,999	6,020	86,371	90,297	3.8%	6.7%	3.5%	6.7%	6.4%	7.2%	0.4%
Shikoku	1,206	1,808	1,438	2,372	40,855	39,042	3.0%	4.6%	3.5%	6.1%	4.1%	5.1%	-0.5%
Kyushu	3,092	7,137	3,393	5,534	120,922	121,007	2.6%	5.9%	2.8%	4.6%	8.7%	5.0%	0.0%
Okinawa	202	126	306	320	8,604	8,963	2.3%	1.4%	3.6%	3.6%	-4.6%	0.5%	0.4%
Total	46,809	73,597	43,724	72,483	1,433,515	1,439,716	3.3%	5.1%	3.1%	5.0%	4.6%	5.2%	0.0%

Source: METI, Interregional Input-Output Tables for 1995 and 2005



Source: Economic and Social Research Institute, Cabinet Office, Japan. Annual Report on Prefectural Accounts

Figure 3.6: Regional income per capita

3.3.1 Data sources

The following data sources are used to develop a Japanese regionally extended ICIO database for reference year 2005 (summarized in Table 3.3):

1) The 2015 edition of OECD Inter-Country IO table for year 2005

   http://www.oecd.org/sti/ind/input-outputtablesedition2015accesstodata.htm

   The OECD Inter-country IO table 2015 edition includes 62 economies and 34 sectors in an industry-by-industry format valued at basic prices.

2) Trade Statistics of Japan, Customs and Tariff Bureau, Ministry of Finance.

   http://www.customs.go.jp/toukei/info/index_e.htm

The bilateral trade statistics of Japanese Customs have monthly exports and import information at product classification at 9 digits (the first 6-digit international HS codes and the last 3-digit domestic codes) for relatively detailed geographical resolution (Table 3.4, Figure 3.7 and Table 3.5).

Exported and imported products are not necessarily cleared by the customs offices in their own regions. Products are often aggregated with products from neighboring regions for economic (scale of economies) and physical reasons (accessibility and capacity of regional ports).

3) Ministry of Economy Trade and Industry (METI), 2005 Inter-Regional Input-Output Table

http://www.meti.go.jp/english/statistics/tyo/tiikiio/index.html

The 2005 Interregional Input Output table for Japan by METI (2011) includes 9 domestic regions with 53 sectors in a format of product-by-product symmetric tables and valued at producers' prices. The interregional trade flows include the direct purchases by non-residents; thus, tourism-oriented regions have a relatively large amount of exports in tourism services such as transportation, hotel, restaurant and rental equipment products. The discrepancies of regional and sectoral classifications among these data sources must be adjusted prior to their integration. For simplicity, the industries are aggregated to 8 industries (Table 3.6 and Table 3.7) and countries are aggregated to 4 region blocs in the region extended ICIO (REX-ICIO).

Table 3.3: Industry and regional classifications of data sources

	Region	No. of sector (classification)	Trade partner
Inter-regional IO, METI	9 regions	53 products (JSIC)	total world
Customs trade statistics, MOF	110 regions	5711 products for exports and 7862 products for imports (HS2002)	Over 160 countries
Inter-country IO, OECD	JAPAN	34 industries (ISIC Rev.3)	61 economies
Regionally extended ICIO	9 regions	9 industries (ISIC Rev.3)	6 region-blocs

Sources: OECD (2015), Ministry of Economy, Trade and Industry, Japan (2011) and Ministry of Finance, Japan (2015)

Table 3.4: Japan Customs regional offices and Regional I-O regions

Hokkaido	Tohoku	Kanto	Chubu	Kinki	Chugoku	Shikoku	Kyushu	Okinawa
800 HAKODATE	140 SAKATA	100 TOKYO	440 FUSHIKI	300 KOBE	320 UNO	360 SAKAIDE	600 MOJI	900 OKINAWA
802 MURORAN	250 ONAHAMA	101 TOHKOH B.C	442 TOYAMA	302 AMAGASAKI	321 OKAYAMA AP	362 TAKAMATSU	602 KANDA	902 OKINAWA BR
803 TOMAKOMAI	252 SOMA	103 HANEDA B.C	443 TOYAMA AP	303 HIMEJI	322 MIZUSHIMA	363 TAKUMA	603 TOBATA	905 HIRARA
804 OTARU	253 FUKUSHIMA	104 NARIKOH BC	450 NANAO	304 AIOI	340 ONOMICHI	364 MARUGAME	604 HAKATA	906 ISHIGAKI
805 RUMOI	260 SEN.SHIO B	120 NIIGATA	452 KANAZAWA	305 H-HARIMA	342 FUKUYAMA	370 MATSUYAMA	605 FUKUOKA AP	907 NAHA AP
806 SAPPORO	262 ISHINOMAKI	122 NAOETSU	453 KOMATSU AP	400 OSAKA	343 INNOSHIMA	372 IMABARI	640 KARATSU	
807 KUSHIRO	264 KESENNUMA	123 KASIWAZAKI	500 NAGOYA	402 SAKAI	344 KURE	373 NIIHAMA	642 IMARI	
808 NEMURO	265 SENDAI S.B	124 NIIGATA AP	502 CHUBU KUKO	403 KISHIWADA	345 HIROSHIMA	374 MISHIMA	650 IZUHARA	
809 WAKKANAI	820 AOMORI	200 YOKOHAMA	504 TOYOHASHI	404 KANSAI AP	346 TAKEHARA	375 UWAJIMA	660 OITA	
810 ABASHIRI	822 HACHINOHE	202 KAWASAKI	505 KINUURA	422 MIYAZU	347 H'SHIMA AP	380 KOCHI	661 OITA AP	
811 MONBETSU	823 AOMORI AP	203 YOKOSUKA	540 YOKKAICHI	423 KYOTO	350 SAKAI	382 SUSAKI	662 TSUKUMI	
812 CHITOSE	840 MIYAKO	220 CHIBA	543 TSU	424 SHIGA	352 HAMADA	390 KOMATUSIMA	664 SAIKI	
814 ISHIKARI	842 KAMAISHI	222 KISARAZU		430 MAIZURU	620 SIMONOSEKI		670 HOSOSHIMA	
815 TOKACHI	843 OFUNATO	243 KASHIMA		460 TSURUGA	622 HAGI		671 MIYAZAKIAP	
816 ASAHIKAWA	850 AKITA	244 HITACHI		461 FUKUI	623 UBE		672 ABURATSU	
	854 AKITA AP	245 TSUKUBA		470 SHIMOTSU	624 TOKUYAMA		700 NAGASAKI	
		271 UTSUNOMIYA		472 WAKAYAMA	626 HOFU		703 SASEBO	
		520 SHIMIZU		474 SHINGU	627 HIRAO		704 NAGASAKI A	
		522 TAGONOURA			628 IWAKUNI		720 MIIKE	
		523 OMAEZAKI					740 MISUMI	
		524 SHIZUOKAAP					742 MINAMATA	
							743 YATSUSHIRO	
							744 KUMAMOTO A	
							745 KUMAMOTO	
							750 KAGOSHIMA	
							752 KAGOSIMA A	
							754 SHIBUSHI	
							755 SENDAI	
							756 MAKURAZAKI	

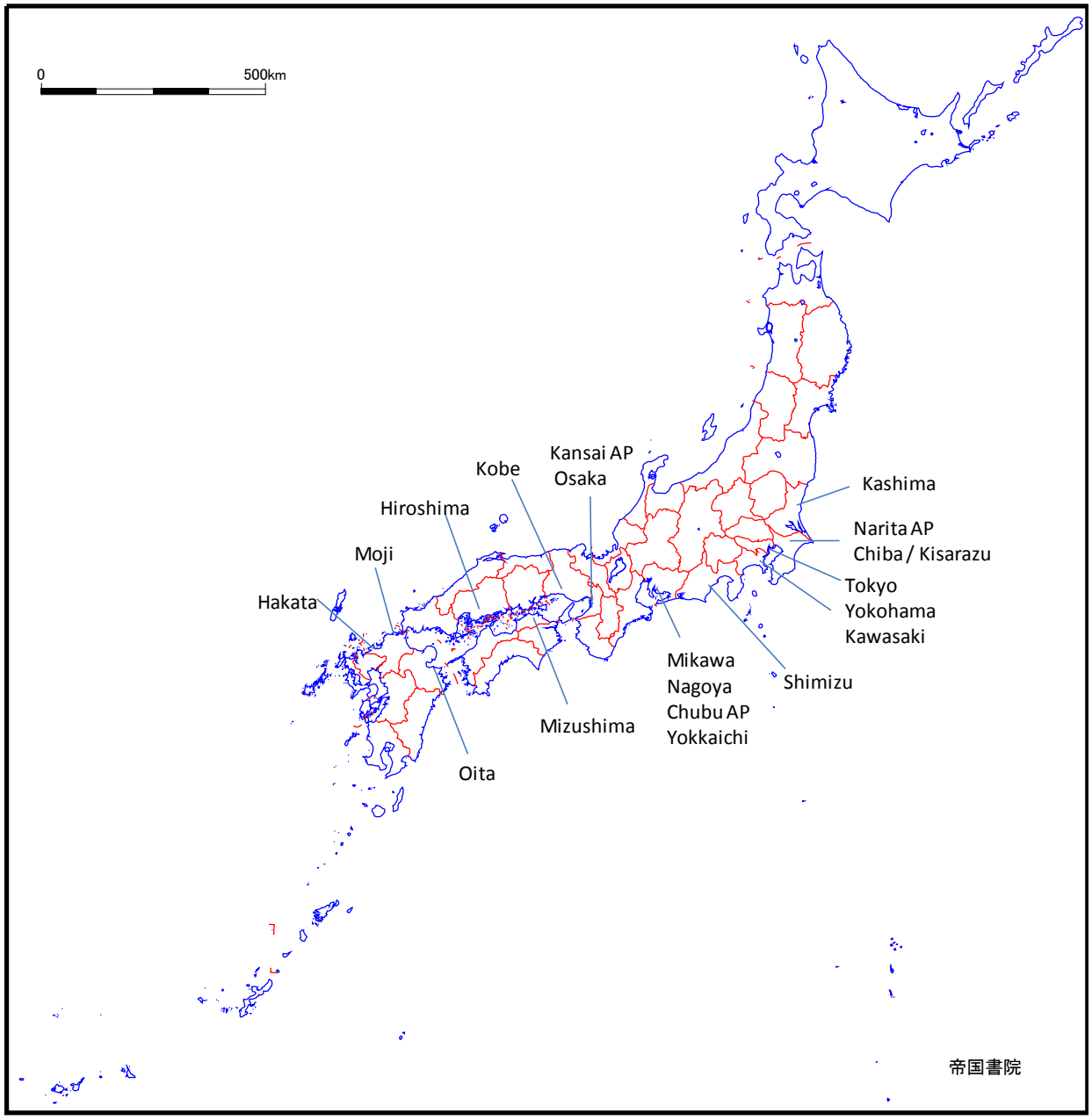


Figure 3.7: Locations of major international trading ports

Table 3.5: Top 40 international trade ports in Japan (2015)

