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International Fragmentation, Specialization and Comparative Advantage: An Asian-Pacific Input-Output Approach

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Abstract

In this paper the relationship between three types of trade specialization is analyzed for the period 1990 to 2000. For nine East-Asian countries and the United States the developments in international fragmentation, export specialization and intra-industry specialization are investigated. Asian countries, and specifically China, now play a larger role in international trade. The formation of production networks and international fragmentation of production processes in this region has not gone unnoticed. This paper tries to establish a link between the extent of international fragmentation, comparative advantage, and intra-industry specialization using the Asian-Pacific input-output tables of 1990, 1995, and 2000. The results show an increase in the extent of international fragmentation in all countries, concentrated in the 1995 to 2000 period. Relative international fragmentation shares are compared to relative export specialization shares to test whether international fragmentation can be explained using (neo-)classical trade theory. Evidence is presented of a positive relationship between these two variables. A comparison of international fragmentation with the results of the intra-industry specialization measure does not indicate a relationship, leaving less room for new trade theory explanations of international fragmentation. These results suggest that international fragmentation follows comparative advantages and takes place when factor cost differentials can be exploited.

Keywords: trade, international fragmentation, specialization, comparative advantage

1. Introduction

Starting in the 1960s four East Asian countries began displaying increasing growth rates that persisted for decades. The impressive growth rates of Hong Kong, South Korea, Singapore, and Taiwan did not go unnoticed.[1] In articles they were alternately named the 'Newly Industrialized Countries' or – more imaginative – the 'East Asian Tigers' or the 'Four Little Dragons'. Due to the changes in the structure of the economy and the increasing growth rates the economies started to converge towards the income levels of Europe and the United States. This growth experience was considered to be a miracle by most[2], but some noted some less miraculous reasons for the impressive growth rates[3]. Over time other Asian countries also started to realize higher growth rates and nowadays a substantial number of countries in East Asia are associated with rapid economic development and catching up to the industrialized countries.

In order to take advantage of the economic growth and industrialization, an increasing number of non-Asian companies decided to move part of their production process to the four East Asian tigers either by subcontracting or by foreign direct investment. Next to the fact that Asia, and especially China, are rapidly growing markets, a major reason for the relocation of production activities to, and within, Asian countries is the exploitation of factor cost differentials. The low wages of industrial workers, in combination with declining transport cost, and the industrialization and export-promoting policies of Asia were generally indicated as the main reasons that made this a very attractive way of organizing the production chain. The initial growth of a few countries initiated a restructuring of the economies of all countries in the region. Production chains of intermediate and final goods were linked across borders to form intricate production networks to serve the European and American markets and increasingly their own region. This shift of economic activity has been a major topic in both business and economic literature. The relocation trends are often covered under such names as international production sharing, production networks, off shoring and international outsourcing.

[1] Hong Kong is not a country, but a special administrative region of China. Taiwan has a separate government although it is not formally recognized by China to be independent.
[2] The World Bank (1993) uses this word to describe the development in East Asia. Other authors share this view, see for example: Lucas Jr. (1993).
[3] See Krugman (1994) for the less euphoric view and his references to other critics.

Multiple studies investigate these dynamics and show more empirical evidence of this phenomenon. Ng and Yeats (1999), Kimura and Ando (2005), and Shrestha (2007) find that the dependence of East Asia on imported intermediate goods is relatively high. Trade of products that are classified as parts and components has increased over the last decade. Ando (2006) finds that vertical intra-industry trade, which is defined as intra-industry trade where the goods differ in unit-prices, has increased sharply. The share of vertical intra-industry trade in machinery parts and components has increased even more rapidly than that of trade in machinery products. Kimura and Ando (2005) conclude that intra-regional trade in East Asia has increased. From a business perspective, Kuroiwa (2006) finds that the interaction between industrial clusters in Asia has increased. Countries specialize in specific activities of a production chain, as shown by Ng and Yeats (1990). Japan, Singapore, and Taiwan specialize in the manufacture of components and Indonesia, Malaysia, and Thailand are the most important assembly countries in East Asia.

To explain international trade there are two mainstream economic theory strands. The (neo-)classical trade theory, of which the Ricardian trade theory and the Heckscher-Ohlin model are the fundaments, features comparative advantage embodied in technological differences or factor endowments as the determinant of the direction of trade. A country has a comparative advantage in the production of a good if the good has the lowest relative price before any trade takes place. Although the source of the comparative advantage can be anything that induces relative price differences in autarky, as soon as free trade occurs, each country will specialize in the production of the good it has a comparative advantage in.

Relatively recently, a new trade theory has been developed (Krugman; 1979), that builds directly on the Dixit and Stiglitz (1977) monopolistic competition model. International specialization in this model is driven by increasing returns to scale at the firm level and a love for variety. In Krugman (1980) transportation costs are introduced in the model, which results in the specialization of a country in the production of the good for which it has a large home market. Krugman (1991) extended these models to include the location choice of firms. These models have been devised to find answers to empirical observations related to intra-industry trade and trade between countries for which the comparative advantages are harder to distinguish. A sizeable part of total

trade is trade of products that originate from the same type of industry, incapacitating explanations based on comparative advantage.

This study tries to build a bridge between international trade theory and the industrial structure and production chain analyses performed in business literature. International fragmentation of business has direct repercussion for supply chains and their management. These changes are widely observed in business literature. International fragmentation also results in more trade in (intermediate) products. These trade flows, and hence international fragmentation, can be explained using international trade theory. In this paper we test whether the increase in international fragmentation can be explained using (neo-)classical trade theory or new trade theory. As the increase of international fragmentation has gone hand in hand with the rise in intra-industry trade and the development of new trade theory to explain these trade flows, they seem to be outcomes of the same dynamics.

We use the term international fragmentation to refer to the splitting of a production process into two or more production blocks, of which at least one is internationally relocated either within the firm or between firms, but which are still linked through trade in intermediate products in order to produce the same final product. The production of a good, either an intermediate or final good, in one location, within a firm is referred to as a production process. When a production process is fragmented, two production blocks are created, which after relocation continue to exist as two individual production processes. Consecutive production processes that are linked through trade in intermediate products are referred to as production chains. When companies can fragment their production process it implies that an even finer division of labor is possible than without fragmentation and hence a higher level of specialization. It allows firms to specialize in a certain part of the production chain, producing and trading intermediate products that were previously integrated in the production process.

Empirical evidence of international fragmentation is not widespread and in general focuses only on direct linkages. The use of international input-output tables offers the opportunity to include domestic as well as international indirect linkages for the countries included in the table. In order to study international fragmentation this study first gives an overview of the extent of international fragmentation in East Asia.

The measure for international fragmentation as developed by Hummels *et al*. (2001) is extended in two ways. First, not only indirect domestic linkages, but also indirect international linkages are incorporated in the measure. Second, the new measure is more restrictive as it only includes exports of intermediate goods and therefore guarantees that the product crosses at least twice a border to be further processed.

First, the relationship between international fragmentation and (neo-)classical trade theory is investigated by looking at the association between the extent of international fragmentation and the revealed comparative advantage. According to (neo-)classical trade theory countries gain by specializing in the production of goods in which they have a comparative advantage. When fragmented production processes are considered, there are even more opportunities for a country to specialize in the production of a certain input, or in a certain part of the production chain.

The second step is to relate the extent of international fragmentation to intra-industry specialization to investigate whether these developments are related. The standard measure of intra-industry specialization is defined as 1 minus inter-industry specialization. In order to be able to test whether (neo-)classical trade theories or new trade theories explain international fragmentation we develop two independent measures that each focus on a dimension of intra-industry specialization. The first measure investigates the relative length of the international production chain in which a sector participates. The length of the international production chains can be taken to be indicative of the type of product a sector produces. The type intermediate inputs can be derived from the backward linkages of the sector. The type of goods in which the sector's product is used as input can be deduced from the forward linkages of the sector. The second measure focuses on the relative position of the sector in the international production chain. The position of a sector might indicate whether a sector has specialized in a different activity, like production or assembly, compared to the same sector in another country.

Our results show that despite the contemporary increase in international fragmentation and intra-industry specialization, the association between international fragmentation and inter-industry specialization is stronger. The models devised to explain the growing trade in products that originate from the same industry, an indication of increasing intra-industry specialization, cannot be used to explain

international fragmentation. In contrast, the explanation based on comparative advantage and factor cost differentials shows promising results.

The rest of this paper is organized as follows. Section 2 gives an overview of the data used in the present analysis. In section 3 the methods are discussed that are applied to the data in order to analyze the different types of specialization. The results are presented and discussed in chapter 4 and chapter 5 concludes.

2. Data description

The analysis in this study is performed based on the 1990, 1995, and 2000 Asian international input-output tables (IDE 1998, 2001, 2006). See Figure 1 for the lay-out of the Asian international input-output table for the year 2000. These tables contain sector specific information on the inputs and outputs of more than seventy sectors over ten endogenous countries; Indonesia, Malaysia, Philippines, Singapore, Thailand, China, Taiwan, Korea, Japan, and the United States. The complete group of countries is referred to as 'region'. In order to be able to compare individual industries over years, sector detail is reduced to 63 separate sectors. In Appendix A the sector correspondence table is given, which also indicates which sectors of the original data tables have been aggregated.

Figure 1

The data available in the Asian input-output tables can be represented using four indices. Two superscript indices indicate the origin and destination country of the trade flows, two subscript indices denote the industry of origin and destination. Chapter 4 introduces several equations in which these indices are used. They are associated with the following values. The superscript index R runs from 1 to 12 for the 1990 and 1995 tables. This includes the countries 1 to 10 that are included in the full information (central) part of the table and which are referred to as the endogenous countries. The exogenous countries, which are in fact regions, are for the 1990 and 1995 tables Hong Kong and the Rest of the World. In the 2000 table Europe is added as exogenous region. This implies that the index R runs from 1 to 13 for the 2000 table. For all tables the superscript index S runs from 1 to 10. The index i and j run from 1 to 63. Only in the sensitivity analysis i respectively runs from 1 to 64, 1 to 76 (2000 table) and 1 to 78 (1990 and 1995 tables).

Sector 64, the unclassified sector, is not part of the analysis. There are two distinct reasons to separate sector 64 out. The practical reason is the problem with this sector in the 2000 table for Malaysia. Total inputs of the unclassified sector in Malaysia are ascribed to only itself, implying zeros in the rest of the column including the value added categories, leading to the computational problem that the matrix cannot be inverted. The conceptual reason for leaving out the unclassified sector is the lack of real information. Each product of unknown origin or destination is allocated to the unclassified sector implying a structural relationship between these products that does not exist.

This thesis focuses on international fragmentation and international trade flows. The following figures present an overview of the relative magnitudes of international trade flows of the countries. The data represented in de figures are obtained from the 1990, 1995, and 2000 Asian international input-output tables. The trade flows are shown as percentages of value added. Recall that total output is roughly twice as large as value added. The percentages therefore also give an indication of the share of imported inputs in total inputs used. Note that the scaling of the axes is different for each figure.

