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International Trade and FDI with Fragmentation: the Gravity Model Approach

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Abstract

The formation of international production/distribution networks was one of the most important phenomena in East Asia in the past decade. Firms, particularly in machinery sectors, developed sophisticated patterns of production-process-wise division of labor across countries with different income levels and started trading massive amount of parts and components back and forth. This paper applies the gravity equation approach to international trade flows of machinery parts and components as well as vertical foreign direct investment and tries to clarify the empirical importance of some of the key factors in the fragmentation theory.

Detailed examinations on the coefficients for distance indicate that service link costs matter particularly for trade in parts and components. Our estimates also present a sharp contrast among regions; the amount of trade in parts and components is relatively small within EU while in East Asia it is much larger with active production. Furthermore, gravity equations for vertical FDI indicate that the East Asian countries are distinctive in attracting more vertical FDI than the gravity equation predicts.

JEL classification: F10, F14, F23

Key words: International Production/Distribution Networks, Service Link Cost, Cross-Border Production Sharing, Outsourcing, Distance

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1. Introduction

The formation of international production/distribution networks was one of the most important phenomena in East Asia in the past decade. Backed up by globalizing forces of corporate activities in developed countries and the drastic transition of development strategies in developing countries, extensive production/distribution networks were formulated. Such formulation resulted in a surge of trade in parts and components for global production sharing. The most quantitatively important industrial sectors in such networks were machinery sectors including general machinery, electric machinery, transport equipment, and precision machinery. Firms in these sectors developed sophisticated patterns of production-process-wise division of labor across countries with different income levels and started trading massive amount of parts and components back and forth. Networks consist of both intra-firm transactions and arm's-length transactions with the same and different firm nationalities. 70% of total exports by East Asian countries are now machineries, and 30% are parts and components of machineries. The current dominant pattern of intra-regional trade in East Asia is neither inter-industry trade based on the traditional comparative advantage argument as being dominant in typical North-South trade nor intra-industry trade with horizontal and vertical product differentiation as being observed in Europe.

Despite the profound importance of explosive development of production/distribution networks, the formal economic analysis, both theoretical and empirical, has not yet been thoroughly conducted. The fragmentation theory seems to provide a sound basis for understanding the mechanics of international production/distribution networks, but its empirical relevance has not been carefully examined yet. In particular, what would be the important factors in the location decision of fragmented production blocks and how significant service link costs would be are crucial questions to be investigated.

This paper applies the gravity equation approach to international trade flows of machinery parts and components as well as vertical foreign direct investment (FDI) and tries to clarify the empirical importance of some of the key factors in the fragmentation theory. The estimated coefficients for distance are carefully examined as a partial proxy of service link costs. The income level of countries participating in production/distribution networks is also discussed as one of the key factors in location decision of fragmented production blocks. Then, the effects of unexplained elements, including unrepresented part of service link costs, location advantages/disadvantages not represented by income level, and possibly positive or negative agglomeration effects, are quantified in lump sum as the magnitude of coefficients for country/regional dummies.

The paper plan is as follows: section 2 provides an overview of global production sharing with international trade data and discusses economic logic behind with special emphasis on the fragmentation theory and its link with the agglomeration theory. Section 3 reports the results of core empirical analysis on parts and components trade in the gravity equation approach. Section 4 presents supplementary study on bilateral flows of FDI also in the gravity equation approach. Section 5 concludes.

2. International Production/Distribution Networks

2.1 Overview of global production sharing

In the past decade, we observed extensive development of global production sharing particularly in machinery sectors in which the geographical separation of production processes is relatively easy. As a result, trade in machinery parts and components was explosively growing. At present, trade in intermediate goods has a large share in total trade. In 2001, the share of machinery parts and components in total world trade reaches 22.5%.[1] The ratio of parts and components to total machinery trade is 46.9%. Tables 1-4 show the share of machinery and its parts and components in total trade in selected countries and years.[2]

Table 1

Table 2

Table 3

Table 4

In these tables, apparent differences emerge among regions. First, the shares of

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[1] This share is calculated with the sample that is used in the analysis of Section 3. See Table 7 in details. The definition of parts and components is based on Ando and Kimura (2003) and Kimura and Ando (2003).