Port	Port	Region	Exports (share%)		Imports (share%)		Total (share%)	
	Total	JAPAN	75,614	100%	78,406	100%	154,019	100%
1	NARITA AP*	Kanto	8,910	11.8%	12,612	16.1%	21,522	14.0%
2	TOKYO	Kanto	6,246	8.3%	11,366	14.5%	17,612	11.4%
3	NAGOYA	Chubu	11,472	15.2%	5,399	6.9%	16,871	11.0%
4	YOKOHAMA	Kanto	7,531	10.0%	4,623	5.9%	12,154	7.9%
5	KOBE	Kinki	5,551	7.3%	3,266	4.2%	8,817	5.7%
6	KANSAI AP*	Kinki	5,307	7.0%	3,906	5.0%	9,212	6.0%
7	OSAKA	Kinki	3,420	4.5%	5,002	6.4%	8,421	5.5%
8	CHIBA	Kanto	994	1.3%	3,561	4.5%	4,555	3.0%
9	KAWASAKI	Kanto	1,565	2.1%	2,427	3.1%	3,993	2.6%
10	YOKKAICHI	Chubu	923	1.2%	1,662	2.1%	2,586	1.7%
11	OSAKA SAKAI	Kinki	494	0.7%	1,600	2.0%	2,093	1.4%
12	HAKATA	Kyushu	1,621	2.1%	1,113	1.4%	2,733	1.8%
13	MIZUSHIMA	Chugoku	857	1.1%	1,338	1.7%	2,195	1.4%
14	MIKAWA	Chubu	2,697	3.6%	637	0.8%	3,335	2.2%
15	SHIMIZU	Chubu	1,810	2.4%	959	1.2%	2,769	1.8%
16	OOITA	Kyushu	652	0.9%	1,310	1.7%	1,962	1.3%
17	KASHIMA	Kanto	470	0.6%	1,073	1.4%	1,543	1.0%
18	CHUBU AP*	Chubu	1,028	1.4%	1,097	1.4%	2,125	1.4%
19	KISARAZU	Kanto	295	0.4%	966	1.2%	1,261	0.8%
20	HIROSHIMA	Chubu	1,460	1.9%	401	0.5%	1,861	1.2%
21	MOJI	Kyushu	777	1.0%	851	1.1%	1,628	1.1%
22	KAGOSHIMA	Kyushu	2	0.0%	938	1.2%	940	0.6%
23	TOMAKOMAI	Hokkaido	235	0.3%	732	0.9%	966	0.6%
24	SENDAISHIOGAMA	Tohoku	300	0.4%	591	0.8%	891	0.6%
25	FUKUOKA AP*	Kyushu	1,039	1.4%	439	0.6%	1,478	1.0%
26	FUKUYAMA	Chugoku	453	0.6%	419	0.5%	872	0.6%
27	HIMEJI	Kinki	215	0.3%	571	0.7%	786	0.5%
28	TOKUYAMA	Chugoku	440	0.6%	420	0.5%	859	0.6%
29	TOBATA	Kyushu	448	0.6%	339	0.4%	787	0.5%
30	NIIGATA	Kanto	121	0.2%	646	0.8%	767	0.5%
31	HANEDA AP*	Kanto	405	0.5%	597	0.8%	1,002	0.7%
32	SHIMOTSU	Kinki	152	0.2%	319	0.4%	471	0.3%
33	SHIMONOSEKI	Chugoku	531	0.7%	258	0.3%	789	0.5%
34	IMABARI	Shikoku	293	0.4%	364	0.5%	657	0.4%
35	HITACHI	Kanto	403	0.5%	312	0.4%	715	0.5%
36	HOFU	Chugoku	637	0.8%	70	0.1%	707	0.5%
37	KANDA	Kyushu	760	1.0%	26	0.0%	786	0.5%
38	NIIHAMA	Shikoku	245	0.3%	398	0.5%	644	0.4%
39	UBE	Chugoku	127	0.2%	355	0.5%	482	0.3%
40	HIGASHIHARIMA	Kinki	344	0.5%	207	0.3%	551	0.4%
	Other		5,862	7.8%	6,223	7.9%	12,085	7.8%

*AP Airports

Table 3.6: Industry classification of IRIO (53 products) and Regional extended ICIO (8 industries)

		REX ICIO							
		Agriculture	**Mining and quarrying**	**Material manuf.**	**Machinery and equipment**	**Other manuf.**	**Electricity, Gas and Water Supply**	**Construction**	**Services**
	ISIC Rev.3 code	***01 to 05***	***10 to 14***	***20 to 28***	***29 to 35***	***15 to 19; 36,37***	***40,41***	***45***	***50 to 95***
1	Agriculture, forestry and fishery	1							
2	Mining		1						
3	Coal mining , crude petroleum and natural gas		1						
4	Beverages and Foods					1			
5	Textile products					1			
6	Wearing apparel and other textile products					1			
7	Timber, wooden products and furniture			1					
8	Pulp, paper, paperboard, building paper			1					
9	Printing, plate making and book binding			1					
10	Chemical basic product			1					
11	Synthetic resins			1					
12	Final chemical products			1					
13	Medicaments			1					
14	Petroleum and coal products			1					
15	Plastic products			1					
16	Ceramic, stone and clay products			1					
17	Iron and steel			1					
18	Non-ferrous metals			1					
19	Metal products			1					
20	General machinery				1				
21	Machinery for office and service industry				1				
22	Electrical devices and parts				1				
23	Other electrical machinery				1				
24	Household electric appliances				1				
25	Household electronics equipment				1				
26	Electronic computing equipment and accessory equipment of electronic computing equipment				1				
27	Electronic components				1				
28	Passenger motor cars				1				
29	Other cars				1				
30	Motor vehicle parts and accessories				1				
31	Other transport equipment				1				
32	Precision instruments				1				
33	Miscellaneous manufacturing products					1			
34	Reuse and recycling					1			
35	Construction							1	
36	Electricity						1		
37	Gas and heat supply						1		
38	Water supply and waste disposal business						1		
39	Commerce								1
40	Finance and insurance								1
41	Real estate								1
42	House rent (imputed house rent)								1
43	Transport								1
44	Other information and communications								1
45	Information services								1
46	Public administration								1
47	Education and research								1
48	Medical service, health, social security and nursing care								1
49	Advertising services								1
50	Goods rental and leasing services								1
51	Other business services								1
52	Personal services								1
53	Others								1

Table 3.7: Industry classification of ICIO (34 industries) and Regional Extended IO (8 industries)

			REX ICIO							
			Agriculture	Mining and quarrying	Material manuf.	Machinery and equipment	Other manuf.	Electricity, Gas and Water Supply	Construction	Services
		ISIC 3 division code	*01 to 05*	*10 to 14*	*20 to 28*	*29 to 35*	*15 to 19; 36,37*	*40,41*	*45*	*50 to 95*
1	**Agriculture, hunting, forestry and fishing**	***01 to 05***	1							
2	**Mining and quarrying**	***10 to 14***		1						
3	**Food products, beverages and tobacco**	***15,16***					1			
4	**Textiles, textile products, leather and footwear**	***17,19***					1			
5	**Wood and products of wood and cork**	***20***			1					
6	**Pulp, paper, paper products, printing and publishing**	***21,22***			1					
7	**Coke, refined petroleum products and nuclear fuel**	***23***			1					
8	**Chemicals and chemical products**	***24***			1					
9	**Rubber and plastics products**	***25***			1					
10	**Other non-metallic mineral products**	***26***			1					
11	**Basic metals**	***27***			1					
12	**Fabricated metal products**	***28***			1					
13	**Machinery and equipment, nec**	***29***				1				
14	**Computer, Electronic and optical equipment**	***30,32,33***				1				
15	**Electrical machinery and apparatus, nec**	***31***				1				
16	**Motor vehicles, trailers and semi-trailers**	***34***				1				
17	**Other transport equipment**	***35***				1				
18	**Manufacturing nec; recycling**	***36,37***					1			
19	**Electricity, gas and water supply**	***40,41***						1		
20	**Construction**	***45***							1	
21	**Wholesale and retail trade; repairs**	***50,51,52***								1
22	**Hotels and restaurants**	***55***								1
23	**Transport and storage**	***60,61,62,63***								1
24	**Post and telecommunications**	***64***								1
25	**Financial intermediation**	***65,66,67***								1
26	**Real estate activities**	***70***								1
27	**Renting of machinery and equipment**	***71***								1
28	**Computer and related activities**	***72***								1
29	**R&D and other business activities**	***73,74***								1
30	**Public admin. and defence; compulsory social security**	***75***								1
31	**Education**	***80***								1
32	**Health and social work**	***85***								1
33	**Other community, social and personal services**	***90,91,92,93***								1
34	**Private households with employed persons**	***95***								1

3.3.2 Regional extended ICIO

The REX-ICIO database is estimated using the methodology and data sources described in the previous sections. Some strict constraints on exports and imports have been relaxed to gain the balanced figures in the numerical optimization procedures. Table 3.8 and Table 3.9 show the descriptive statistics from the estimated REX-ICIO for 2005. As expected, the industrial structures vary across regions. The value added to output ratios for Chubu (47.7%) and Chugoku (47.7%) are relatively low due the concentration of manufacturing industrial activities. The shares of manufacturing output in total output are between 9.0% (Okinawa) to 48.4% (Chubu). The national average of manufacturing share is similar to the ones for the current members of European Union (EU28) and the rest of the world.

Table 3.8: Sectoral value added by Japanese region (2005)

	Hokkaido	Tohoku	Kanto	Chubu	Kinki	Chugoku	Shikoku	Kyushu	Okinawa
Value added (Million USD)									
Agriculture	8.7	8.0	13.8	5.0	3.6	3.3	3.0	9.6	0.4
Mining and quarrying	0.3	0.4	1.3	0.3	0.3	0.2	0.2	0.5	0.1
Material manuf.	11.1	19.8	149.7	64.0	72.2	39.2	14.0	25.6	1.0
Machinery and equipment	2.0	21.9	149.1	87.2	58.7	24.8	6.3	22.4	0.1
Other manuf.	5.6	12.7	57.8	20.9	27.1	8.8	3.9	16.1	0.8
Electricity, Gas and Water Supply	4.0	14.2	49.9	17.0	24.8	7.9	4.1	12.9	1.0
Construction	11.8	18.9	111.0	30.0	42.6	14.6	8.3	23.4	2.7
Services	130.8	188.9	1451.8	310.2	519.0	168.5	84.8	282.4	24.8
Total	174.3	284.8	1984.4	534.6	748.3	267.3	124.6	392.9	30.9
Output (Million USD)									
Agriculture	17.3	16.7	27.7	9.9	6.6	6.3	6.2	21.3	0.9
Mining and quarrying	0.8	0.9	3.2	1.0	0.8	0.6	0.4	1.1	0.2
Material manuf.	28.6	51.7	447.5	188.5	210.0	141.6	43.3	79.3	2.6
Machinery and equipment	5.4	63.5	474.7	297.8	164.1	83.8	16.8	71.3	0.2
Other manuf.	21.0	34.1	157.6	56.5	72.2	24.6	11.4	44.7	1.9
Electricity, Gas and Water Supply	9.4	28.1	96.2	32.0	45.6	17.3	7.8	23.5	2.3
Construction	26.3	41.0	240.0	65.9	91.9	32.8	18.1	50.5	5.8
Services	199.0	283.9	2261.9	469.2	790.8	254.2	128.8	428.2	38.5
Total	307.8	519.9	3708.8	1120.8	1382.0	561.2	232.8	719.9	52.4
Value added sectoral share									
Agriculture	5.6%	3.2%	0.7%	0.9%	0.5%	1.1%	2.7%	3.0%	1.7%
Mining and quarrying	0.3%	0.2%	0.1%	0.1%	0.1%	0.1%	0.2%	0.2%	0.4%
Material manuf.	9.3%	9.9%	12.1%	16.8%	15.2%	25.2%	18.6%	11.0%	5.0%
Machinery and equipment	1.8%	12.2%	12.8%	26.6%	11.9%	14.9%	7.2%	9.9%	0.4%
Other manuf.	6.8%	6.6%	4.2%	5.0%	5.2%	4.4%	4.9%	6.2%	3.6%
Electricity, Gas and Water Supply	3.1%	5.4%	2.6%	2.9%	3.3%	3.1%	3.4%	3.3%	4.4%
Construction	8.5%	7.9%	6.5%	5.9%	6.6%	5.8%	7.8%	7.0%	11.1%
Services	64.7%	54.6%	61.0%	41.9%	57.2%	45.3%	55.3%	59.5%	73.5%
Value added / Output (%)									
Agriculture	50%	48%	50%	50%	55%	53%	48%	45%	49%
Mining and quarrying	43%	42%	41%	33%	38%	39%	42%	41%	40%
Material manuf.	39%	38%	33%	34%	34%	28%	32%	32%	40%
Machinery and equipment	37%	35%	31%	29%	36%	30%	38%	31%	39%
Other manuf.	27%	37%	37%	37%	38%	36%	35%	36%	42%
Electricity, Gas and Water Supply	43%	51%	52%	53%	54%	46%	52%	55%	43%
Construction	45%	46%	46%	46%	46%	44%	46%	46%	46%
Services	66%	67%	64%	66%	66%	66%	66%	66%	64%
Total	57%	55%	54%	48%	54%	48%	54%	55%	59%