In Figure 2 the imports of intermediate products per country are shown, and in Figure 3 the imports of intermediate goods from the region are depicted These are imports that are used for further processing by industries or are in any other way involved in production. Most countries show an increase of the imports of intermediates over the period 1990 to 2000. The countries are presented in order of magnitude of value added. In general it can be said that the smaller countries are more open. Indonesia, however, does not really fit in the picture with its very low percentage of imports of inputs. Singapore is quite special considering its low number of square meters, which explains its very large degree of openness. Also notable are the large increases in the imports of Malaysia. The U.S. and Japan are both very domestically oriented regarding the source of their inputs in the sense that less than 10 percent of inputs is imported.

Figure 2

Figure 3

In Figure 4 total exports are represented instead of exports of intermediates, because the data do not incorporate a distinction between exports for intermediate use and exports for final demand purposes to the countries outside of the region. It is clear that countries that import more relatively to their value added also export a larger percentage compared to value added. In Figure 5 the exports of intermediate goods to the nine other countries in the region are displayed. Indonesia now scores rather high compared to the other figures, indicating that Indonesia is in more export oriented with a focus on the region. In the exports of intermediate goods to the regions Malaysia has even surpassed Singapore.

Figure 4

Figure 5

3. Methods

This section introduces and discusses the measures used in this paper. The first section focuses on the measure of international fragmentation, the second section discusses the measure of revealed comparative advantage and the third section elaborates on the two measures of intra-industry specialization.

3.1 The extent of international fragmentation

The measure applied in this study builds on the measure as introduced by Hummels *et al.* (2001). In the section 3.1.1 the concept of international fragmentation is explained including a simple way to measure it. The measure Hummels *et al.* (2001) apply in their study combines the conceptual measure with the input-output model and corresponding data tables. This combination and the resulting measure are described in section 3.1.2. The present study takes advantage of the availability of bilateral linkages in the Asian international input-output table to extent the measure. This work is related to Shrestha (2007), who has also incorporated the bilateral linkages in the measure of Hummels *et al.* (2001), although in a slightly different fashion. Section 3.1.3 discusses the measure that is used in the rest of this study.

3.1.1 The concept of international fragmentation

International fragmentation refers to the phenomenon that companies, instead of managing a complete production chain domestically, are more and more part of

international production chains that span multiple countries. Table 1 shows the two dimensions of fragmentation.

Table 1

International fragmentation has been studied in several ways. Most studies look at trade in intermediate goods. These data imply that there are at least two countries involved in the production of a good. Whether these international linkages are just bilateral or involve more countries cannot be examined on the basis of macro-economic trade data. Hummels *et al*. (2001) introduce a more specific specification of what they call vertical specialization. These authors investigate the same conceptual idea, which we will here continue to refer to as international fragmentation. Instead of considering only bilateral trade of intermediate goods, the concept of international fragmentation also requires that part of the production of a sector, which is produced using imported inputs, is exported to other countries. The minimum requirements to consider a production chain as international fragmented are: 1) a sector imports intermediate goods that are used in production, and 2) some of the products produced by this sector are exported.

The measure of international fragmentation represents the value of imports that are embodied in a product that is exported. As there is no separate account of the inputs that go solely into export goods in input-output tables (or trade data), it is assumed that the share of imports in exports is equal to the share of imports in total output. This is reasonable as long as the same technology is used to produce for domestic demand as well as for exports purposes. See equation (1).

$$IF_i^S = \frac{M_i^S}{X_i^S} \times E_i^S \qquad \textbf{(1)}$$

Where *IF* stands for international fragmentation, *M* is imports, *X* is total inputs (which equals total outputs), and *E* is exports. The indices *S* and *i* refer to the country and sector respectively. The total value of imports that is embodied in a country's total exports is a simple summation of the sector *IF* values.

$$IF^S = \sum_i IF_i^S \qquad \textbf{(2)}$$

In order to compare these values across countries they are normalized with respect to the total value of exports. This measure is referred to as the international fragmentation share of a country; IFS^S. See equation (3).

$$IFS^S = \frac{\sum_i IF_i^S}{\sum_i E_i^S} \quad \textbf{(3)}$$

Returning to the sector level, the value of imports that is embodied in exports, IF_i^S, is not divided by the value of sector exports as this would divide out the export value altogether and only leave the import-to-output ratio. First aggregating the embodied values and then dividing by the total exports is actually equal to an export-weighted summation of import-to-output ratios. See equation (4).

$$IFS^s = \sum_i \left(\frac{E_i^S}{\sum_i E_i^S} \times \frac{M_i^S}{X_i^S} \right) \quad \textbf{(4)}$$

The part between brackets of (4) represents an export weighted average of the import share in output per sector. This can also be interpreted as the value of imports that is required for producing the exports of the sector per unit of total exported products.

3.1.2 Introducing the input-output model

In the input-output framework, next to direct linkages, all indirect linkages can also be taken into account. For example, extra demand for products of sector *i* will be met by an increase in *i*'s production. However, sector *i* uses inputs from sector *j*, of which the required output will therefore also increase. If *j* then uses products of *i* to produce the inputs there is an indirect effect on sector *i* next to the direct increase in production to meet the new final demand. Shown in a matrix equation this system is represented by equation (5).

$$\mathbf{x = Ax + f} \quad \textbf{(5)}$$

In this equation **x** is the vector of total outputs. The elements a_{ij} of matrix **A** represent the input shares of each industry *i* in the output of each industry *j*. The vector **f** represents final demand. Solving this system for **x** results in equation (6).

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f} \tag{6}$$

Where the identity matrix **I** is of the same size as **A**. The final demand vector or matrix is multiplied by $(\mathbf{I} - \mathbf{A})^{-1}$ to obtain the required output. The matrix $(\mathbf{I} - \mathbf{A})^{-1}$ is often called the Leontief inverse. Each element l_{ij} of this matrix represents the extra output that is needed from industry *i* in order to fulfil one extra unit of final demand for the product of industry *j*.

The concept of international fragmentation share combined with the input-output model results in a matrix definition of IFS^S making use of the Leontief inverse.

$$IFS^s = \mathbf{u'A_M(I-A_D)^{-1}s} \tag{7}$$

In this equation **u'** represents a summation row vector, $\mathbf{A_M}$ represents the import matrix of which each element $a_{ij}^{\circ S}$ represents the share of imported inputs produced by industry *i* in all foreign countries used in the goods produced by industry *j* in country *s*. The Leontief inverse $\mathbf{(I-A_D)^{-1}}$ represents the total, direct and indirect linkages, between the domestic industries. The vector **s** is a column vector of exports shares, which represents the value shares of products that are exported to satisfy intermediate and final foreign demand. The result of this multiplication is a single scalar that is conceptually similar to the result of equation (3), although (7) will result in larger values due to the inclusion of domestic indirect linkages between industries.

In order to obtain *IF* shares per sector the vector with export values **e** has to be transformed to a diagonal matrix $\hat{\mathbf{s}}$. This matrix has the export shares of the sectors on the main diagonal. The result is that the sector *IF* shares are not directly summed up as a result of the matrix calculations, but that the outcome is a row vector of 63 values that represents all the individual sectors.

3.1.3 International input-output tables

The above matrix calculations are all based on national or country input-output tables of domestic and imported intermediate inputs. In the rest of the paper this definition is

referred to as the national method to calculate *IFS* values. In case of an international input-output table, indirect linkages between each of the endogenous countries are taken into account in the calculation of the international fragmentation measure. The following equation shows the measure based on an international input-output model. This measure is related to the measure used by Shrestha (2007). The difference in calculation originates from a broader definition of international fragmentation that we employ. This definition will be referred to in Chapter 5 as the international method. The structure of the inter-country *IFS* equation (8) reminisces of the structure of the national equation as given in (7).

$$\mathbf{IFS_I} = \mathbf{u}'\mathbf{A_T}\mathbf{L_{AIOT}}\hat{\mathbf{s}}_{\mathbf{AIOT}} - \mathbf{u}'\breve{\mathbf{A}}_{\mathbf{T}}\breve{\mathbf{L}}_{\mathbf{AIOT}}\hat{\mathbf{s}}_{\mathbf{AIOT}} \tag{8}$$

The result $\mathbf{IFS_I}$ is a row vector with dimensions 1 × 630, which represents the *IFS* values of 63 sectors for 10 countries. In this equation $\mathbf{A_T}$ represents all inputs produced in the endogenous and exogenous countries including domestically produced inputs. The number of rows of this matrix in case of the 1990 and 1995 tables is 12 × 63 = 756 and 13 × 63 = 819 in the 2000 table[4]. The matrix $\mathbf{A_T}$ has 630 columns representing 63 sectors in the 10 endogenous countries. The matrix $\mathbf{L_{AIOT}}$ includes all endogenous countries and instead of a domestic Leontief matrix it represents the Leontief matrix of the region, which includes all the indirect linkages between any of the industries in any of the endogenous countries. The export share vector is replaced by the diagonalized export vector represented by $\hat{\mathbf{s}}_{\mathbf{AIOT}}$. The export shares cover both the exports to the exogenous countries and the exports to the endogenous countries. This presumes the exports to the endogenous countries to be exogenous, which is inconsistent with the model, but justified when regarding the *IFS* measure as a picture taken at a particular point in time.

Our measure differs from the one used by Shrestha (2007) with respect to the matrix that is deducted from the first term on the right hand side of equation (8). The result of the multiplication $\mathbf{u}'\mathbf{A_T}\mathbf{L_{AIOT}}\hat{\mathbf{s}}_{\mathbf{AIOT}}$ incorporates all intermediate inputs that are required to produce the exports. A share of the products of sector *j* that are produced in

[4] In each of the three tables the first 10 sub-matrices belong to the 10 endogenous countries. In the 1990 and 1995 table there are two exogenous regions: Hong Kong and the 'Rest of the World'. In the 2000 table Europe is added as the third exogenous region.

country *S*, represented by an element of $\mathbf{A_T}$, are used in production processes in other countries, which is recorded by $\mathbf{L_{AIOT}}$. If some of the products of a certain industry are exported, the input *i* embodied in the exports represents international fragmentation. However, when two elements of $\mathbf{A_T}$ and $\mathbf{L_{AIOT}}$ are multiplied that are both related to the same country *S*, the term concerns solely domestic production and not international fragmentation. This domestic production has to be deducted from the international *IFS* measure. The term $\mathbf{u}'\breve{\mathbf{A}}_\mathbf{T}\breve{\mathbf{L}}_{\mathbf{AIOT}}\hat{\mathbf{s}}_{\mathbf{AIOT}}$ takes care of this. The matrix $\breve{\mathbf{A}}_\mathbf{T}$ is the matrix $\mathbf{A_T}$ from which all the off-diagonal blocks are deleted. Remaining is a matrix with domestic sub-matrices on the diagonal. The matrix $\breve{\mathbf{L}}_{\mathbf{AIOT}}$ is defined likewise; it is the $\mathbf{L_{AIOT}}$ matrix from which the off-diagonal bilateral matrices are deleted. This term leads to the deduction of all entirely domestic transactions from the international fragmentation share.[5]

Each element of the $\mathbf{L_{AIOT}}$ matrix gives the value of inputs produced by *i* in country *R* that are embodied in the exports of industry *j* in country *S* per unit of total exports of country *S*. The international measure does not represent shares, in contrast to the Hummels *et al.* (2001) measure, but multipliers. This measure inherently results in some double counting, because part of the endogenous part of exports is double-counted in the imported inputs values of $\mathbf{IFS_I}$. Also there is an implicit assumption that time is not a relevant dimension. The $\mathbf{L_{AIOT}}$ matrix represents all extra production required when all effects of extra demand have rippled through the system. Pre-multiplying this matrix by the input coefficient matrix $\mathbf{A_T}$ is done to obtain the inputs that are needed for the extra production as represented by the elements of $\mathbf{L_{AIOT}}$. However, different products have production chains of different lengths. The measure as introduced in (8) does not take the multiple rounds of production in account but assumes instantaneous extra production as given by the $\mathbf{L_{AIOT}}$ matrix.