Sources: OECD Inter-Country Input-Output 2015ed, METI 2005 Inter-Regional Input-Output

Table 3.9 : Descriptive statistics for REX ICIO 2015

REX ICIO regions		Output (2005) Billion USD	of which Primary* (%)	of which Manuf. (%)	Exports** (2005) Billion USD	Exports to Output ratio (%)	VA to Output ratio (%)
JAPAN	Hokkaido	308	5.9	17.9	9	3.0	56.6
	Tohoku	520	3.4	28.7	32	6.2	54.8
	Kanto	3709	0.8	29.1	252	6.8	53.5
	Chubu	1121	1.0	48.4	126	11.2	47.7
	Kinki	1382	0.5	32.3	100	7.3	54.1
	Chugoku	561	1.2	44.5	51	9.1	47.7
	Shikoku	233	2.8	30.7	17	7.1	53.5
	Kyushu	720	3.1	27.1	65	9.0	54.6
	Okinawa	52	1.9	9.0	2	4.3	59.0
Japan	Total	8608	1.4	32.5	654	7.6	52.8
China, PR		6559	11.1	49.6	795	12.1	34.4
United States		21618	2.9	21.8	1201	5.6	54.1
European Union 28		25730	2.6	28.3	1717	6.7	48.0
The rest of the world		23630	11.6	31.1	2848	12.1	49.5

* Agriculture and Mining
** Only exports to foreign destinations; intra-regional flows are excluded (intra-EU28 and intra-RoW).
Sources: OECD (2015) 2010 ICIO, METI (2011) 2005 IRIO

3.3.3 Participation in global value chains of Japanese regions

The inter-industry input structures of Japanese regions (Table 3.10) indicate that larger foreign economies, i.e., United States (USA), People's Republic of China (China, PR) and European Union (EU28) are important sources of intermediate products in all regions. The shares of intermediate imports from foreign countries in total intermediate inputs vary from 8.3% to 14.2%. The intermediate suppliers in Japanese regions are, therefore, competing not only with domestic regions but also with foreign suppliers.

Table 3.10: Input structures of regions (total input = 100, 2005)

	JPN_ Hokkaido	JPN_ Tohoku	JPN_ Kanto	JPN_ Chubu	JPN_ Kinki	JPN_ Chugoku	JPN_ Shikoku	JPN_ Kyushu	JPN_ Okinawa
JPN_Hokkaido	0.273	0.008	0.004	0.004	0.003	0.002	0.001	0.002	0.001
JPN_Tohoku	0.009	0.252	0.012	0.006	0.005	0.004	0.004	0.004	0.002
JPN_Kanto	0.062	0.097	0.352	0.085	0.050	0.057	0.062	0.057	0.042
JPN_Chubu	0.014	0.020	0.020	0.314	0.030	0.024	0.021	0.022	0.017
JPN_Kinki	0.014	0.017	0.018	0.038	0.298	0.038	0.044	0.025	0.018
JPN_Chugoku	0.006	0.006	0.007	0.014	0.016	0.300	0.027	0.021	0.010
JPN_Shikoku	0.002	0.003	0.003	0.005	0.007	0.010	0.226	0.006	0.002
JPN_Kyushu	0.004	0.005	0.006	0.008	0.010	0.018	0.013	0.275	0.020
JPN_Okinawa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.263
China, PR	0.006	0.007	0.006	0.007	0.006	0.007	0.006	0.006	0.003
United States	0.007	0.008	0.006	0.007	0.006	0.007	0.007	0.007	0.003
EU28	0.005	0.007	0.006	0.007	0.005	0.007	0.006	0.006	0.002
Rest of the world	0.030	0.022	0.023	0.028	0.021	0.047	0.047	0.021	0.026
Taxes less subsidies	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.001	0.001
Value added	0.566	0.548	0.535	0.477	0.541	0.477	0.535	0.546	0.590
Output	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

The roles of regions in production networks can be also examined by the sales structures of output coefficients. While the intermediate transactions within the regions are relatively higher for the larger industrial regions i.e. Kanto, Chubu and Kinki, the shares of production for household consumption expenditures are relatively high for the peripheral smaller regions i.e. e.g. Hokkaido (52.8%), Kyushu (48.1%) and Okinawa (59.4%).

Applying calculation methods similar to TiVA indicators (OECD-WTO, 2012); the REX-ICIO system allows various analytical indicators of direct and indirect economic relationship between countries and regions to be generated. The indicators specifically measured in this paper are based on the origin of value added embodied in final demand:

$$\text{FDVA}^{\text{rs}} = \sum \frac{V^r}{X^r} B^{rs} FD^s, , r \neq s \quad \textbf{(3.34)}$$

where FDVA^{rs} is the value added generated by region r embodied in the final demand of region (or foreign country) s, V^r and x^r are the vectors of value added and output of region r respectively and B^{rs} is the part of global Leontief inverse matrix covering output of region r meeting demand of region s, FD^s is the final expenditures demand in region s (other Japanese regions and foreign economies).

Direct and indirect exports by sector

The largest exporter in the 8-sector category (Annex Table B) is "Manufacture of machinery and equipment," a group of downstream industries (electronics and motor vehicles) in the manufacturing sector for Japan. For this group, international exports are significantly higher than interregional transactions. Meanwhile, higher shares of "domestic exports" are observed for upstream industries e.g. material manufacturing products and business services (Table 3.12). These differences suggest that the cross-border activities of material manufacturing and services are lower and these sectors are indirectly supporting international export activities.

The trade flows in value added terms shown in Table 3.12 also provide a different perspective on sectoral exports compared to the conventional gross exports flows. On average, more than half of the regional value added is created in services sectors while the dominant exported products for most regions are goods sectors in the gross exports flows. The services sectors such as distribution, communication and business services are indirectly integrated in the regional and global supply chains.

Bilateral trade flows

The bilateral export partner shares of Figure 3.9 show that the destination shares of value added-based exports are higher than conventional gross exports shares for the United States and the EU28. These differences in partner shares indicate that the intermediate upstream goods and services products are first exported to immediate domestic neighbors and the products are transformed to other forms of the intermediate and final products and eventually exported and consumed in foreign economies. A similar pattern of indirect exports is observed in the national total figures of TiVA indicators (OECD 2015, Trade in Value Added indicators). Japan exports intermediate products, particularly machinery components, chemicals and basic metals, to neighboring East and South Eastern Asian countries to be used in production by the immediate importers e.g., by their transport equipment and electronics machinery and equipment industries.

Imported value added by source region and country

As can be seen, the shares of international imports vary across regions from 8.3% to 14.2%. The pattern of foreign value added penetration in the final demand-based estimates (Table 3.13) shows that the levels of foreign value added penetration ratios are quite uniform across regions (8.5% to 11.7%). The differences of patterns in value added sources are more observed in the backward linkages in the domestic sources (See the examples of two medium size economies in Figure 3.8).

Table 3.11: Destinations of regional output

output coefficient (destinations of products)

	Intermediate												
	JPN_ Hokkaido	JPN_ Tohoku	JPN_ Kanto	JPN_ Chubu	JPN_ Kinki	JPN_ Chugoku	JPN_ Shikoku	JPN_ Kyushu	JPN_ Okinawa	CHN	USA	EU28	ROW
JPN_Hokkaido	0.273	0.013	0.051	0.014	0.014	0.003	0.001	0.004	0.000	0.003	0.003	0.003	0.007
JPN_Tohoku	0.005	0.252	0.085	0.014	0.014	0.005	0.002	0.006	0.000	0.008	0.008	0.005	0.016
JPN_Kanto	0.005	0.014	0.352	0.026	0.019	0.009	0.004	0.011	0.001	0.009	0.008	0.006	0.019
JPN_Chubu	0.004	0.009	0.066	0.314	0.037	0.012	0.004	0.014	0.001	0.014	0.014	0.009	0.030
JPN_Kinki	0.003	0.006	0.048	0.031	0.298	0.015	0.007	0.013	0.001	0.010	0.009	0.006	0.021
JPN_Chugoku	0.003	0.006	0.047	0.027	0.040	0.300	0.011	0.028	0.001	0.013	0.011	0.007	0.029
JPN_Shikoku	0.003	0.006	0.054	0.023	0.039	0.023	0.226	0.018	0.000	0.010	0.009	0.006	0.022
JPN_Kyushu	0.002	0.004	0.030	0.013	0.018	0.014	0.004	0.275	0.001	0.012	0.011	0.007	0.025
JPN_Okinawa	0.000	0.001	0.024	0.004	0.011	0.003	0.000	0.010	0.263	0.004	0.004	0.003	0.009

	Final demand													Out put
	JPN_ Hokkaido	JPN_ Tohoku	JPN_ Kanto	JPN_ Chubu	JPN_ Kinki	JPN_ Chugoku	JPN_ Shikoku	JPN_ Kyushu	JPN_ Okinawa	CHN	USA	EU28	ROW	
JPN_Hokkaido	0.528	0.007	0.039	0.008	0.010	0.002	0.001	0.002	0.000	0.001	0.004	0.002	0.006	1.000
JPN_Tohoku	0.007	0.447	0.071	0.010	0.011	0.003	0.001	0.005	0.000	0.003	0.007	0.004	0.011	1.000
JPN_Kanto	0.005	0.011	0.428	0.016	0.015	0.006	0.003	0.008	0.001	0.003	0.008	0.005	0.012	1.000
JPN_Chubu	0.005	0.007	0.050	0.315	0.027	0.007	0.004	0.010	0.001	0.005	0.014	0.008	0.020	1.000
JPN_Kinki	0.004	0.005	0.036	0.021	0.413	0.010	0.006	0.011	0.001	0.003	0.008	0.005	0.012	1.000
JPN_Chugoku	0.003	0.004	0.030	0.011	0.022	0.352	0.007	0.017	0.001	0.003	0.009	0.005	0.014	1.000
JPN_Shikoku	0.001	0.003	0.027	0.011	0.025	0.015	0.445	0.010	0.000	0.002	0.007	0.004	0.011	1.000
JPN_Kyushu	0.001	0.003	0.025	0.010	0.015	0.011	0.003	0.481	0.001	0.004	0.010	0.006	0.016	1.000
JPN_Okinawa	0.001	0.001	0.028	0.005	0.008	0.000	0.000	0.005	0.594	0.004	0.006	0.003	0.010	1.000

Table 3.12: Exports to other domestic regions and foreign countries (sectors share, %)

	Japan		Hokkaido		Tohoku		Kanto		Chubu		Kinki		Chugoku		Shikoku		Kyushu	
	Dom	Intl	Dom	Intl	Dom	Intl	Dom	Intl	Dom	Intl	Dom	Intl	Dom	Intl	Dom	Intl	Dom	Intl
Agriculture	1%	0%	9%	0%	3%	0%	1%	0%	1%	0%	1%	0%	1%	0%	3%	0%	3%	0%
Mining and quarrying	0%	0%	1%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Material manufacturing	14%	16%	19%	4%	10%	11%	12%	13%	17%	13%	15%	20%	25%	32%	18%	27%	11%	15%
Machinery and equipment	11%	49%	3%	4%	10%	48%	10%	47%	21%	66%	9%	44%	12%	43%	5%	37%	6%	52%
Other manuf.	5%	2%	10%	1%	7%	2%	4%	2%	5%	3%	5%	3%	5%	3%	5%	1%	6%	4%
Electricity, Gas and Water Supply	3%	0%	4%	0%	6%	0%	3%	0%	3%	0%	4%	0%	3%	0%	4%	0%	4%	0%
Construction	7%	0%	1%	1%	8%	0%	7%	0%	7%	0%	7%	0%	6%	0%	8%	0%	8%	0%
Services	58%	32%	53%	86%	56%	39%	63%	37%	45%	18%	59%	33%	48%	22%	57%	33%	63%	28%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Total(Billion USD)	7747	654	130	9	484	32	3438	252	990	126	1276	100	508	51	216	17	654	65