The analysis of the results will focus on overall country *IFS* values. These are computed as they try to capture in one value the extent of fragmentation of a country. The country *IFS* value is a simple summation of the sector *IFS* values. Case studies and empirical evidence suggest that there is a truth to the public sentiment that international

[5] Instead of only deducting the entirely domestic flows of country *S* represented by $\mathbf{A}_\mathbf{T}^{SS}\mathbf{L}_{\mathbf{AIOT}}^{SS}$, Shrestha (2007) deducts matrices $\mathbf{A}_\mathbf{T}^{SR}\mathbf{L}_{\mathbf{AIOT}}^{RS}$ for all *R* including *S*, which total to 10 sub-matrices.

fragmentation has increased over the years. Therefore it is expected that the international fragmentation measure used in this study will also indicate that international fragmentation has increased over the period 1990 to 2000.

Instead of including all exports, the *IFS* values of the countries are also calculated using only intermediate exports instead of all exports. In this measure the imports embodied in exports that are used again in another production process are captured. In the original measure there are (at least) two production processes involved. When only looking at imports embodied in exports that are used again as inputs, it is guaranteed that at least three different production processes are linked together. However, the third production process might be in the country from which the original imports are sourced, there is an extra fragmented block.

As indicated in the data description, for the countries outside the region there is no distinction between the exports for intermediate use and the final demand exports. In order to be able to calculate the *IFS* values for intermediate exports it is assumed that the same percentage of exports is used in intermediate production in these other countries as the average percentage of intermediate exports in total exports of the countries within the region.

3.2 Export specialization

In the real world autarky prices are unobservable. Due to the problems with estimating the unobservable autarky prices, Balassa (1965) introduced the concept of 'revealed' comparative advantage. The proxy used in empirical research for comparative advantage is based on export specialization patterns. The idea is that when a country has a comparative advantage in the production of a good it will specialize in its production and hence export the good – as stated by the law of comparative advantage. The type of products a country exports can be taken to be indicative of the type and strength of the comparative advantage of a country

Theory indicates that export specialization, as measured by the revealed comparative advantage, occurs in line with existing comparative advantages of the countries. The comparative advantages of a country can be relatively better exploited in sectors where the factor that enjoys that comparative advantage, for example labour, is relatively important in the production process. This sector will have a production cost

advantage compared to the same sector in other countries without the comparative advantage. Exports of this particular sector will thus be relatively higher than the exports of the same sector in other countries. The same production cost advantage that leads to export specialization can be the force behind a larger extent of international fragmentation. A cost advantage will be a stimulant for the sector to produce the product that enjoys this cost advantage. The sector will specialize in the production of this product and will outsource the required inputs to countries that enjoy a comparative advantage in the production of these inputs. Sectors that display high levels of international fragmentation would then be expected to be the same sectors that are characterized by export specialization.

The additive measure of revealed comparative advantage (ARCA) as proposed by Hoen & Oosterhaven (2006) will be used to investigate in which industries a country is specialized. Country *S* has a revealed comparative advantage in industry *i* if the export share of industry *i* in total exports is larger than the share it has in the total exports of the reference countries. In this case it can be said that *S* is specialized in industry *i*. See equation (9).

$$ARCA_i^S = E_i^S \Big/ \sum_{i=1}^{63} E_i^S - \sum_{REF=1}^{9} E_i^{REF} \Big/ \sum_{REF=1}^{9} \sum_{i=1}^{63} E_i^{REF} \qquad \textbf{(9)}$$

The reference group consists of the other nine countries that are part of the Asian international input-output table. These countries are indicated by the abbreviation *REF*. The group of reference countries does not include the country for which the measure is calculated. Although each country is compared to a different group of reference countries, each country is more fairly compared. For example, large countries score higher on export specialization if they are not included in the reference group due to the large influence they would have on the reference group export specialization.

Country *S* has a revealed comparative advantage in industry *i*, if the export share of industry *i* in total exports is larger than the average share the sector has in the total exports of the reference countries. In this case it can be said that country *S* is specialized in industry *i*. If an industry does not have a comparative advantage or disadvantage the value of *ARCA* is zero. A comparative disadvantage results in values between –1 and 0, a comparative advantage results in values between 0 and 1.

The revealed comparative advantage is measured as the deviation of the sector's export share from the average export share of the same sector in the nine reference countries. For the *IF* shares a corresponding calculation will be made in order to be able to interpret the magnitude of the sector *IF* shares relatively to the same sector in the reference countries. See equation (10). Here *RIFS* refers to relative international fragmentation share. The *IFS* values that enter this equation are calculated using the international fragmentation measure as defined in equation (8).

$$RIFS_i^s = IFS_i^s - \sum_{REF=1}^{9} IF_i^{REF} \Big/ \sum_{REF=1}^{9} E_i^{REF} \qquad \textbf{(10)}$$

The correlation between the *ARCA* and the sector relative *IF* shares will be analyzed in order to see whether there is agreement between the two different kinds of specialization. If an association is found the (neo-)classical trade theory can provide explanations for the increase in international fragmentation. Each sector in each country will specialize in the good, or that part of the production chain, in which it has a comparative advantage.

3.3 Intra-industry specialization

Intra-industry specialization represents the deviation of sector *j*'s production process from the production process in general associated with sector *j*. It is assumed that deviations of the production process of a certain sector from the average production process imply that the sector in that specific country has specialized in producing differentiated goods. These differentiated goods are characterized by the use of different inputs and are in turn used as inputs by different downstream sectors. The (international) production chain a sector *j* participates in is thought to be represented by these backward and forward linkages related to this sector. Backward and forward linkages of sector *j* that are different from the backward and forward linkages of sector *j* in other countries indicate the presence of intra-industry specialization.

In an input-output model an element l_{ij} of the Leontief inverse represents the extra output that is needed from industry *i* in order to fulfil one extra unit of final demand for the product of industry *j*. (See also equations (5) and (6) and their accompanying texts.) They show the additional production of inputs, which are earlier or backward stages in the production chain. The elements are also often referred to as

multipliers, because they show all the extra output necessary for one more unit of final demand, including the production of the good itself and all the intermediate inputs included in each of the inputs used in the production chain. The magnitudes of the backward multipliers can be interpreted as indicative of type of production chain sector *j* participates in.

Comparably the Gosh forward linkages can be calculated. The Gosh supply model and its solution are given in equation (11).

$$\mathbf{x' = x'B + v} \quad \rightarrow \quad \mathbf{x' = v(I - B)^{-1}} \tag{11}$$

The **B** matrix is comparable to the **A** matrix, except that the elements represent output shares, i.e. all values in a row of the inter-sector transaction flows are divided by total output instead of all the values in a column as is the case for the **A** matrix.

The interpretation of the elements g_{ji} of the Gosh inverse matrix has been subject of a discussion on implied causality. Early interpretations assert that these elements show the extra production in sector *i* if there is one unit of extra value added available (one unit extra spend on wages) in sector *j*. Due to the increase in the value added in sector *j*, it can produce more. This additional amount is sold to each sector *i*, which increases the output of sector *i* by the ratio of inputs *j* sold to sector *i* over total production by *j*. In turn, sector *i* increases its outputs and sales to all other sectors due to the increase in inputs of *j* that have become available (Miller and Blair, 1985). Oosterhaven (1988) uncovers problems with the implied causality and its economic interpretation in this quantity version of the Gosh model. However, he also argues that usage of the Gosh model for descriptive purposes is acceptable. In this study the forward linkages combined with the backward linkages are used as indicator of the deviation of a sector *i*'s production chain from the average production chain a sector *i* is associated with.

Intra-industry specialization is measured along two dimensions. The first measure focuses on the total length of the international production chain while the second measure represents the relative location of the sector in the international production chain compared to the same sector in other countries. The country values as reported in section 4 are obtained by calculating the average percentage deviation of the sector values.

3.3.1 Intra-industry specialization total length measure

From each backward linkage and forward linkage of sector *j* the (absolute) difference is calculated from the average backward and forward linkage sector *j* in the reference countries has to each of these sectors. All these differences are summed up to one overall indicator of the intra-industry specialization of the sector. In correspondence to the export specialization measure, the difference of the average linkage of the same sector in the other nine countries will be deducted from the country specific value of that sector in order to find the deviation of the production chain of sector *j* from the average. See equation (12). The abbreviation *RIIS*1 is used to reflect the fact that the measure gives an indication of the relative intra-industry specialization of a sector based on the total length of the production chain in which it participates.

$$RIIS1_j^S = \sum_{R=1}^{10}\sum_{i=1}^{63}\left[\left| l_{ij}^{\bullet S} - \frac{1}{10}\sum_{REF=1}^{10} l_{ij}^{\bullet REF}\right| + \left| g_{ji}^{S\bullet} - \frac{1}{10}\sum_{REF=1}^{10} g_{ji}^{REF\bullet}\right|\right] \qquad \textbf{(12)}$$

3.3.2 Intra-industry specialization relative position measure

For this measure the backward linkage $l_{\bullet j}$ is divided by the total length of the production chain ($l_{\bullet j} + g_{j\bullet}$) to get an indication of the position of the sector. If the backward linkage is exactly as large as the forward linkage the result of the calculation is ½. If the backward linkage is larger than the forward linkage the measure will be larger than ½, and if the forward linkage is larger the measure will be smaller than ½.

In correspondence to the export specialization measure, the average position of the same sector in all ten countries will be deducted from the country specific value of that sector in order to find the deviation of the country from the average position. See equation (12). In this measure • refers to all countries including the country that the measure is calculated for. *RIIS*2 is used to denote relative intra-industry specialization based on the position of an industry in the international production chain.

$$RIIS2_i^S = \left| \frac{l_{\bullet j}^{\bullet S}}{l_{\bullet j}^{\bullet S} + g_{i\bullet}^{S\bullet}} - \sum_{REF=1}^{10} l_{\bullet j}^{\bullet REF} \Big/ \sum_{REF=1}^{10}\left(l_{\bullet j}^{\bullet REF} + g_{i\bullet}^{\bullet REF}\right)\right| \qquad \textbf{(13)}$$

The larger the absolute value of this deviation the more the product of this sector deviates from the product of the same sector in the other countries. This measure

also indicates a larger degree of specialization, in this particular case related to product differentiation. The results for this differentiation measure are compared to the results for the international fragmentation and the export specialization measures.

3.4 Methods for comparison

In the next section the results of the different measures are compared using straightforward techniques. Scatter plots are used to visually inspect the relationship between the measures. Correlation coefficients are then calculated to obtain a quantitative result. The sample correlation coefficient r_{xy} can be used to determine whether there is a significant linear relationship between the variables x and y. The following hypotheses are tested about the population correlation coefficient ρ_{xy}. The null hypothesis is H_0:$\rho_{xy} = 0$. The alternative hypothesis is H_a:$\rho_{xy} \neq 0$. The test statistic is defined in (14).

$$t = r_{xy}\sqrt{\frac{n-2}{1-r_{xy}^2}} \qquad \textbf{(14)}$$

Here n is the number of observations. The rejection rule is stated as follows: reject the null hypothesis if $t < -t_{\alpha/2}$ or if $t > t_{\alpha/2}$, where $t_{\alpha/2}$ is based on a t distribution with $n - 2$ degrees of freedom. This means that if the null hypothesis can be rejected there is a significant linear relationship between the variables.

4. Results and discussion

In this chapter the results of the discussed methodologies are presented. The chapter is divided into sections that correspond to the research questions. All calculations are on basis of the 63 sector tables from which the unclassified sector is removed.[6]

4.1 Three measures of international fragmentation

The first step in the characterization of the international fragmentation in East Asia is undertaken by using the Hummels *et al.* (2001) specification of the international fragmentation measure; $\mathbf{u'A_M(I - A_D)^{-1}s}$. This initial measure can be applied at two levels in the international input-output tables. First it can be applied at the national

[6] The extent of international fragmentation has also been calculated for 64 and 78 sectors for the 1990 and 1995 tables. With a decrease in the number of sectors the *IFS* values decrease. However, this effect can only be seen at the third or fourth significant digit of the values.

level. In this case the international tables are reduced to country tables by aggregating all endogenous and exogenous import matrices into a single national import matrix, and all endogenous export matrices and exogenous export vectors into a single export vector per country. The export vector is then normalized by dividing each element by the value of total exports.

The results of the calculations can be found in Figure 6. The countries in the figure are displayed according to their ranking of total value added. The results are comparable to the results of Hummels *et al*. (2001) for the nine OECD countries between the years 1970 and 1990. They note that the small countries appear to have the largest IF shares. In our case, comparing the IF shares to country rankings on the basis of value added, we can conclude that indeed the United States and Japan have the lowest shares and the highest value added. When considering the geographic size of the countries Indonesia is the third largest country behind the United States and China[7]. However, next in size is Korea and only then Japan, so this also only partly explains the IFS values. For the rest of the countries there is not a clear relationship between the IFS and value added rankings[8].

Figure 6

Without exception the growth rates for the second period 1995 – 2000 are larger than the growth rates for the first period. In the period 1990 – 1995 there are even three negative growth rates relating to Japan, Korea and Singapore. The increase in their self-reliance might be due to several reasons that cannot be derived from this table. Possibly, the decline in their international fragmentation shares is related to their development level and corresponding industry structure.

The single most important event during the 1990 – 2000 decade in terms of impact on the region was the Asian crisis of 1997. According to the growth rates for the 1995 to 2000 period the international fragmentation shares more likely increased due to the crisis than that they reduced. This is somehow unexpected as crises in generally make countries more inward focused. It can be concluded here that despite the Asian crisis these countries have increased the foreign sourcing of their inputs required in the production of their exports.

[7] See for the geographical sizes Appendix B: Table 1.

The national international fragmentation shares as displayed in Figure 6 do not reflect the additional information on bilateral linkages of the international Asian input-output table. The international fragmentation shares calculated on basis of the full information contained in the international table are displayed in Figure 7. These values have been calculated using equation (8). The overall picture is the same as the results of the national method. The values displayed in Figure 7 are substantially larger than the values calculated with the Hummels *et al.* (2001) national measure. Each IFS value is approximately increased by 2/3 of the value of the measure based on the national tables due to the inclusion of international linkages[9]. In both tables Singapore has by far the largest extent of international fragmentation in 1990, but in Figure 7 several other countries display an extent of fragmentation comparable to Singapore in 2000. However, if the countries would be ranked according to *IFS* values both tables would lead to almost the same rankings for all years. Thus the relative extent of fragmentation does not change qualitatively when applying the international measure.

Figure 7

The growth rates have increased in comparison with the values based on the national measure. The negative growth rates for Japan and Korea have vanished. Remarkable are the increased growth rates (for the total period) of Japan and China. The source of the growth rate difference between the two types of measures is related to the inclusion of the non-domestic Leontief linkages in the international analysis. These multipliers have increased relatively more for Japan and China indicating an increased reliance on inputs sourced in other countries in the region. The international fragmentation shares of China, combined with its economic size indicate that this country is becoming very important in the Asian production structure.

Comparing the growth rates of the first period between the two tables all countries show larger (or less negative) rates in case of the international measure. In contrast, when comparing the growth rates of the second period four countries (the United States, Korea, Indonesia and Singapore) have a lower growth rate in the second table. This indicates that the source of the growth in international fragmentation in the

[8] The overview of these rankings can be found in Appendix B: Table 2.
[9] See Appendix B: Table 3 for the changes in the values using the international method instead of the national method.

first period is the increase in non-domestic Leontief linkages. In the second period the increase of the *IFS* values results from an increase of the domestic Leontief linkages.

The *IFS* values presented in Figure 7 are calculated using the international method and only including intermediate exports. Here it is interesting to note that for almost all countries the year 1995 shows a fall back in the *IFS* value, while in the year 2000 there is a large increase, which in several countries even increases to twice the earlier value. Comparing Figure 8 with Figure 7 it can be said that in the year 2000 there is a large increase in the imports of inputs that are stimulated by intermediate exports compared to final demand exports.

Figure 8

4.2 International fragmentation and export specialization

4.2.1 RIFS and ARCA results

In order to compare the three types of specialization all measures are calculated as relative values, using the sector average value of the other nine countries as reference. First, the results of the relative international fragmentation share *(RIFS)* computations are briefly presented, as they are directly related to the results presented in the previous section. The *RIFS* values are calculated using only intermediate exports, which is the most restrictive type of international fragmentation. Next, the additive revealed comparative advantage *(ARCA)* values are reported. Finally, these two types of specialization are compared.

The calculated *RIFS* values for each country are presented in Figure 9. These are simple summations of the sector *RIFS* values. A larger value indicates that the country, on average, is more fragmented than the countries with lower values. Singapore has the largest relative fragmentation share in 1990, but is overtaken by Malaysia in 2000. Both Malaysia and the Philippines substantially increase their relative fragmentation shares. Again, Indonesia does not fit into the picture when considering a possible relationship between the size of the economy in terms of value added and the *RIFS* value. The fact that Singapore is a city without an agricultural hinterland explains the very high relative fragmentation share. However, the increased integration of the economies due to the creation of international production chains have caused some of

the other countries to reach the same level of fragmentation as Singapore. The *RIFS* values of the U.S. and China become more negative in both the year 1995 and 2000.

Figure 9

Figure 10 shows the relative export specialization (*ARCA*). The sector values are summed again over the countries, and the total is divided by 2, which results in a range of theoretically possible values of zero to one. When a country has an export package precisely equal to the package of the reference countries the value will be zero. When a country is completely specialized and has a unique export packages the value will be one. A larger value therefore indicates a larger extent of export specialization of a country.

Figure 10

The most striking result is that the *ARCA* value of almost all countries declines over the years, indicating that each country's export package is becoming more like the rest. Trade is probably more and more of the intra-industry type. Export shares of each individual sector per country are converging to the export shares that the same industry has in total exports of the reference group. This indicates a reduction in the sector specialization of each country in the Asian production network. Also intriguing is the fact that Indonesia has the largest values of relative export specialization in contrast to the relatively low values of international fragmentation. This indicates that Indonesia primarily exports products that do not use (or only a limited amount) of imported inputs and has a comparative advantage in the production of these goods. Sectors that come to mind are the ones referred to as primary sectors, like agriculture and fishing. A point that has to be kept in mind is that the aggregate 63 sector level does not differentiate between specific kinds of products produced by these sectors and the quality of the products.

4.2.2 Correlation analysis of specialization and fragmentation

The scatter plots of the 1990, 1995 and 2000 series of the ARCA and RIFS values that include all countries and all sectors can be seen in respectively Figure 11, Figure 12, and Figure 13. The reported correlation coefficients are thus based on 630 observations. These plots are drawn for all the values, without making a country distinction. It can be seen that most values are clustered around zero and that there are relatively few values

outside of the cluttered area. The values that are individually identifiable, because they are outside the cluttered area, are labelled to get an impression of the sectors that might be thought of as outliers. Sector 47, Electronics and electronic products, may be noted in this respect as it is labelled on most relatively extreme values. The correlation coefficient increases over the time period, but most of this change is probably caused by shifts in the extreme observations.

Figure 11

Figure 12

Figure 13

The results give a strong indication that there is indeed a relationship between international fragmentation and export specialization. In the literature review it has been argued that the export specialization measure is a well-established proxy for comparative advantage. The correlation coefficients can then be interpreted to show that international fragmentation also occurs following the pattern of comparative advantage.

In Table 2 the correlation coefficients of the individual country values of *ARCA* and *RIFS* based on 63 sectors are shown. Most correlation coefficients are significantly different from zero at the one percent significance level. All coefficients of Japan are not significant. The coefficients for Thailand in 1990 and 1995, and the coefficient for the Philippines in 1995 are also not significant at the 1 percent significance level. In general there is an increase in the correlation coefficients of these two series, indicating that the sectors in which the country has a comparative advantage are more and more also the sectors that are characterized by a relatively large extent of fragmentation. Japan seems to be a strange outlier with its very low correlation between the two series. For the years 1990 and 1995 there is even a negative correlation of the *ARCA* and *RIFS* series. Except for Thailand and Japan the correlation coefficients are rather high and for Taiwan, Singapore, Malaysia, and the Philippines they are even larger than 0.9. These results give a strong indication that there is indeed a relationship between international fragmentation and export specialization. In the literature review it has been argued that the export specialization measure is a well-established proxy for comparative advantage. The correlation coefficients can then be interpreted to show that international fragmentation also occurs following the pattern of comparative advantage.

Table 2

4.3 Intra-industry specialization

First, in this section the results of the calculations of intra-industry specialization of the Asian sectors are described. First the results for *RIIS*1 are presented, then the results for *RIIS*2. Second, the relationships with the revealed comparative advantage (*ARCA*) and the relative international fragmentation share (*RIFS*) are investigated.

4.3.1 Relative intra-industry specialization total length measure

A sector's relative intra-industry specialization is based on the deviation of the backward linkages and forward linkages of a sector from the average linkages associated with the sector. A larger value of this measure is taken to represent the intra-industry specialization of a sector compared to the same sector in other countries. The country measures of relative intra-industry specialization are the average percentage deviations of the sector values. The results are shown in Figure 14.

Figure 14

The values obtained for the *RIIS*1 measure show high values, so higher intra-industry specialization, for the larger countries. China has by far the highest scores of the *RIIS*1 values. The backward linkages and forward linkages of the Chinese sectors can be concluded to be relatively different than the average backward and forward linkages of the same sectors in the nine reference countries. This is interpreted to mean that the Chinese sectors are characterized by (more) intra-industry specialization. The fact that China is still a transition economy from a communist to a market economy may (partially) explain this result.

4.3.2 Relative intra-industry specialization position measure

The results for the intra-industry specialization measure that are based on the relative position of the sector in the international production chain of which it is part are shown in Figure 15. Here the picture is rather mixed. China, Taiwan and Singapore are found to have sectors that are positioned towards the end of the international production chain.