Table 3.13: Value added created by regional final demand (% of total regional demand)

		Final demand region									
		JAPAN	Hokkaido	Tohoku	Kanto	Chubu	Kinki	Chugoku	Shikoku	Kyushu	Okinawa
VA	JAPAN (total)	88.8	88.6	89.3	88.6	88.3	89.5	88.1	88.5	89.3	91.5
source	Hokkaido	3.7	63.3	1.3	1.0	0.8	0.7	0.5	0.3	0.4	0.3
	Tohoku	5.7	2.2	59.2	2.5	1.5	1.2	1.1	0.9	1.0	0.6
	Kanto	39.1	13.7	19.1	74.0	17.2	11.7	13.2	13.4	11.7	10.7
	Chubu	9.8	3.3	3.4	3.8	56.8	5.2	4.1	4.2	3.5	4.4
	Kinki	14.7	3.6	3.6	3.9	7.5	65.2	7.1	7.9	5.0	3.7
	Chugoku	5.1	1.2	1.2	1.4	1.8	2.3	56.8	3.6	3.0	1.6
	Shikoku	2.5	0.4	0.5	0.6	0.8	1.1	1.6	56.1	0.8	0.4
	Kyushu	7.7	0.9	1.1	1.4	1.8	2.0	3.7	2.1	63.9	2.7
	Okinawa	0.6	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.1	67.0
	China PR	1.7	1.7	1.6	1.7	1.7	1.6	1.6	1.6	1.6	0.9
	USA	2.0	2.0	2.0	2.1	2.1	1.9	2.0	1.9	2.0	1.1
	EU28	1.8	1.7	1.8	1.9	1.9	1.8	1.8	1.8	1.8	1.1
	RoW	5.6	6.1	5.3	5.6	5.9	5.2	6.4	6.2	5.4	5.4
Foreign	share (%)	11.1%	11.5%	10.7%	11.3%	11.6%	10.5%	11.8%	11.5%	10.8%	8.5%

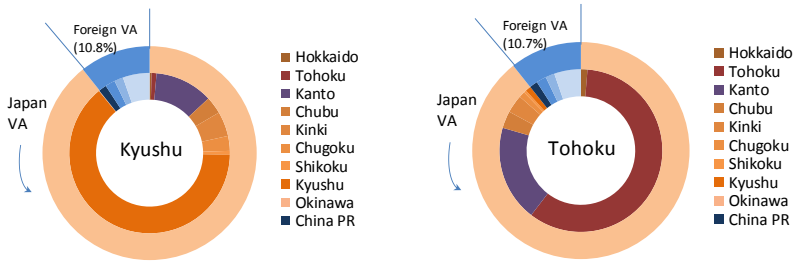


Figure 3.8: Domestic and foreign value added sources embodied in regional final demand

(Tohoku and Kyushu, 2005)

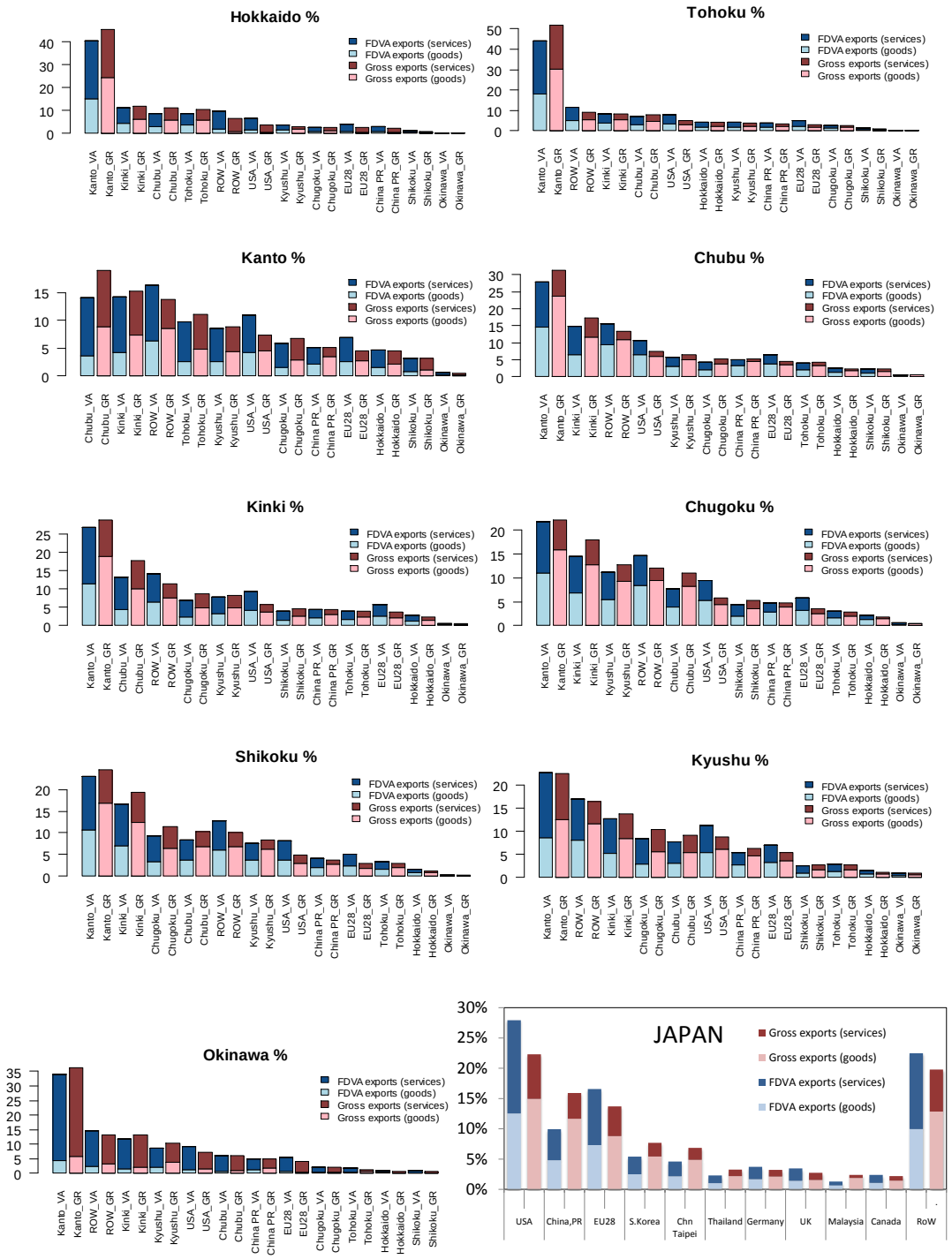


Figure 3.9 : Exports destination shares in value added (FDVA) and gross exports (GR) terms

3.4 SUMMARY

The methodology developed in this chapter takes a general approach to compile an integrated database of interregional and inter-country Input-Output system (REX-ICIO) from various regional data sources in different format. The procedure first starts with the harmonization of data sources. Industry and regional classifications are converted to a standard list and the price definitions are adjusted. Then, the intermediate and final expenditure items are balanced for domestic transactions within the target country. The last steps of the procedure are to balance the exports and imports of all regions with the "Rest of the World." The REX-ICIO database of Japanese regions for 2005 are developed using the interregional input-output table and regional customs trade statistics as a "proof of concept" case study. To the author's knowledge, the integration of Japanese IRIO and National Accounts compatible global-scale ICIO with regional customs merchandise trade statistics is the first study to complete this task.

The developed REX-ICIO for Japan (JPN-REX-ICIO) provides various opportunities for enhanced regional economic analysis. The model, specifically, allows the development of unique indicators to measure interregional connectedness and the interconnectedness of Japanese regions with the rest the world. The participation of regional economies in global value chains (GVCs) are confirmed both from direct and indirect routes in the production networks. The notable finding compared to ordinary ICIO analysis in this study is that the roles of industry hierarchy of economically small regions are different from some of the smaller countries in ICIO. This could also suggest that the ordinary distance decay setting of gravity models may not work in the multi-industry analytical frameworks because the physical distances to immediate neighbors are relatively irrelevant compared to the economic ties between regions and countries.

Further extensions of the REX-ICIO model can even enhance the capability of the model beyond trade linkage analysis. The integration with land transportation network information can further improve the "true" destinations and origins of products produced and source by regions. In particularly, the development of highways connecting to major airports and maritime ports have increased the logistics options of manufacturing producers' to optimize their transportation cost management.

Other extensions are considered for social issues such as regional pollution, jobs and innovation accumulation are priority policy issues in most regions. Appropriate satellite accounts could be linked to the industrial structures of this REX-ICIO analytical framework to provide new insights to inform regional policy.

CHAPTER 4 : FIRM HETEROGENEITY EXTENDED INTER-COUNTRY INPUT-OUTPUT MODEL FOR AN INTER-CONNECTEDNESS ANALYSIS

4.1 INTRODUCTION

Many global value chains (GVCs) analyses using a global Inter-country Input-Output (ICIO) model have become available in recent years (Johnson and Noguera, 2012; Koopman *et al*., 2013; OECD-WTO, 2013, 2015 and 2016; European Commission, 2015; Stehrer, 2013). TiVA related indicators estimated in these studies have emphasized the usefulness of an ICIO database for analyses of globally fragmented production processes. The main conclusions include 1) alternative views on bilateral trade balances, 2) indirect involvements of non-trading industries e.g. SMEs and supporting services companies for exporting industries and 3) high fragmentation of manufacturing processes particularly for motor vehicles and electronics equipment industries.

However, it is well known that the firms intensively involved in international trade have different production structures compared to firms whose products are destined mainly for the domestic market (household consumption and capital formation by industries). One of the reasons for different production structures by firm characteristics can be attributed to the activities of multinational enterprises (MNEs) operating in the export processing zones. Multinational enterprises play dominant roles in coordination of international fragmented production networks (Arndt and Kierzkowski, 2001) in addition to conventional trade managed in intra-firm and arm's-length trade relationships (Sturgeon and Kawakami, 2011; Gereffi and Lee, 2012). For example in certain economies (People's Republic of China, Costa Rica and Mexico), a majority of exported electronics products are manufactured in trade processing zones and their dependencies on imported intermediates are much higher than domestic-sales

companies. Also, the labor-intensive manufacturing processes are apparent in the firms in export processing zones.

While the international fragmentation of production processes has been observed in many countries, most of the industrial economic statistics and standard tools are still insufficient for policy planners to understand how their domestic firms are positioned along GVCs (Sturgeon and Gereffi, 2008). Recently, some institutions are now able to provide extended information on firm heterogeneity within manufacturing industries in an input-output framework (Chinese Academy of Science for China 2007, Banco Central de Costa Rica for Costa Rica 2011 and INEGI for Mexico 2008).

Due to confidentiality issues, disaggregated industrial information can be only estimated by collaborations among different national statistics agencies using micro data from customs office, central bank and economic census bureau. In general, export oriented sectors have lower value added - output ratios (Table 4.1) and higher dependency on imported intermediate supplies and labor-intensive sectors.

This chapter aims to develop a methodology to integrate the firm heterogeneity extended national IO with the global Inter-country IO system. This chapter also aims to develop annual time series data rather than a limited number of data points. As discussed earlier in chapter 1, many policy analyses requires multi-year annual databases and the unique technique applied in this chapter contributes to integrate the annual ICIO and customs trade data with national firm heterogeneity I-O tables that are often only available for benchmark years (e.g. China for 2007 and Mexico for 2008).

A similar methodology to integrate an interregional IO table (intra-country) with a country-based Inter-country IO (ICIO) in the previous chapter can be applied here. Schematic representations of the 3-country 2-industry inter-country input-output database, firm heterogeneity extended national input-output table and firm heterogeneity extended ICIO are respectively presented in Figure 4.1, Figure 4.2 and Figure 4.3. When the national tables are actually integrated with the country-aggregate ICIO, the import rows are expanded to import matrices. In the case of China, since the customs data are available for different firm group (domestic, processing exporters and non-processing exporters), the different column constraints (products imported by different firm group) are available to improve the quality of the import matrices.