Figure 15

4.3.3 Intra-industry specialization, export specialization and fragmentation

The correlation coefficients of the intra-industry specialization measure *RIIS*1 and *RIIS*2 with *RIFS* are shown in Table 3. These values indicate that there is no reason to conclude that either *RIIS* variable is convincingly related to relative fragmentation (*RIFS*) of a sector. The *RIIS*1 measure scores best. Some of the values are significant at the 1 percent confidence level. However, the correlation coefficients of the *ARCA* and *RIFS* values are much higher. Most of the correlation coefficients even show a negative sign, while the hypothesized relationship is positive.

Table 3

The scatter plots of 1990, 1995 and 2000 of the alleged relationships are all quite alike. Therefore only two of them are presented here, of each relationship one and both relating to the year 2000. The scatter plots for the years 1990 and 1995 can be requested from the authors. Both scatter plots indicate a very weak, or no, relationship between international fragmentation and relative intra-industry specialization.

Figure 16

Figure 17

5. Conclusion

Globalization is a process often written about, but extensive empirical evidence to create supporting evidence for case study results and general observations has fallen behind. This thesis is an attempt to provide empirical evidence related to the increase in global business networks and international production linkages.

The main focus of this thesis is the extent of international fragmentation in East Asia, its alleged enormous increase, and how it can be related to international trade theory. Accepting the premise that a country specializes in the production of the good in which it has a comparative advantage is at the core of (neo-)classical trade theory. A well-established proxy for comparative advantage is the export specialization of a country. An investigation of the relationship between export specialization and international fragmentation can answer the question whether international fragmentation indeed follows the pattern of comparative advantage. New trade theory has been

developed to explain the rise in intra-industry trade and specialization. The increase in international fragmentation is a contemporary development of the rise of intra-industry trade. As intra-industry specialization is explained by new trade theories, these theories might also offer an explanation for international fragmentation.

The extent of fragmentation is shown to considerably increase over the period investigated. The fact that this increase is primarily observed in the period 1995 – 2000 is somewhat difficult to account for, as the region was hit by the Asian crises in 1997. The large extent of fragmentation of Singapore is easily explained by the fact that it is more or less a city state. There is literally little space for extensive industrial operations. However, it can clearly be observed that other countries in the region, and more specific the countries that are still the least developed ones (included in the study), are substantially increasing their extent of fragmentation – almost up to the level of Singapore. This indicates a shift in the prominence of countries in the international production chains that have been established in the region and beyond.

Next, the definition of *IFS* is extended to measure a larger extent of fragmentation by focusing on (at least) three production processes that are internationally linked instead of two. This is achieved by measuring the imported inputs in intermediate exports instead of in total exports, which may also be exported to satisfy final demand. Using the international method to calculate *IFS* values, and only looking at the intermediate exports, the largest deviations from the *IFS* values related to total exports are obtained. These results show that for all countries the *IFS* values of intermediate exports fall considerable in 1995 compared to 1990, and rise substantially in 2000 compared to the 1995 value. The reduction in the values may be related to the prelude of the Asian crises as all countries seem to experience this reduction in international linkages. The crises itself will have contributed to the fact that all production processes had to become more efficient, which will have stimulated fragmentation in order to reap to benefits of lower production costs in surrounding countries.

The analysis further indicates a positive relationship between export specialization, a measure related to (neo-)classical trade theory, and the extent of international fragmentation. Based on theory it can be assumed that the driving force behind both the export specialization and the international fragmentation is the

comparative advantage of a country. This is an indication that international fragmentation might be a rather recent phenomenon but is related to the well-know division of labor concept as introduced by Adam Smith. International fragmentation increases the opportunities for companies to source activities in the country that can undertake them at the lowest cost. These lower production cost give any products that can profit from these lower cost an advantage in the export market, hence increasing the share the sector has in the total exports of a country. International fragmentation increases the efficiency of the production of goods making use of the lowest factor cost that prevail anywhere in the world.

For intra-industry specialization there is no clear relation with the export specialization and international fragmentation of a sector. However, contributions to the literature have indicated that product variety does matter for international trade and the pattern of specialization. It is likely that the measure based on multipliers is to crude a measure to pick up real product differentiation. The rather arbitrary nature of classifications might also play a role. Trade data is classified according to product type. Several product types can be aggregated to a product group, which can be aggregated to even higher level groups until all trade is included. Which industry has produced the product is not reflected in the classification. Also quality differences may not be reflected in the data. It is common to denote a product group as being produced by a certain industry. If a country then exports these products, but also imports products from the same product group it is referred to as intra-industry trade. However, which products precisely belong to this product group and which level of aggregation of products is used to denote an industry, directly influences what is seen as intra-industry and inter-industry trade. Schott (2004) observes in this respect that unit values of traded products vary widely even if the product classification is very detailed.

Further research may include an investigation of the origin of the imported inputs with the purpose of establishing which countries rely more on inputs from within the region and which are more oriented towards the rest of the world.

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Tables:

Table 1

Table 1 – Modes of fragmentation

Ownership / Location	***- National fragmentation -*** Within national borders	***- International fragmentation*** **-** Across national borders
Integrated in firm	Domestic investment	Foreign direct investment
Outside of firm	National outsourcing	International outsourcing

Table 2

Table 2: Correlation coefficients of the *RIFS* and *ARCA* series

	1990	1995	2000
U.S.	0.62	0.75	0.74
	(6.09)	(8.73)	(8.70)
Japan	-0.18	-0.26	0.00
	(-1.47)	(-2.10)	(-0.01)
China	0.65	0.74	0.58
	(6.71)	(8.61)	(5.62)
Korea	0.46	0.79	0.75
	(4.03)	(9.96)	(8.80)
Taiwan	0.53	0.68	0.92
	(4.90)	(7.20)	(18.49)
Indonesia	0.62	0.70	0.68
	(6.19)	(7.63)	(7.22)
Thailand	0.12	0.19	0.44
	(0.92)	(1.47)	(3.84)
Malaysia	0.58	0.87	0.92
	(5.56)	(13.85)	(18.34)
Singapore	0.92	0.94	0.92
	(18.54)	(22.25)	(18.76)
Philippines	0.41	0.06	0.87
	(3.46)	(0.50)	(13.76)

Each correlation coefficient is based on 63 observations
t-statistics in brackets, the 1% critical *t*- value for *n*=60 is 2.66
Source: Asian input-output tables of 1990, 1995, and 2000 + author's calculations

Table 3

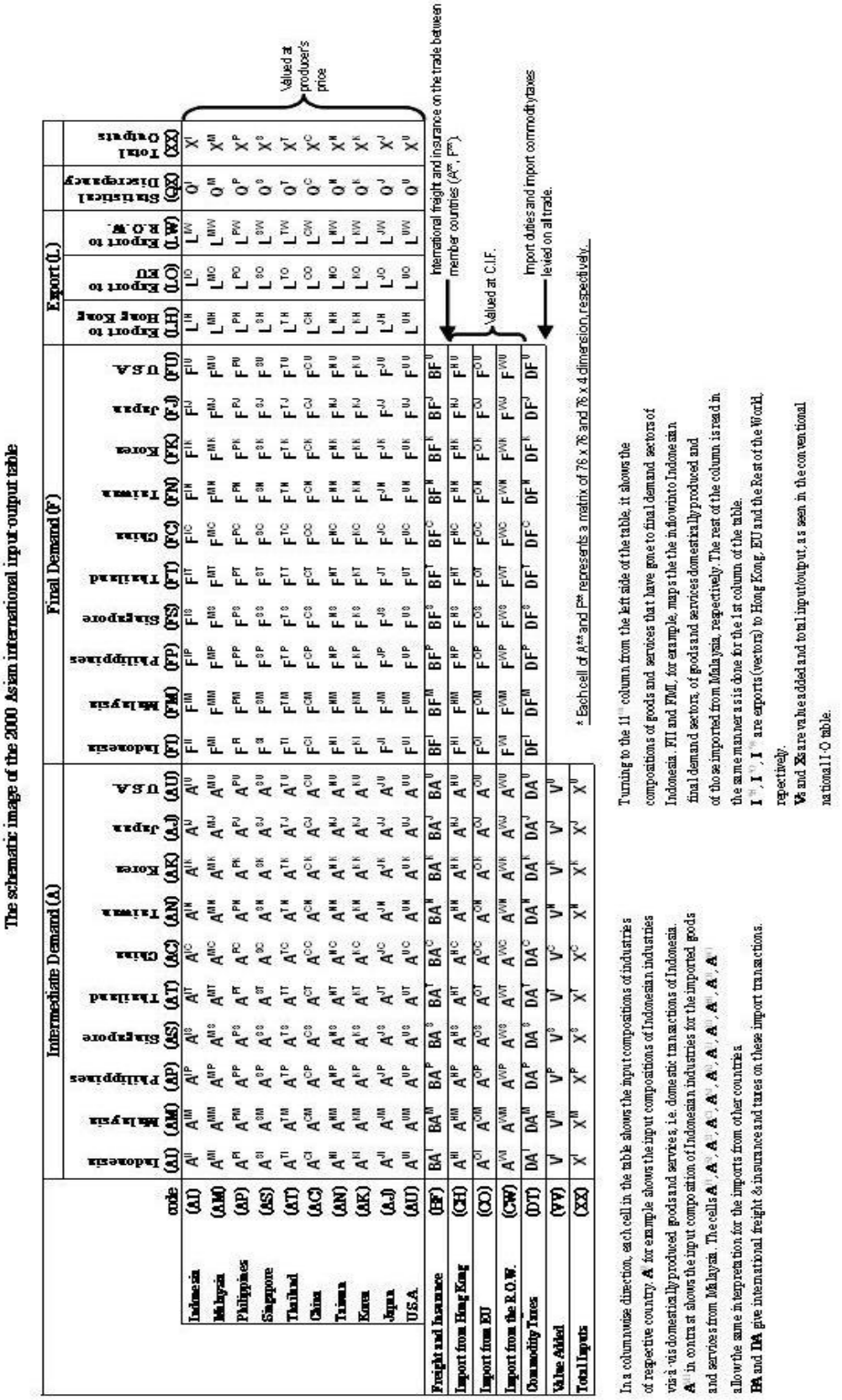
Table 3: Correlation coefficients of *RIFS – RIIS*1 and *RIFS – RIIS*2

	*RIFS – RIIS*1				*RIFS – RIIS*2		
	1990	1995	2000		1990	1995	2000
U.S.	0.20	0.23	0.31		0.06	0.10	0.05
	(1.61)	(1.81)	(2.51)		(0.48)	(0.77)	(0.36)
Japan	0.20	0.22	0.31		0.11	0.02	0.02
	(1.62)	(1.80)	(2.56)		(0.84)	(0.15)	(0.13)
China	0.17	0.22	0.32		-0.11	-0.07	-0.02
	(1.38)	(1.77)	(2.65)		(-0.84)	(-0.51)	(-0.14)
Korea	-0.12	-0.18	-0.21		0.07	-0.02	-0.01
	(-0.92)	(-1.40)	(-1.65)		(0.56)	(-0.19)	(-0.06)
Taiwan	-0.17	-0.16	-0.26		0.09	0.21	0.03
	(-1.37)	(-1.31)	(-2.14)		(0.70)	(1.70)	(0.23)
Indonesia	0.28	0.29	0.39		0.05	0.11	-0.13
	(2.26)	(2.34)	(3.30)		(0.43)	(0.87)	(-0.99)
Thailand	-0.31	-0.22	-0.34		0.20	0.10	0.07
	(-2.53)	(-1.78)	(-2.83)		(1.63)	(0.80)	(0.56)
Malaysia	-0.14	-0.26	-0.31		-0.01	-0.02	0.06
	(-1.08)	(-2.07)	(-2.53)		(-0.09)	(-0.17)	(0.45)
Singapore	-0.12	-0.21	-0.27		0.07	0.12	-0.09
	(-0.94)	(-1.66)	(-2.17)		(0.52)	(0.92)	(-0.71)
Philippines	-0.40	-0.26	-0.30		0.02	-0.05	-0.09
	(-3.36)	(-2.08)	(-2.42)		(0.16)	(-0.42)	(-0.73)

Each correlation coefficient is based on 63 observations
t-statistics in brackets, the 1% critical *t*- value for *n*=60 is 2.66
Source: Asian input-output tables of 1990, 1995, and 2000 + author's calculations

Figures:

Figure 1



Source: Inomata *et al*. (2006), online available at (last accessed, 19-08-2007): http://www.ide.go.jp/Japanese/Publish/Books/Tokei/xls/AIO(85-00).xls

Figure 1: Layout of the Asian input-output table

Figure 2

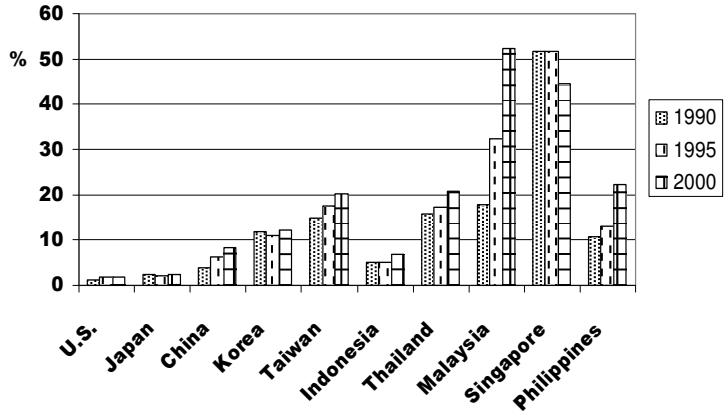


Figure 2: Imports of intermediate products

Figure 3

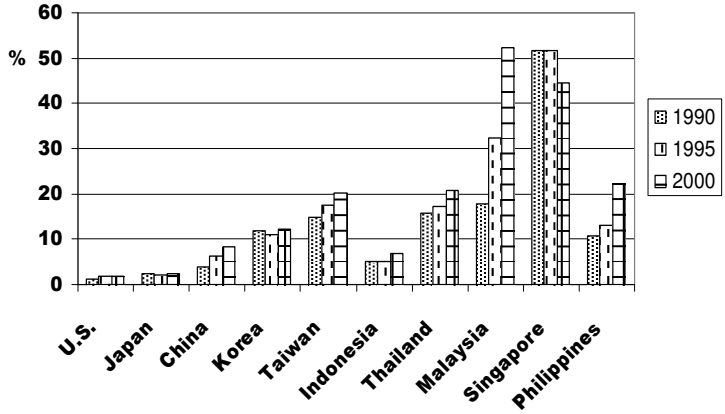


Figure 3: Imports of intermediate products from the region

Figure 4

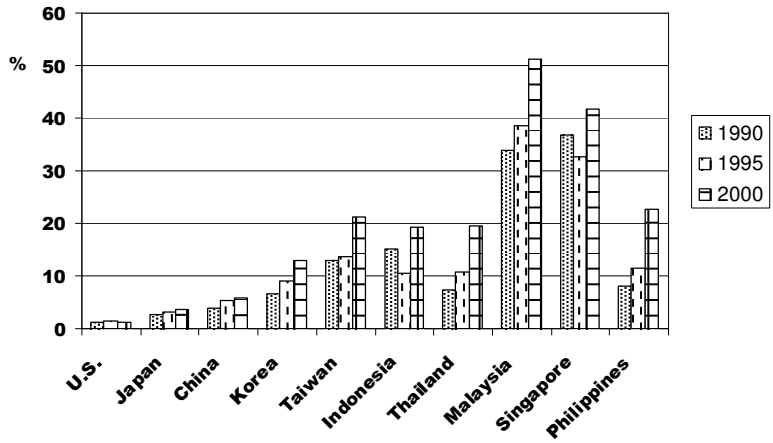


Figure 4: Total exports

Figure 5

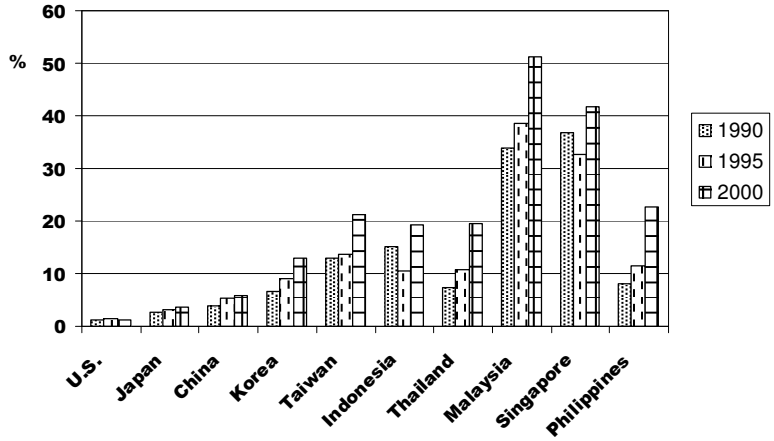


Figure 5: Exports of intermediate goods to the region

Figure 6

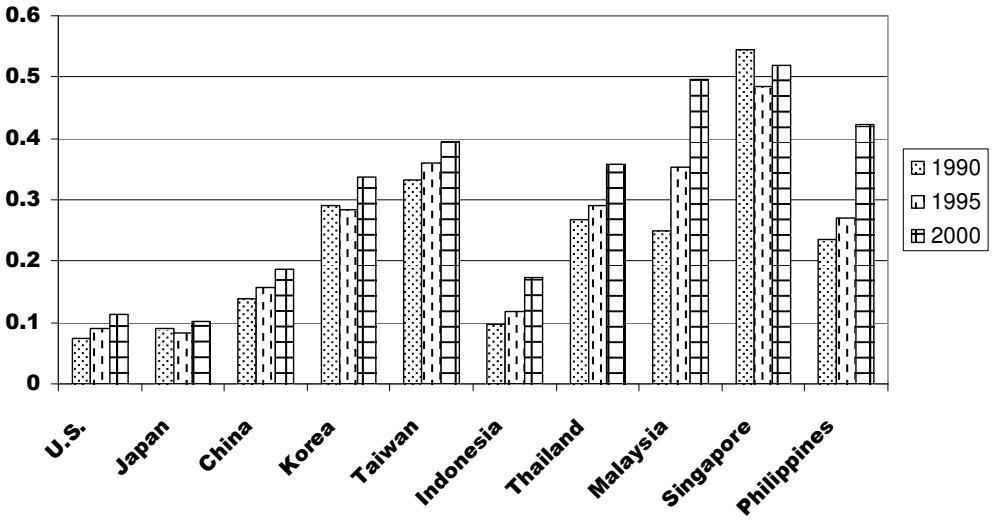


Figure 6: *IFS* values based on the national method

Figure 7

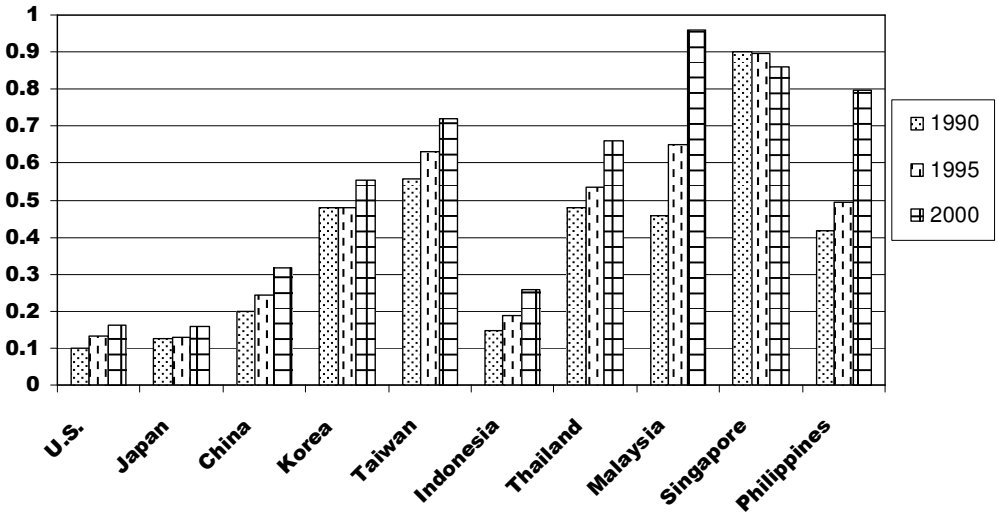


Figure 7: *IFS* values based on the international measure

Figure 8

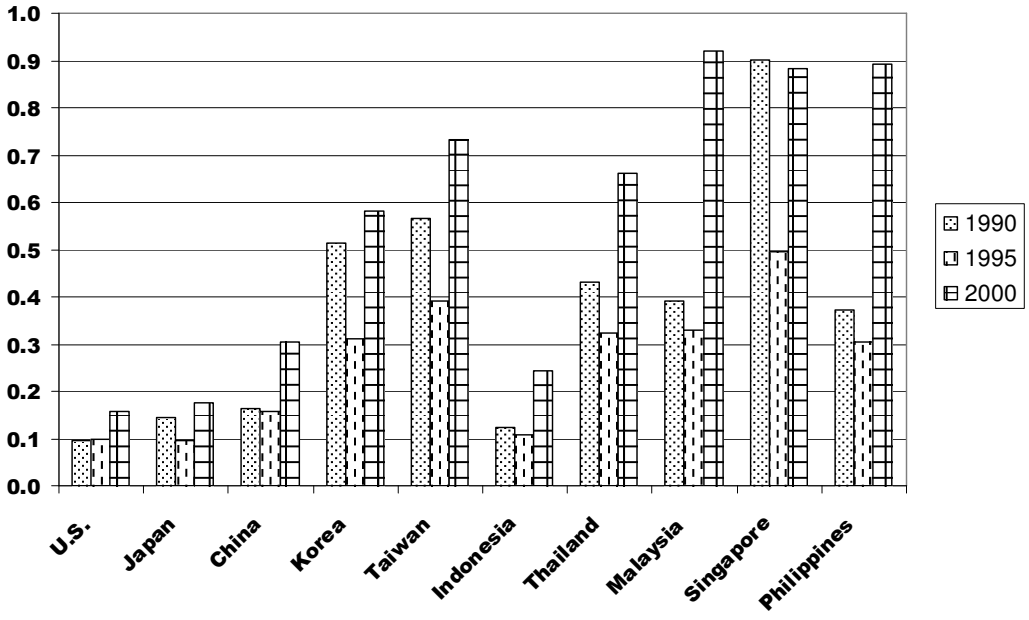


Figure 8: IFS values (international method) only including intermediate exports

Figure 9

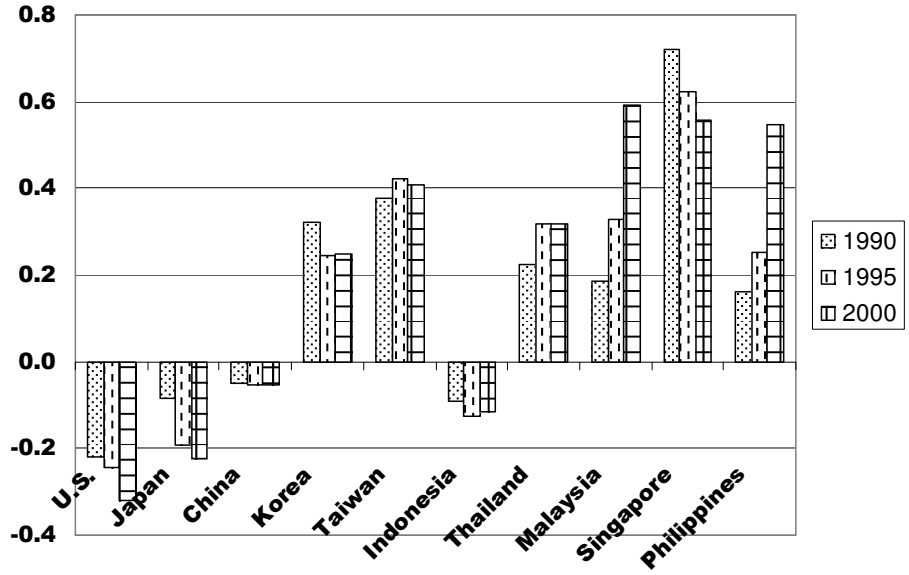


Figure 9: Relative fragmentation shares including only intermediate exports

Figure 10

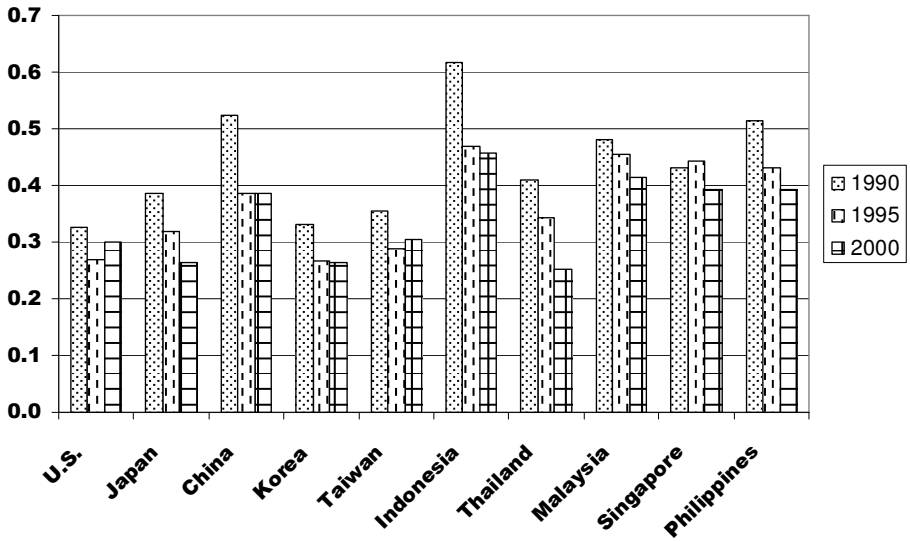


Figure 10: Relative export specialization (*ARCA*)