Table 4.1 : Firm heterogeneity within manufacturing industry (China, Costa Rica and Mexico)

	Value added - output share (%)	Exports share of manuf. production (%)	Production share of % of manufacturing
China, PR (2007)			
Total	21.1	100	100
Non-exporters	20.7	0.6*	61.4
Processing exporters	15.3	53.5	10.3
Non-processing exporters	23.9	46.0	28.2
Costa Rica (2011)			
Total	31.8	100	100
Processing exporters	20.9	62.3	26.0
Non-processing exporters	35.6	37.7	74.0
Mexico (2008)			
Total	32.7	100	100
Global manufacturers	18.8	66.1	21.8
Domestic firms	36.5	33.9	78.2

* non-exporters export to inbound non-residents in domestic territory

Sources: Chinese Academy of Science, Banco Central de Costa Rica and INEGI, Mexico

This chapter proceeds as follows: The methodology to integrate firm heterogeneity extended ICIO (FHEX-ICIO) is described in the next section. The third section presents the procedure applied to reconcile the data sources of target countries (China and Mexico). The fourth section compares the FHEX-ICIO with an original country aggregate ICIO and the last section is summary.

Inter-country I-O		Intermediate demand						Final expenditure			Output
		Cou A		Cou B		Cou C		Cou A	Cou B	Cou C	
		Ind 1	Ind 2	Ind 1	Ind 2	Ind 1	Ind 2				
Country A	Industry 1	Z(AA11)	Z(AA12)	Z(AB11)	Z(AB12)	Z(AC11)	Z(AC12)	FE(AA1)	FE(AB1)	FE(AC1)	X(A1)
	Industry 2	Z(AA21)	Z(AA22)	Z(AB21)	Z(AB22)	Z(AC21)	Z(AC22)	FE(AA2)	FE(AB2)	FE(AC2)	X(A2)
Country B	Industry 1	Z(BA11)	Z(BA12)	Z(BB11)	Z(BB12)	Z(BC11)	Z(BC12)	FE(BA1)	FE(BB1)	FE(BC1)	X(B1)
	Industry 2	Z(BA21)	Z(BA22)	Z(BB21)	Z(BB22)	Z(BC21)	Z(BC22)	FE(BA2)	FE(BB2)	FE(BC2)	X(B2)
Country C	Industry 1	Z(CA11)	Z(CA12)	Z(CB11)	Z(CB12)	Z(CC11)	Z(CC12)	FE(CA1)	FE(CB1)	FE(CC1)	X(C1)
	Industry 2	Z(CA21)	Z(CA22)	Z(CB21)	Z(CB22)	Z(CC21)	Z(CC22)	FE(CA2)	FE(CB2)	FE(CC2)	X(C2)
Taxes less subsidies on intermediate and final products		NTZA1	NTZA2	NTZB1	NTZB2	NTZC1	NTZC2	FEA	FEB	FEC	
Value-added		V(A1)	V(A2)	V(B1)	V(B2)	V(C1)	V(C2)				
Output at basic prices		X(A1)	X(A2)	X(B1)	X(B2)	X(C1)	X(C2)				

Figure 4.1 : Inter-Country Input-Output Database (example of 3 countries and 2 industries world)

		Intermediate demand				Final expenditure		Output
		Agriculture	Manufacturing		Services	Domestic	Exports	
			[P]	[N]				
Agriculture							*	XA
Manu	[Processing]	na	na	na	na	na	*	XMP
facturing	[Non-processing]						*	XMN
Services							*	XS
Imports		***	***	***	***	***	**	
Taxes less subsidies on intermediate and final products								
Value-added		VA	VMP	XMN	VS			
Output at basic prices		XA	XMP	XMN	XS			

na: no value by definition, * re-exports are not included here, ** re-exports, *** includes re-imports

Figure 4.2 : Firm heterogeneity national input output database

Firm Heterogeneity Extended Inter-country I-O	Intermediate demand							Final expenditure			Output
	Cou A		Cou B		Cou C			Cou A	Cou B	Cou C	
	Ind 1	Ind 2	Ind 1	Ind 2	Ind 1[P]	Ind 1[N]	Ind 2				
Country A Industry 1	Z(A1A1)	Z(A1A2)	Z(A1B1)	Z(A1B2)	Z(A1C1p)	Z(A1C1n)	Z(A1C2)	F(A1A)	F(A1B)	F(A1C)	X(A1)
Industry 2	Z(A2A1)	Z(A2A2)	Z(A2B1)	Z(A2B2)	Z(A2C1p)	Z(A2C1n)	Z(A2C2)	F(A2A)	F(A2B)	F(A2C)	X(A2)
Country B Industry 1	Z(B1A1)	Z(B1A2)	Z(B1B1)	Z(B1B2)	Z(B1C1p)	Z(B1C1n)	Z(B1C2)	F(B1A)	F(B1B)	F(B1C)	X(B1)
Industry 2	Z(B2A1)	Z(B2A2)	Z(B2B1)	Z(B2B2)	Z(B2C1p)	Z(B2C1n)	Z(B2C2)	F(B2A)	F(B2B)	F(B2C)	X(B2)
Country C Industry 1[P]	Z(C1pA1)	Z(C1pA2)	Z(C1pB1)	Z(C1pB2)	na	na	na	F(C1pA)	F(C1pB)	na	X(C1P)
Industry 1[N]	Z(C1nA1)	Z(C1nA2)	Z(C1nB1)	Z(C1nB2)	Z(C1nC1p)	Z(C1nC1n)	Z(C1nC2)	F(C1nA)	F(C1nB)	F(C1nC)	X(C1N)
Industry 2	Z(C2A1)	Z(C2A2)	Z(C2B1)	Z(C2B2)	Z(C2C1p)	Z(C2C1n)	Z(C2C2)	F(C2A)	F(C2B)	F(C2C)	X(C2)
Taxes less subsidies on intermediate and final	NTZA1	NTZA2	NTZB1	NTZB2	NTZC1P	NTZC1N	NTZC2	FA	FB	FC	
Value-added	V(A1)	V(A2)	V(B1)	V(B2)	V(C1P)	V(C1N)	V(C2)				
Output at basic prices	X(A1)	X(A2)	X(B1)	X(B2)	X(C1P)	X(C1N)	X(C2)				

Figure 4.3 : Firm heterogeneity extended Inter-Country Input-Output Database

4.2 METHODOLOGY

The methodology of integrating a global ICIO and a national firm heterogeneity extended IO involves procedures of data collection, reconciliation of national IOs and splitting the aggregated transaction flows of ICIO to different firm types with multiple constraints and assumptions. The data sources required in this analysis to integrate a country-based ICIO and firm heterogeneity production structures are summarized as follows.

1) Global scale ICIO table such as the one estimated in previous chapter

2) Firm heterogeneity split national input-output tables

3) If firm heterogeneity split IO is not available, customs trade statistics and balance of payments statistics can complement the missing industrial activity information

4.2.1 Firm heterogeneity incorporated national IO table

The national heterogeneity split national IO table is first re-balanced using the constraints of domestic inter-industry transactions and international exports and imports by sector from a

reference ICIO table. Besides distinguishing between exporters and non-exporters, other splits of firm types can be considered such as foreign/domestic-owned firms, large/small firms and multinational/non-multinational enterprises. See Figure 4.4 for a schematic representation of the processing exporters and non-processing exporters split example.

		Intermediate demand				Final expenditure				Output
		Agriculture	Manufacturing [P]	Manufacturing [N]	Services	Domestic	Direct purchases abroad by residends	Direct purchases by non-residents	Cross border exports	
Domestic	Agriculture						***		*	XA
Domestic	MA-P	**	**	**	**	**	***	**	*	XMP
Domestic	MA-NP						***		*	XMN
Domestic	Services						***		*	XS
Imports	Agriculture								na	
Imports	Manufacturing								na	
Imports	Services								na	
Taxes less subsidies on intermediate and final products										
Value-added		VA	VMP	XMN	VS					
Output at basic prices		XA	XMP	XMN	XS					

* re-exports and re-imports are not included here
** re-imports of products produced in export processing zones
*** direct purchases abroad by residents on originally exported final products from domestic industries
MA-P : Manufacturing processing trade
MA-NP : Manufacturing processing trade
na: no value by definition

Figure 4.4 : ICIO benchmarked firm heterogeneity national Input-Output Database

(3 aggregated industries and 2 firm types for manufacturing sector)

The output, value added, trade flows and domestic expenditure items are rescaled according to country total figures from the country aggregated ICIO table (Equations 4.1 to 4.5). The notation * indicates the constraint variables from the country aggregate ICIO. This rebalancing procedure includes the conversion of price valuation to basic prices, harmonization of industry classification, reconciliation of the expenditure items of final demand, estimation of

import matrix, removal of re-exports and shifting re-imports to domestic transactions. Since national firm heterogeneity IO is usually only available in a product-by-product format, the interindustry intermediate transactions are converted to industry-by-industry format using the product supply ratios from the supply table i.e. DZD, where Z is product-by-product domestic transaction of national IO and D is a matrix of product supply ratios.

Output and value added are constrained by the country aggregate ICIO as

Output constraints: $XA^*(i) = XA(ip) + XA(in)$ **(4.1)**

and

Value added constraints: $VA^*(i) = VA(ip) + VA(in)$ **(4.2)**

where $XA^*(i)$ and $VA^*(i)$ are output and value added of industry i in country A respectively in ICIO database, of which, *XA(ip)* and *VA(ip)* are those for processing exporters and *XA(in)* and *VA(in)* are those for non-processing exporters respectively.

By definition, products produced by processing exporters are not consumed within domestic territory, so only the non-processing trade sectors produce goods for consumption of non-residents in domestic territory.

$XA_{ip} = EX_{ipA}$ **(4.3)**

where XA_{ip} is production of processing trade industry and EX_{ipA} is exports of products produced in country A's processing trade industry.

The exports and imports flows in national IO tables must be explicitly separated into direct purchases and cross-border trade flows in the ICIO framework. Thus, the exports and imports of firm heterogeneity IO are defined as follows.

Cross-border export constraints: $\sum_c EX^*(A,c,i) = EX(A,ip) + EX(A,in)$ **(4.4)**

Cross-border import constraints: $\sum_c IMZ^*(A,c,j) = IMZ(A,jp) + IMZ(A,jn)$ **(4.5)**

Where $EX^*(A,c,i)$ is exports of products from industry i of country A to country C, $EX(A,ip)$ and $EX(A,in)$are the cross-border exports from processing exporters and non-processing exports. Similarly, $IMZ^*(A,c,j)$ is the variable for intermediate imports by industry j of country A in ICIO and $IMZ(A,jp)$ and $IMZ(A,jn)$ are the intermediate imports by processing exporters and non-processing exporters.

Direct purchases of non-residents in country A's territory are constrained as

$$\sum_c DP^*(A,c,i) = DP(A,in) \quad \textbf{(4.6)}$$

where $DP^*(A,c,i)$ is direct purchases of product i in country A by Country C's residents and *DP(A,in)* is direct purchases of product *i* by all non-residents in Country *A*.

The constraint for domestic final expenditures is given as:

$$FA^{*}(i) = FA(in) \quad \textbf{(4.7)}$$

where $FA^{*}(i)$ is final demand expenditure for industry *i* products in country *A* in ICIO and $FA(in)$ is the final demand expenditures in country *A* of products produced by non-processing trade industries.

The methodology to re-balance the firm heterogeneity national IO to an ICIO compatible table can be estimated by a RAS variant biproportional adjustment methodology such as GRAS methodology (Junius and Oosterhaven, 2003; Temurshoev *et al*., 2013).

4.2.2 Balancing international trade flows by firm characterizes

In the previous section, the trade flows in the national firm heterogeneity extended IO (FHIO) are fully reconciled with the trade flows derived from an ICIO table. The main adjustments include removal of re-exports and re-imports from the exports and imports flows in the national IO and conversion of imports data from c.i.f. at purchasers' prices to f.o.b. at basic prices of products origin countries. The remaining adjustments are trade flows of intermediate matrix.