Figure 11

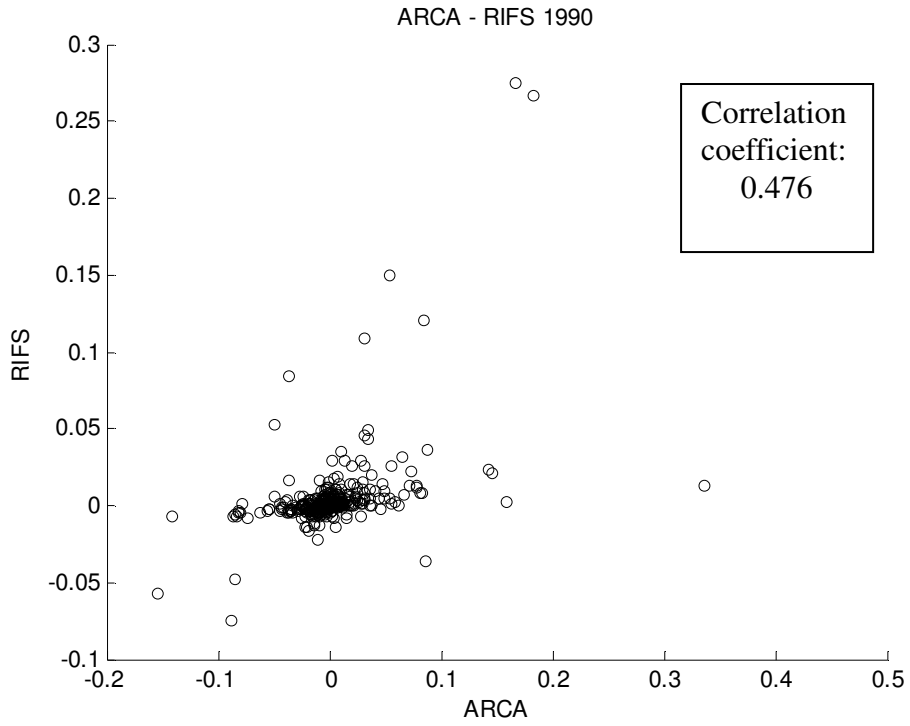


Figure 11: Scatter plot of *ARCA* and *RIFS*, 1990

Figure 12

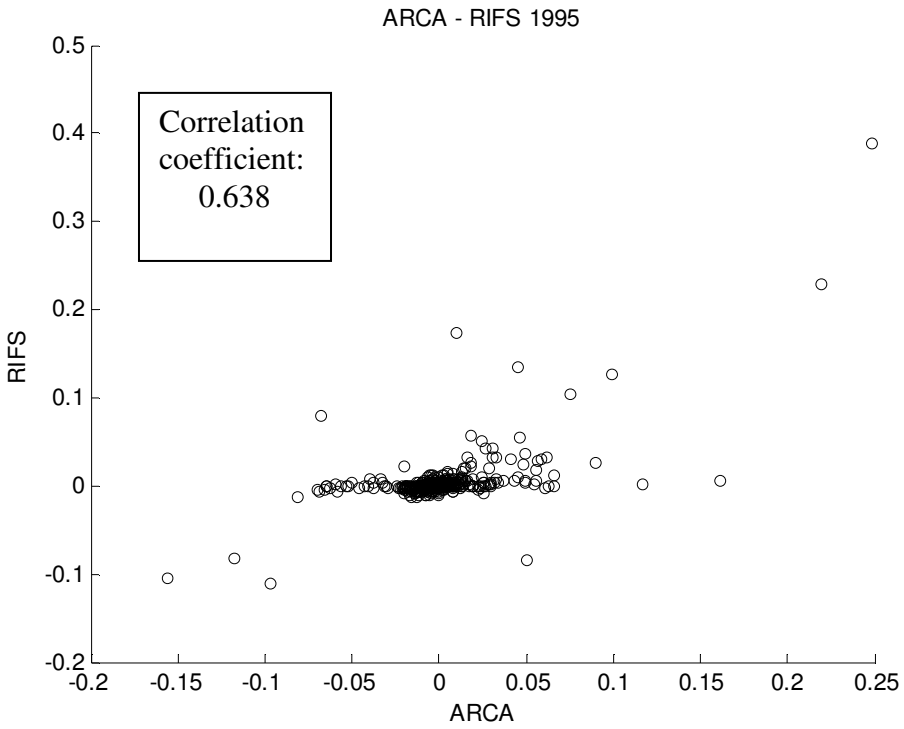


Figure 12: Scatter plot of *ARCA* and *RIFS*, 1995

Figure 13

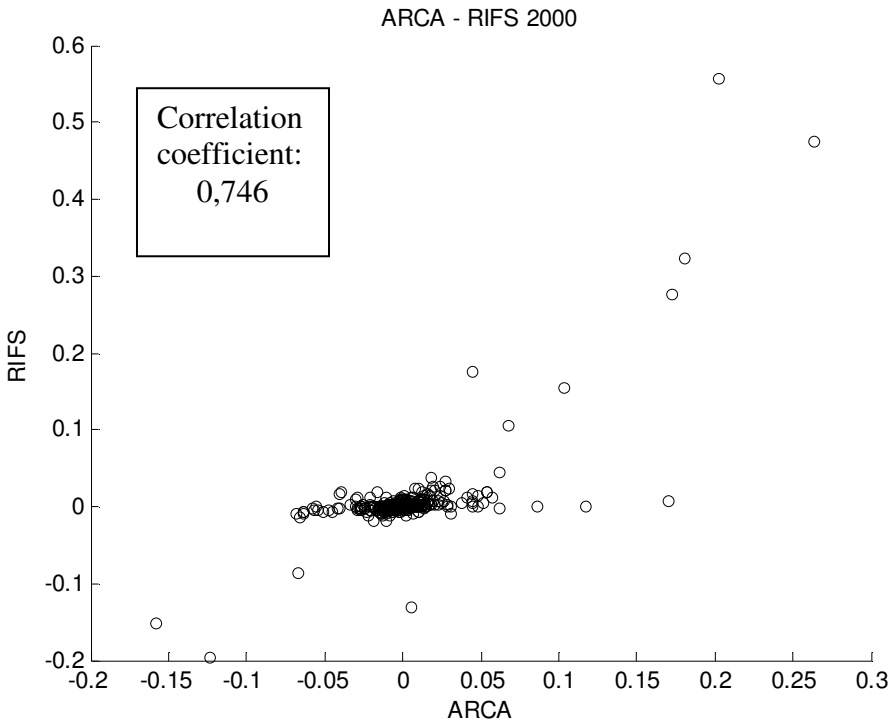


Figure 13: Scatter plot of *ARCA* and *RIFS*, 2000

Figure 14

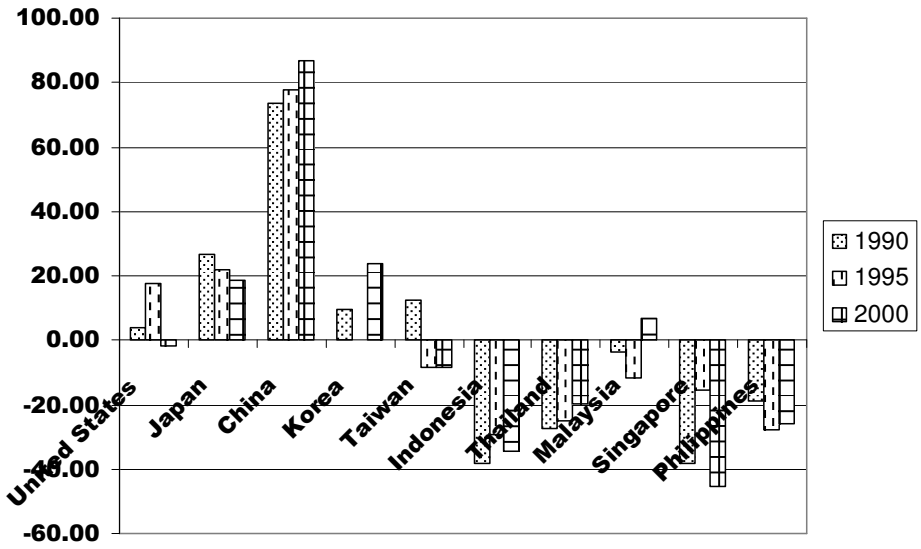


Figure 14: Relative intra-industry specialization total length measure

Figure 15

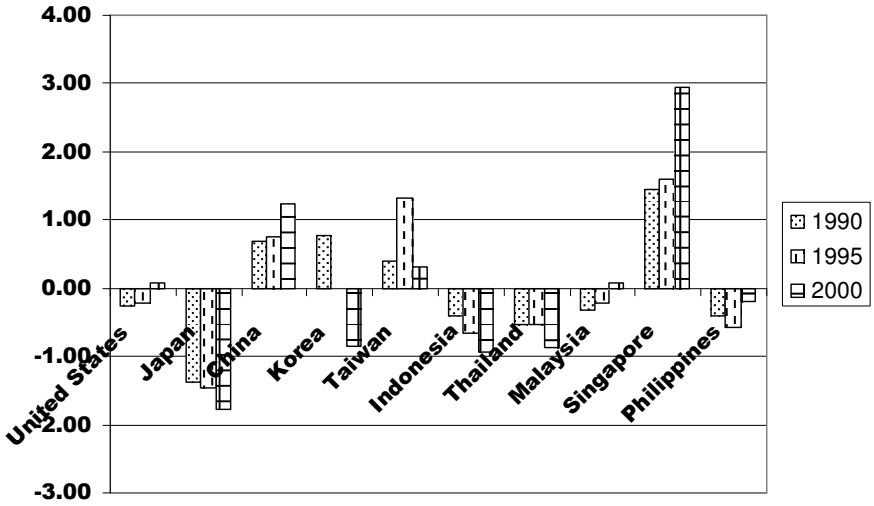


Figure 15: Relative intra-industry specialization position measure

Figure 16

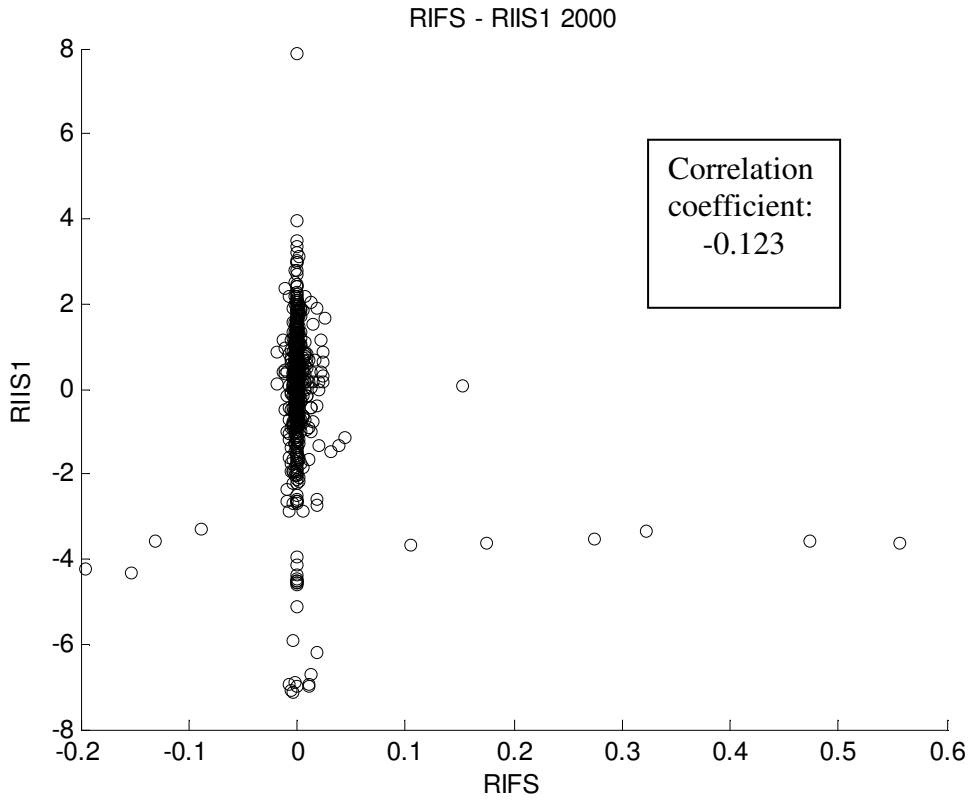


Figure 16: Scatter plot of *RIFS* and *RIIS1* for the year 2000

Figure 17

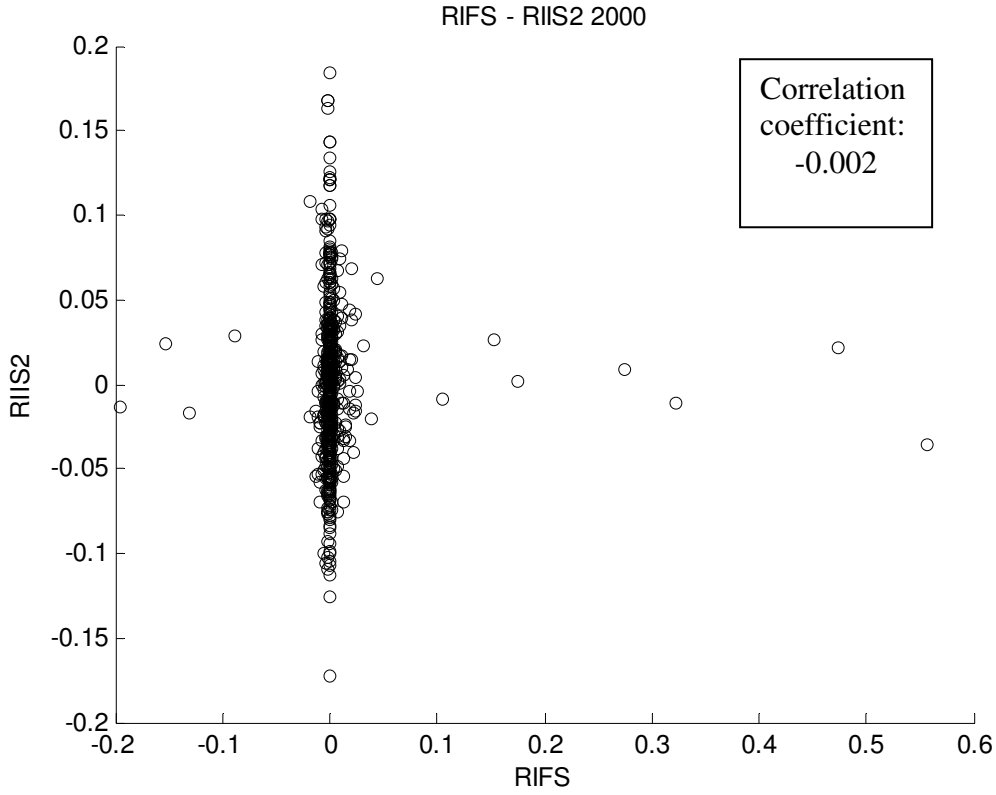


Figure 17: Scatter plot of *RIFS and RIIS*2 for the year 2000

Appendix A

Unified Classification of the 1990, 1995, and 2000 Asian International Input-Output Table			
64 Sector Classification			
Code	Sector name	1990 & 1995	2000
INTERMEDIATE SECTORS			
001	Paddy	001	001
002	Other grain	007A	002
003	Food crops	=002+004+005+007B	003
004	Non-food crops	=003+006+008	004
005	Livestock and poultry	009	005
006	Forestry	010	006
007	Fishery	011	007
008	Crude petroleum and natural gas	012	008
009	Iron ore	015A	009
010	Other metallic ore	=013+014+015B	010
011	Non-metallic ore and quarrying	016	011
012	Milled grain and flour	=018+019	012
013	Fish products	021A	013
014	Slaughtering, meat products and dairy products	021B	014
015	Other food products	=017+020+021C	015
016	Beverage	022A	016
017	Tobacco	022B	017
018	Spinning	023	018
019	Weaving and dyeing	024	019
020	Knitting	025	020
021	Wearing apparel	026	021
022	Other made-up textile products	027	022
023	Leather and leather products	028	023
024	Timber	029	024
025	Wooden furniture	030A	025
026	Other wooden products	030B	026
027	Pulp and paper	031	027
028	Printing and publishing	032	028
029	Synthetic resins and fiber	033A	029
030	Basic industrial chemicals	033B	030
031	Chemical fertilizers and pesticides	034	031
032	Drugs and medicine	035A	032
033	Other chemical products	035B	033
034	Refined petroleum and its products	036	034
035	Plastic products	050A	035
036	Tires and tubes	037	036
037	Other rubber products	038	037