The intermediate exports between split target country *A* and a trade partner country *c* is the sum of exports from the processing exporters and non-processing exporters defined as

$$\mathrm{Z}_{\mathrm{ij}}^{\mathrm{Ac}} = Z_{ip,j}^{AC} + Z_{in,j}^{Ac} \quad \textbf{(4.8)}$$

where Z_{ij}^{Ac} is intermediate exports of product *i* from country *A* to country *c*'s industry *j* in ICIO table, $Z_{ip,j}^{AC}$ is intermediate exports from processing exporters and $Z_{in,j}^{Ac}$ is intermediate exports from non-processing exporters.

The initial values for the bilateral trade flows for intermediate and final products for processing exporters and non-processing exports are given from the trade partner shares calculated from an ICIO.

The final products trade is also the sum of exports from processing and non-processing exports written as:

$$F_i^{AC} = F_{ip}^{AC} + F_{in}^{Ac} \quad \textbf{(4.9)}$$

where F_i^{AC} is final product *i*'s trade between countries *A* and *c* in ICIO, F_{ip}^{AC} is final exports from processing exporters and F_{in}^{Ac} is final exports from non-processing exporters.

The exports from country *A* to all partners are constrained to the FHIO's exports constraints as

$$EX_{ip,A} = \sum_j \sum_c Z_{ip}, j^{AC} + \sum_c F_{ip}^{AC} \quad \textbf{(4.10)}$$

and

$$EX_{in,A} = \sum_j \sum_c Z_{in}, j^{AC} + \sum_c F_{in}^{AC} \quad \textbf{(4.11)}$$

where $EX_{ip,A}$ is exports from processing exporters and $EX_{in,A}$ is exports from non-processing exporters in firm heterogeneity extended national IO.

The sum of intermediate imports by processing and non-processing exporters are constrained to the ICIO import flows of target country *A* for each trade partner as:

$$\mathrm{Z_{ij}^{cA}} = \mathrm{Z_{i,jp}^{cA}} + \mathrm{Z_{i,jn}^{cA}}\,, \quad \textbf{(4.12)}$$

where $\mathrm{Z_{ij}^{cA}}$ are intermediate imports of product *i* by Country *A* from country *c* in ICIO, $\mathrm{Z_{i,jp}^{cA}}$ are intermediate imports by the processing exporters and $\mathrm{Z_{i,jn}^{cA}}$ are intermediate imports by non-processing exporters.

The imports from all partners are constrained to the FHIO's import part as:

$$\mathrm{IMZ_{i,jp}^{A}} = \sum_c Z_{i,jp}^{cA} \quad (4.13)$$

and

$$\mathrm{IMZ_{i,jn}^{A}} = \sum_c Z_{i,jn}^{cA} \quad (4.14)$$

where $IMZ^{A}_{i,jp}$ and $IMZ^{A}_{i,jn}$ are intermediate imports by processing exporters and non-processing exporters respectively in firm heterogeneity IO. The imports of final demand products remain the same, because the split is only considered in the types of firms; there are no differentiations in household types.

The components of exports and imports are separately balanced using a framework of linear programming optimization. However, the optimization constraints can be relaxed for the bilateral trade constraints from an ICIO database, since the bilateral trade flows and import matrix of most countries are derived by the numerical non-survey calculations anyway.

4.3 DATA SOURCES

As described above, the data sources required in this analysis are a global inter-country IO table, national firm heterogeneity IO and sectoral constraints of output, value added and trade components.

The base Inter-Country IO table used to estimate the extended ICIO in this paper is the 2015 edition of OECD Inter-Country IO table (http://oe.cd/icio). The OECD Inter-country IO table includes 62 economies and 34 sectors in an industry-by-industry format value at basic prices. The target countries are China and Mexico for years from 1995 to 2011.

The types of firms in both China and Mexico are summarized as follows.

1) China

- Domestic (non-exporters) (DOM)
- Processing exporters (PX)

- Non-processing exporters (NPX)
- Services (SVC)

The characteristics of firms are explicitly separated by the product destinations. The products of domestic sales-only firms are only consumed within Chinese territory and all products of processing exporters are exported by definition.

2) Mexico

- Global manufacturing (GM)
- Non-global manufacturing (NGM)
- Services (SVC)

The global manufacturing sector[19] defined by INEGI, Mexico consists of enterprises intensively involved in exports and imports in their production activities. The definition of the global manufacturing is characterized as 1) majority of intermediate supplies are imported and 2) minimum of two-third of its production is destined for exports (INEGI, 2014). In 2008, 21.8% of manufacturing output is produced by global manufacturing while 66.1% of exports are originated from this sector (Table 4.1).

[19] http://www3.inegi.org.mx/sistemas/tabuladosbasicos/tabniveles.aspx?c=33690

product-by-product Million CNY		Intermediate demand					Final expenditure		Output
		Agri.	Manufacturing			Services	Domestic	Exports	
			[D]	[P]	[N]				
Agriculture								*	XA
Manu	[Domestic]							na	XMD
facturing	[Processing]	na	na	na	na	na	na	*	XMP
	[Non-processing]							*	XMN
Services								*	XS
Imports		***	***	***	***	***	***	**	
Value-added		VA	VMD	VMP	VMN	VS			
Output at basic prices		XA	XMD	XMP	XMN	XS			

na: no value by definition, * re-exports are not included here, ** re-exports, *** includes re-imports

Source: Chinese Academy of Science, China

Figure 4.5 : China firm heterogeneity IO data (2007)

product-by-product Million MXP		Intermediate demand				Final expenditure		Output
		Agri.	Manufacturing		Services	Domestic	Exports	
			[NGM]	[GM]				
Agriculture							*	XA
Manu	[Non-Glob Manuf]						*	XNGM
facturing	[Global Manuf.]						*	XGM
Services							*	XS
Imports		***	***	***	***	***	**	
Taxes less subsidies on intermediate and final products								
Value-added		VA	VNGM	VGM	VS			
Output at basic prices		XA	XNGM	XGM	XS			

* re-exports are not included here, ** re-exports, *** includes re-imports

Source: INEGI, Mexico

Figure 4.6 : Mexico firm heterogeneity IO data (2008)

4.4 FINDINGS FROM FIRM HETEROGENEITY EXTENDED DATABASE

This section examines the effectiveness of FHEX-ICIO using different globalization indicators e.g. offshoring (Feenstra and Hanson, 1996), import contents of exports (Hummels *et al*. 2001) and domestic value added in foreign final demand (Johnson and Noguera 2012; OECD-WTO, 2013). Mexico and China are chosen for this proof of concept case study because the increasing involvement of their economies in global value chains are evidently observed in the exporting industries of machinery sectors located in export processing zones. The firms located in processing zone are given the economic benefits of lower barriers to imports and exports and the ownership of firms are related to foreign direct investment. Thus, the import penetration of intermediate products is much higher than the non-processing zone exporters by definition.

4.4.1 Descriptive statistics

The value added to output ratio indicates the initial impact of a unit increase in production from each type of industries. The value added to output ratios of processing trade sectors in both China and Mexico are consistently lower than for non-processing activities (Table 4.2). The operations of processing exporters (China) and global manufacturing industries (Mexico) rely more on intermediate inputs, particularly from the foreign sources, and it indicates that the unit impacts on domestic output (Leontief output multiplier) is lower than non-processing exporter firms (Table 4.3).

4.4.2 Impacts on globalization indicators

The higher dependencies on imported intermediate products in the export intensive sectors have significant impacts on unit economic impacts of gross exports for China and Mexico. Figure 4.7 clearly shows that intermediate goods and services are used much more in the production processes of processing trade industries (China) and global manufacturing industries (Mexico). The level of import penetration of Chinese processing exporters has dropped in the period between 2002 and 2008, but the penetration ratio for Mexican global manufacturers has gradually increased from 61% in 1995 to 73% in 2011.

Table 4.2 : Value added to output ratios by firm type (2011)

		China					Mexico			
	ISIC 3 division code	Aggregate	Domestic	Processing exporters	Non-Processing exporters	Services	Aggregate	Non-Global manufacturing	Global manufacturing	Services
Agriculture, hunting, forestry and fishing	01 to 05	0.585	0.584	NA	0.602	NA	0.607	0.607	NA	NA
Mining and quarrying	10 to 14	0.452	0.450	0.162	0.539	NA	0.858	0.858	NA	NA
Food products, beverages and tobacco	15,16	0.201	0.193	0.154	0.237	NA	0.391	0.393	0.156	NA
Textiles, textile products, leather and footwear	17,19	0.191	0.170	0.152	0.231	NA	0.387	0.427	0.203	NA
Wood and products of wood and cork	20	0.225	0.217	0.241	0.280	NA	0.456	0.457	0.215	NA
Pulp, paper, printing and publishing	21,22	0.221	0.201	0.155	0.251	NA	0.443	0.455	0.232	NA
Coke, refined petroleum products	23	0.189	0.181	0.071	0.240	NA	0.128	0.128	0.507	NA
Chemicals and chemical products	24	0.189	0.198	0.122	0.177	NA	0.292	0.298	0.174	NA
Rubber and plastics products	25	0.171	0.126	0.201	0.291	NA	0.308	0.333	0.151	NA
Other non-metallic mineral products	26	0.209	0.193	0.254	0.320	NA	0.533	0.542	0.325	NA
Basic metals	27	0.186	0.180	0.148	0.230	NA	0.376	0.380	0.320	NA
Fabricated metal products	28	0.197	0.182	0.214	0.231	NA	0.365	0.422	0.165	NA
Machinery and equipment, nec	29	0.219	0.206	0.203	0.273	NA	0.355	0.442	0.139	NA
Computer, Electronic and optical equipment	30,32,33	0.151	0.084	0.141	0.252	NA	0.135	0.184	0.097	NA
Electrical machinery and apparatus, nec	31	0.159	0.135	0.142	0.225	NA	0.269	0.399	0.140	NA
Motor vehicles, trailers and semi-trailers	34	0.170	0.116	0.257	0.302	NA	0.340	0.449	0.273	NA
Other transport equipment	35	0.245	0.186	0.256	0.301	NA	0.352	0.404	0.150	NA
Manufacturing nec; recycling	36,37	0.451	0.542	0.157	0.255	NA	0.376	0.468	0.127	NA
Electricity, gas and water supply	40,41	0.256	NA	NA	NA	0.256	0.425	NA	NA	0.425
Construction	45	0.260	NA	NA	NA	0.260	0.501	NA	NA	0.501
Wholesale and retail trade; repairs	50,51,52	0.646	NA	NA	NA	0.646	0.760	NA	NA	0.760
Hotels and restaurants	55	0.413	NA	NA	NA	0.413	0.733	NA	NA	0.733
Transport and storage	60,61,62,63	0.489	NA	NA	NA	0.489	0.670	NA	NA	0.670
Post and telecommunications	64	0.605	NA	NA	NA	0.605	0.608	NA	NA	0.608
Financial intermediation	65,66,67	0.666	NA	NA	NA	0.666	0.679	NA	NA	0.679
Real estate activities	70	0.599	NA	NA	NA	0.599	0.921	NA	NA	0.921
Renting of machinery and equipment	71	0.294	NA	NA	NA	0.294	0.798	NA	NA	0.798
Computer and related activities	72	0.272	NA	NA	NA	0.272	0.707	NA	NA	0.707
R&D and other business activities	73,74	0.287	NA	NA	NA	0.287	0.750	NA	NA	0.750
Public administration	75	0.516	NA	NA	NA	0.516	0.709	NA	NA	0.709
Education	80	0.592	NA	NA	NA	0.592	0.896	NA	NA	0.896
Health and social work	85	0.423	NA	NA	NA	0.423	0.744	NA	NA	0.744
Other community, social and personal services	90,91,92,93	0.468	NA	NA	NA	0.468	0.637	NA	NA	0.637
Private households with employed persons	95	NA	NA	NA	NA	NA	1.000	NA	NA	1.000

Table 4.3 Output multipliers by firm type (2011)