038	Cement and cement products	039	038
039	Glass and glass products	040	039
040	Other non-metallic mineral products	041	040
041	Iron and steel	042	041
042	Non-ferrous metal	043	042
043	Metal products	044	043
044	Boilers, Engines and turbines	045E	044
045	Machinery	=045A+045B+045C	=045+046+047
046	Heavy Electrical equipment	045D	048
047	Electronics and electronic products	046A	=049+050+051+052
048	Other electric machinery and appliance	046B	=053+054
049	Motor vehicles	047A	055
050	Shipbuilding	048B	057
051	Other transport equipment	=047B+048A+048C	=056+058
052	Precision machines	049	059
053	Other manufacturing products	050B	060
054	Electricity, gas and water supply	051	=061+062
055	Building construction	052A	063
056	Other construction	052B	064
057	Wholesale and retail trade	053A	065
058	Transportation	053B	066
059	Telephone and telecommunication	054A	067
060	Finance and insurance	054B	068
061	Education and research	054C	070
062	Other services	054D	=069+071+072+073+074
063	Public administration	055	075
064	Unclassified	056	076

Appendix B

Appendix B: Table 1: Ranking by geographical size of the countries

	total sq. km.
United States	9,826,630
China	9,596,960
Indonesia	1,919,440
Thailand	541,000
Japan	377,835
Malaysia	329,750
Philippines	300,000
Korea	98,480
Taiwan	35,980
Singapore	692,7

Source: CIA World factbook,
www.cia.gov/library/publications/the-world-factbook/, last accessed: 13-1-2008
Except Taiwan – www.rsf.org/article.php3?id_article=17363, last accessed: 13-1-2008

Appendix B: Table 2: Rankings of countries - value added and IFS international method

	value added rank	*IFS* rank		
	all years	1990	1995	2000
United States	1	1	2	2
Japan	2	2	1	1
China	3	4	4	4
Korea	4	8	6	5
Taiwan	5	9	9	7
Indonesia	6	3	3	3
Thailand	7	7	7	6
Singapore	8	10	10	10
Malaysia	9	6	8	9
Philippines	10	5	5	8

Appendix B: Table 3: Increase in IFS values switching from national method to the international method

	IFS increase in %		
	1990	1995	2000
United States	35.1	46.7	43.8
Japan	39.6	53.6	58.4
China	42.4	54.4	70.6
Korea	65.3	69.4	63.3
Taiwan	67.0	75.8	81.8
Indonesia	52.1	58.5	50.3
Thailand	79.4	83.8	85.2
Singapore	82.4	84.1	92.8
Malaysia	65.0	85.3	65.2
Philippines	77.4	82.7	88.2