		China						Mexico			
	ISIC 3 division code	Original	Domestic	Processing exporters	Non-Processing exporters	Services		Original	Non-Global manufacturing	Global manufacturing	Services
Agriculture, hunting, forestry and fishing	01 to 05	2.093 [5.9]	2.102 [4.9]	NA	2.032 [11.1]	NA		1.743 [14.3]	1.740 [14.1]	NA	NA
Mining and quarrying	10 to 14	2.549 [9.9]	2.569 [8.6]	3.065 [36.1]	2.212 [15.4]	NA		1.266 [8.3]	1.264 [8.1]	NA	NA
Food products, beverages and tobacco	15,16	2.993 [7.6]	3.031 [5.3]	2.991 [31.8]	2.879 [12.1]	NA		2.105 [15.7]	2.097 [15.3]	2.640 [33.3]	NA
Textiles, textile products, leather and footwear	17,19	3.374 [11.5]	3.508 [6.1]	3.246 [34.9]	3.270 [10.3]	NA		2.183 [23.1]	2.059 [17.0]	2.641 [40.6]	NA
Wood and products of wood and cork	20	3.343 [8.7]	3.404 [6.1]	3.055 [30.3]	3.147 [11.1]	NA		2.003 [17.7]	1.995 [17.3]	2.526 [32.8]	NA
Pulp, paper, printing and publishing	21,22	3.325 [14.8]	3.457 [8.8]	3.195 [41.6]	3.195 [17.2]	NA		2.089 [21.3]	2.049 [19.2]	2.606 [42.3]	NA
Coke, refined petroleum products	23	2.933 [16.2]	3.001 [13.4]	2.896 [37.8]	2.635 [25.9]	NA		2.466 [23.9]	2.463 [23.8]	1.821 [21.7]	NA
Chemicals and chemical products	24	3.311 [15.8]	3.353 [10.1]	3.264 [41.5]	3.262 [22.0]	NA		2.256 [21.7]	2.232 [20.2]	2.627 [42.1]	NA
Rubber and plastics products	25	3.643 [14.4]	3.856 [9.7]	3.247 [39.8]	3.211 [18.5]	NA		2.431 [29.7]	2.346 [25.4]	2.877 [48.7]	NA
Other non-metallic mineral products	26	3.200 [11.9]	3.281 [9.8]	2.801 [34.9]	2.767 [18.0]	NA		1.827 [16.4]	1.802 [15.1]	2.282 [32.6]	NA
Basic metals	27	3.663 [10.5]	3.724 [8.1]	3.449 [39.1]	3.458 [14.6]	NA		2.097 [18.2]	2.072 [16.4]	2.335 [34.5]	NA
Fabricated metal products	28	3.233 [15.1]	3.364 [10.3]	2.952 [37.3]	3.008 [20.1]	NA		2.400 [32.3]	2.208 [24.5]	2.976 [49.4]	NA
Machinery and equipment, nec	29	3.569 [13.1]	3.678 [9.2]	3.292 [40.0]	3.361 [15.4]	NA		2.457 [37.6]	2.171 [26.8]	3.074 [54.2]	NA
Computer, Electronic and optical equipment	30,32,33	3.560 [33.8]	3.981 [21.2]	3.440 [46.2]	3.420 [20.0]	NA		3.133 [52.5]	2.701 [29.9]	3.352 [63.5]	NA
Electrical machinery and apparatus, nec	31	3.772 [16.8]	3.964 [10.1]	3.510 [41.0]	3.574 [15.3]	NA		2.732 [44.4]	2.264 [26.5]	3.115 [55.2]	NA
Motor vehicles, trailers and semi-trailers	34	3.898 [14.3]	4.170 [10.5]	3.309 [33.4]	3.410 [17.3]	NA		2.626 [47.2]	2.223 [31.6]	2.808 [53.0]	NA
Other transport equipment	35	3.486 [17.0]	3.785 [11.1]	3.165 [39.6]	3.307 [17.1]	NA		2.431 [34.7]	2.226 [25.8]	3.072 [55.0]	NA
Manufacturing nec; recycling	36,37	2.587 [10.9]	2.349 [5.9]	3.226 [34.7]	3.132 [12.9]	NA		2.329 [32.7]	2.056 [21.6]	2.974 [50.6]	NA
Electricity, gas and water supply	40,41	3.144 [7.0]	NA	NA	NA	3.161 [6.0]		2.156 [17.4]	NA	NA	2.147 [16.9]
Construction	45	3.318 [8.7]	NA	NA	NA	3.342 [7.4]		1.948 [15.3]	NA	NA	1.934 [14.6]
Wholesale and retail trade; repairs	50,51,52	1.972 [5.4]	NA	NA	NA	1.980 [4.5]		1.414 [7.9]	NA	NA	1.410 [7.5]
Hotels and restaurants	55	2.597 [5.0]	NA	NA	NA	2.604 [4.2]		1.483 [6.5]	NA	NA	1.480 [6.3]
Transport and storage	60,61,62,63	2.433 [8.4]	NA	NA	NA	2.448 [7.4]		1.658 [13.0]	NA	NA	1.653 [12.6]
Post and telecommunications	64	2.169 [8.8]	NA	NA	NA	2.188 [7.1]		1.769 [20.0]	NA	NA	1.752 [18.7]
Financial intermediation	65,66,67	1.855 [4.7]	NA	NA	NA	1.860 [4.0]		1.508 [5.4]	NA	NA	1.506 [5.2]
Real estate activities	70	2.126 [6.2]	NA	NA	NA	2.135 [5.2]		1.131 [2.1]	NA	NA	1.131 [2.1]
Renting of machinery and equipment	71	3.114 [10.7]	NA	NA	NA	3.142 [8.7]		1.380 [10.6]	NA	NA	1.375 [10.2]
Computer and related activities	72	3.194 [10.9]	NA	NA	NA	3.224 [8.9]		1.437 [4.3]	NA	NA	1.436 [4.2]
R&D and other business activities	73,74	3.154 [10.8]	NA	NA	NA	3.183 [8.8]		1.399 [5.3]	NA	NA	1.396 [5.1]
Public administration	75	2.337 [6.5]	NA	NA	NA	2.346 [5.4]		1.509 [7.2]	NA	NA	1.505 [6.9]
Education	80	2.133 [6.0]	NA	NA	NA	2.140 [5.0]		1.177 [2.9]	NA	NA	1.176 [2.7]
Health and social work	85	2.786 [9.0]	NA	NA	NA	2.799 [7.5]		1.459 [8.0]	NA	NA	1.454 [7.6]
Other community, social and personal services	90,91,92,93	2.550 [8.0]	NA	NA	NA	2.565 [6.5]		1.606 [8.4]	NA	NA	1.601 [8.0]
Private households with employed persons	95	1.000 [0.0]	NA	NA	NA	1.000 [0.0]		NA	NA	NA	NA

[%] is import contents share %

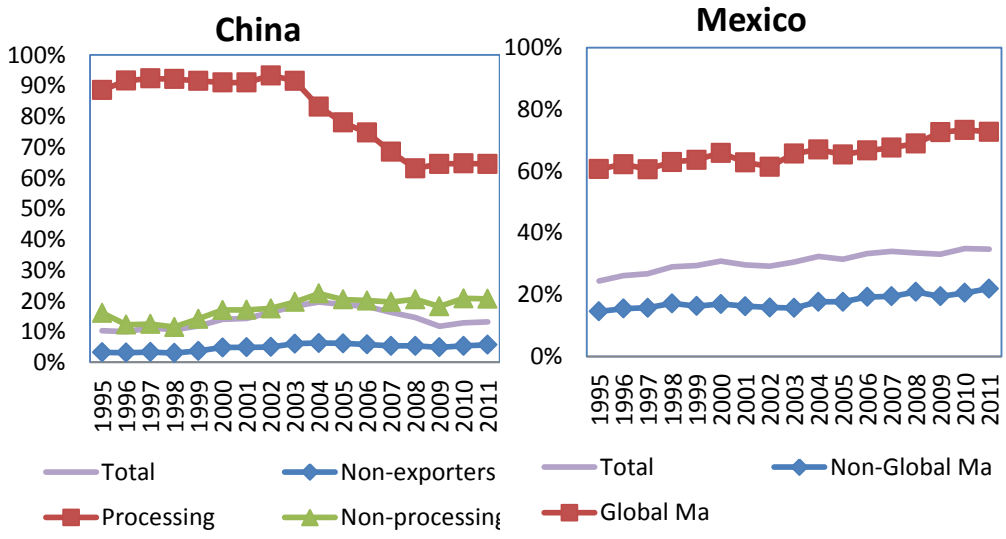


Figure 4.7 : Intermediate import penetrations of manufacturing industry

The differences in value added to output ratios and import penetration ratios of export intensive sectors changes the trend of domestic value added contents shares of gross exports (**Figure 4.8**). The results indicate that the country aggregated ICIO i.e., not distinguishing between export intensive and domestic activities possibly overestimates domestic value added embodied in international trade in both China and Mexico. For China, the biases are much higher in earlier years (approximately 15%) than more recent years (approximately 8%).

Domestic value added content share of exports is defined by the value added multiplier and gross exports for country c ($EXGR\_DVASH_c$) as:

$$EXGR\_DVASH_c = \frac{\sum_i \sum_j \left(\frac{VA_i^c}{X_i^c} B_{ci}^{cj} EXGR_j^c \right)}{\sum_j \left(EXGR_j^c \right)} \quad \textbf{(4.15)}$$

where VA_i^c is value added of country *c*'s industry *i*, X_i^c is output of country *c*'s industry *i*, B_{ci}^{cj} is an element of global Leontief inverse (output increase in country *c*'s industry *i* by a unit increase in the demand of country *c*'s industry *j* product), $EXGR_j^c$ is exports of country *c*'s industry *j*.

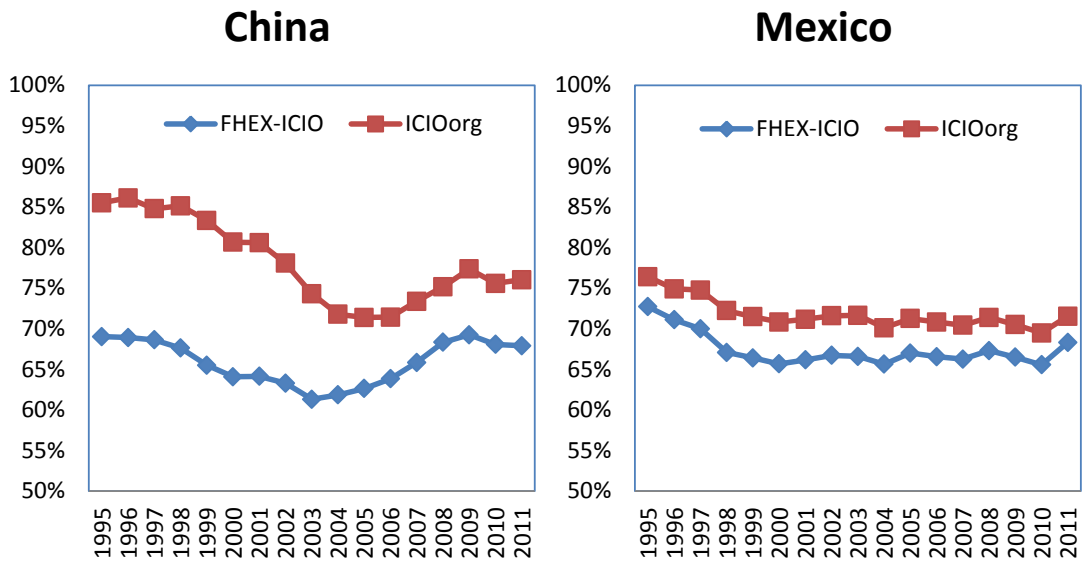


Figure 4.8 : Domestic value added content shares in gross exports

Domestic value added embodied in foreign final demand as a share of total domestic value added for China and Mexico are 17.6% and 20.1% respectively in recent years. If the export-oriented sectors are not split in the ICIO system, the results are overestimated for 2.1% and 1.0% for China and Mexico respectively.

Domestic value added embodied in foreign value added is defined as:

$$FFDDVA_c = \sum_i \left(\frac{VA_i^c}{X_i^c} B_{ci} FFDc \right) \quad \textbf{(4.16)}$$

where *FFDVAc* is Domestic value added embodied in foreign value added, VA_i^c is value added of country *c*'s industry *i*, X_i^c is output of country *c*'s industry *i*, B_{ci} is an element of global Leontief inverse (output increase in country *c*'s industry *i* by a unit increase in the demand of

country *c*'s industry *j* product) and *FFDc* is foreign final demand i.e. final demand of all other countries.

Domestic value added content in foreign final demand of (4.16) can be estimated also by demand countries. Although the bilateral trade partner shares in gross exports terms are not so affected by the country aggregated ICIO and FHEX-ICIO, the biases in partner shares in the value added trade flows may be observed (Figure 4.10). However, the differences are marginal for most partners because the value added content shares equally to all partner countries.

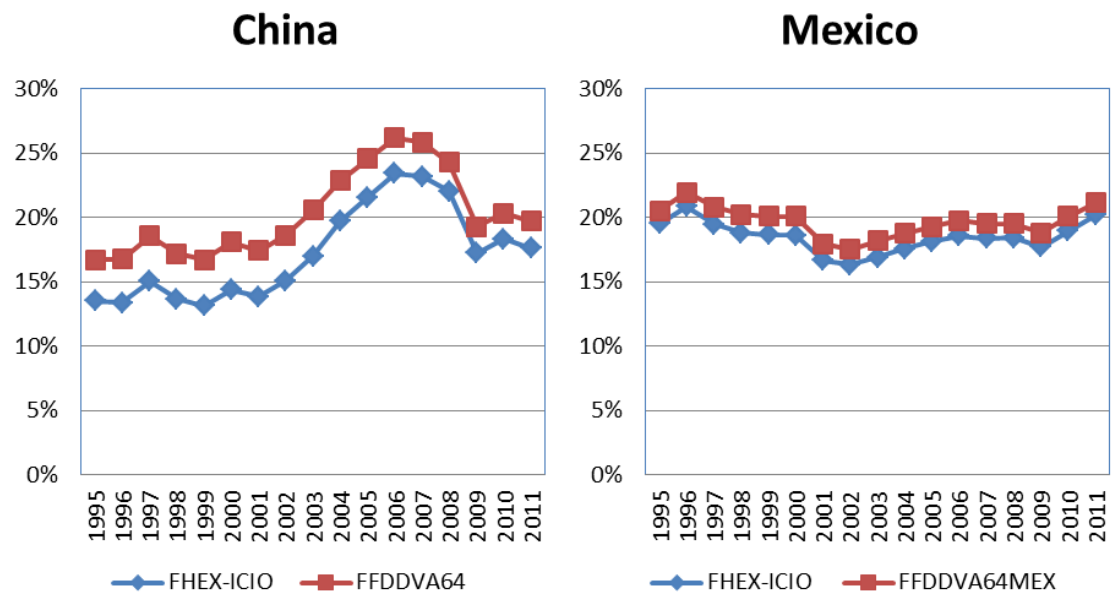


Figure 4.9 : Domestic value added embodied in foreign final demand as a percentage of total value added

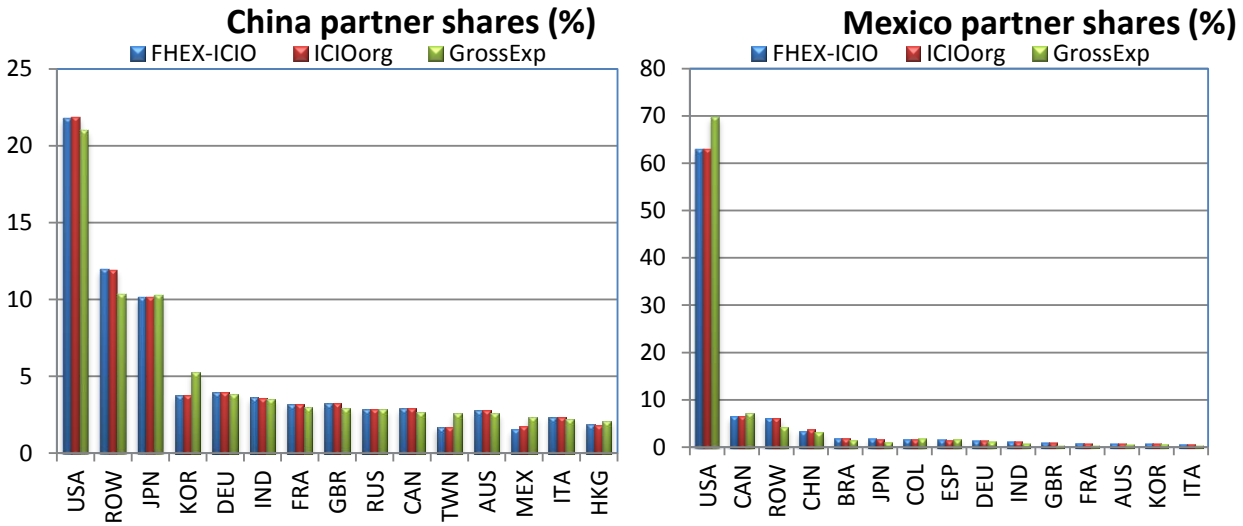


Figure 4.10 : Export partner shares (gross exports and foreign demand-based shares)

4.5 SUMMARY

Taking account of firm heterogeneity in an inter-country input-output (ICIO) model allows improved analysis of the economic and social impacts of globalization phenomena. Since the production structures of exporting industries are significantly different from firms making domestic sales only in China and Mexico, the database developed in this chapter reveals that existing country-based ICIO systems underestimate the imported intermediate products used by exporters. Domestic value added embodied in exports may therefore be overestimated in these countries in conventional ICIO framework. In principle, the firm heterogeneity split tables are also useful for other applications e.g., improved measurements on carbon emissions footprint and jobs sustained by foreign final demands. The country–aggregate models, in theory, always face the issue of over-estimation of domestic economic impacts in any policy context.

Thus, the methodology proposed in this paper is highly desirable to analyze the international flows of value added via exports and imports. Assuming same value added – output ratio and import contents of output for all firms in an industry may limit the use of ICIO analysis. The methodology can be also applied to other firm heterogeneity extensions such as firm size and multinational enterprise activities. However, many challenges remain to collect the necessary data from official statistical sources such as national IOs, business registry and customs trade statistics to split the export oriented industrial activities from the rest of economy due to the confidentiality issues. Collaborations with different national statistics agencies are necessary to proceed with this analytical framework.

CHAPTER 5 : SUMMARY

This summary chapter concludes the application projects and studies described in earlier chapter with some further challenges in the compilation and analytical frameworks of the ICIO database.

Chapter 1, "Policy Discussions using Inter-Country Input-Output System: Overview," discusses various applications of global scale inter-country input-output (ICIO) system. An increased database coverage is consistently requested by national and international agencies to analyze their imminent policy challenges such as environment, productivity, trade negotiations and jobs dependent on the globalized economy. This chapter discusses that any of these pressing policy issues cannot be fully analyzed without developing a large scale Inter-country IO system with the unique specifications extended (regional and firm-heterogeneity extended) in the models developed in this thesis. Parts of Chapter 1 are extended from the earlier book chapter article of Yamano and Webb (2013).

In Chapter 2, "Development of the Inter-Country Input-Output Database," a methodology is described to generate a time series model of ICIO data. In this methodology, various publicly available statistics are effectively integrated to develop a wide coverage international input-output database. Parts of Chapter 2 are extended from a project on development of OECD ICIO system (OECD 2015 and 2016). There are wide ranges of analyses using this database and the firm heterogeneity extension database developed in Chapter 4 of this dissertation. First of all, the OECD-WTO Trade in Value Added indicators, one of the current headline indicators of OECD database are calculated based on this ICIO system (OECD-WTO, 2013, 2015 & 2016; Miroudot and Yamano, 2013). The similar application examples of this ICIO system are found

for jobs embodied in foreign demand (OECD STI Scoreboard 2015ed; http://oe.cd/io-emp) and consumption-based CO2 footprint (OECD Green growth indicator, 2013; Wiebe and Yamano, 2016; http://oe.cd/io-co2). The annual time series data have expanded the application possibilities to examine the phenomenon of economic crisis (Hashiguchi *et al.*, 2017a and 2017b) rather than the benchmark year analysis with country-aggregated ICIOs.

Also, some of the databases estimated in the middle of processes to develop the ICIO are extended in different analyses such as trade network analyses of (Yamano *et al*., 2011, Fukasaku *et al.*, 2011, and Zhu *et al*., 2011), global value chains (De Backer and Yamano, 2008; De Backer and Yamano, 2012; Meng *et al*., 2012; Guo *et al.*, 2016) and methodological development of national Input-Output and supply-use tables (Yamano and Ahmad, 2006; Temurshoev *et al*., 2011).

In Chapter 3, "Development of Regional Extended Inter-Country Input-Output Database", a methodology of splitting the country aggregate based ICIO into subnational Japanese regions is developed and the participation of each region in a global value chains is examined using the trade in value added indicators. The complementary analysis was made jointly with IDE-JETRO for Chinese regions (Meng *et al*., 2016) and the methodological focused paper become available in an article as Meng and Yamano (2017). One of the remaining challenges for subnational region extension is to introduce better estimation framework to develop the domestic commodity flows between international ports and exporting and importing regions. The relationship between product originating regions and shipping hub ports can be, for example, extended using a domestic land transport network model.

In Chapter 4, "Firm Heterogeneity Extended Inter-Country Input-Output Model for an Inter-Connectedness Analysis," the estimated extended ICIO database reassures that an analytical framework to take into account the firm heterogeneity within manufacturing sectors is significantly important for the countries largely involved in the processing trade activities such as China and Mexico. To the author's knowledge, this heterogeneity split ICIO is a unique feature among similar ICIO projects and it has been used as a core system in the development of the OECD-WTO Trade in Value Added indicators (OECD-WTO, 2013, 2015 and 2016). This approach, however, requires additional data work at the national statistics agencies to recompile their databases based on the firm microdata and the continuity of the project of the project has become a challenging issue.

In addition to the extensions on the improvements on regional heterogeneity and trade characteristics heterogeneity in Chapters 3 and 4 of this dissertation, additional perspectives can be also suggested to include the heterogeneity in other dimensions in an inter-country IO framework such as:

1) Household consumption expenditures by income and age groups (Miyazawa, 1976; Kim *et al.*, 2014).

2) Decomposition of value added by ownership i.e. link between the current account and capital accounts of national accounts and balance of payments systems.

3) Firm size (OECD and World Bank Group, 2015; Small and Medium Enterprise Agency, Japan, 2012).

4) Further breakdown on taxes and subsidies margins can increase the potential of ICIO analysis for more extensive policy analyses. The public subsidies on state-owned firms in emerging economies are currently being discussed in many anti-dumping challenges. Separating the import duty from the rest of taxes on imported products can also allow the model to analyze separately the tariff and non-tariff barriers in the context of global supply chains.

Lastly, many statistical and methodological challenges remain to improve the coverage and quality of ICIO databases. More "proof of concept" case studies can contribute to enhance the capability of ICIO databases to further policy analyses such as more detailed sectoral and regional analyses and sustainable development goals challenges.

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APPENDIX: ACRONYMS

APEC: Asia-Pacific Economic Cooperation

ASEAN: The Association of Southeast Asian Nations

BoP: Balance of Payments

BTD: Bilateral Trade Database

c.i.f: Cost, insurance and freight price

EU: European Union

EUROSTAT: Statistical Office of the European Communities

f.o.b.: Free on board price

ICIO: Inter-Country Input-Output

IEA: International Energy Agency

IMF: International Monetary Fund

IRIO: Inter-Regional Input-Output

ISIC: International Standard Industry Classification

NAFTA: North American Free Trade Agreement

OECD: Organisation for Economic Co-operation and Development

SNA: System of National Accounts

NPISHs: Non-Profit Institutions Serving Households

GFCF: Gross Fixed Capital Formation

SUT: Supply and Use Tables

TIS: Trade in Services

TiVA: Trade in Value Added

UN: United Nations

WTO: World Trade Organization