[2] Campa and Goldberg (1997) calculate shares of imported intermediate inputs in total intermediate inputs for selected countries from each country's Input-Output Table and concluded that the importance of imported intermediate inputs has been growing.

machinery goods in total exports and imports are mostly large in the East Asian countries. In Singapore, Malaysia, and the Philippines, for example, shares of machinery goods in total exports in 2000 reach 72%, 64%, and 77%, respectively. On the other hand, the corresponding figures in the Central and Eastern European countries are small. Figures in Latin American countries are not even comparable. The second and more important point is that in the East Asian countries the shares of parts and components are quite large not only in total trade but also in machinery goods trade. In most of the ASEAN countries in 2000, exports and imports of parts and components account for more than 60% or 70% of total machinery goods trade, respectively. On the contrary, these figures of other countries are much smaller. The fact that the East Asian countries mainly engage in trade in intermediate goods rather than final-goods trade implies that global production sharing becomes a prominent form of trade in this region. Finally, the trade balance of parts and components presents another sharp contrast across the regions. In general, developing countries tend to be net importers of parts and components. It is widely recognized that developing countries have comparative disadvantage in producing parts and components and therefore specialize in assembling imported intermediate goods and export final goods. Indeed, this pattern is observed in most of the developing countries. However, East Asia presents a completely different picture. Surprisingly, in 2000, trade balances of parts and components are almost zero or even positive in all developing countries except China. This finding infers that production sharing in this region is not a simple division of labor between developed and developing countries, but rather complicated vertical production sharing involving many developing countries.

To fully understand this ongoing trend of global economy, particularly what is going on in East Asia, a new theoretical framework should be incorporated, because the traditional trade theory mainly focuses on trade in final goods and places little emphasis on vertical production sharing. The rest of this section argues the concept and determinants of fragmentation and agglomeration to shed light on this unexplored aspect of global economy.

2.2 Supporting economic logic (1): fragmentation

Concept and Overall Framework

The production of one final commodity usually consists of plural processes or activities that are vertically integrated. The term "fragmentation" generally means to divide such vertically integrated production processes into separate segments and to shift them to various locations that are most suitable for each activity. Figure 1 illustrates the fundamental concept of fragmentation.[3] The top panel presents the original production method in which all production processes are undertaken in a large factory, while the middle and lower panels depict two examples of fragmented production, the one rather simple and the other more complex. Each activity may be quite different in the way of production in terms of, for example, required technology and factor intensity. Spatial dispersion of production means that the factor intensity of each component becomes more important than the average factor intensity of the final product that consists of many production stages. For instance, the electrical machinery industry represented by semiconductors is on average, capital intensive, but production activities are not necessarily located only in developed countries. Rather, each activity is dispersed across the world. Computer makers, for example, import semiconductors, screens, and motherboards from countries where the cost of factors used intensively for production are relatively low, while knowledge-intensive processes such as product designs are carried out in developed countries.[4] Firms take advantage of differences among countries by optimally fragmenting and locating their production processes in various countries. Such cross-border division of labor consequently formulates international production/distribution networks.

Figure 1

The nature of such kind of trade is completely different from either trade in horizontally differentiated products or trade in vertically differentiated products though all of the three are likely to be classified as intra-industry trade. Intra-industry trade with horizontally differentiated products is typically observed among the core members of EU. The volume of such trade is determined by variety of goods produced in each country and the demand share of those products. Production functions as well as required inputs are supposed to be similar so that differences in location advantages across countries are relatively unimportant. In the vertical product differentiation, both developed and developing countries export goods that are classified in the same statistical category but are heterogeneous in terms of their quality. With the link of income level to technological level and tastes over quality, higher-income countries are supposed to export higher-quality products, and vice versa. Trade of parts and components in the context of fragmentation does not necessarily follow such a pattern.

[3] This figure is drawn from Jones and Kierzkowski (1990).
[4] Other widely cited examples of such products are Barbie dolls, shoes and clothing of Nike, computers, and automobiles.

The motivation of the trade here is not love-of-variety or love-of-quality tendency of consumers but the geographical separation of production blocks and its resulting back-and-forth transactions of parts and components.

While the whole fragmentation pattern may occur within one firm, more sophisticated pattern of fragmentation tends to include both intra-firm and arm's-length transactions. In other words, ownership may also be split in fragmentation. Firms choose whether particular processes are outsourced to other firms or not. This "internalization problem" contains a well-known tradeoff; firms can potentially reduce production cost by outsourcing some processes to specialized suppliers in exchange for facing holdup problems, or firms bear high production cost but well organize the vertical production chain without uncertainty.

Thus, there exist various forms of fragmentation. Figure 2 illustrates a complex nature of fragmentation. This figure classifies fragmentation according to whether it crosses the national border and whether it occurs within a firm. B and D are statistically captured as international trade, while A and C are domestic transactions. A and B are "intra-firm transactions," and C and D are called "arm's-length transactions." Although quantifying the relative importance of them is difficult, all types are no doubt significant in the real world.[5]

Figure 2

A number of authors have investigated various aspects of fragmentation, using their own framework and terminology. Table 5 summarizes the definition and coverage of each terminology. Alphabets in the last two columns correspond to those in Figure 2. Jones and Kierzkowski (1990) is a study that first presents a generic framework for analyzing fragmentation. The coverage of the work is the widest. They mainly focus on whether production blocks are spatially separated or not. They formulate versatile analytical framework in which an increase in the number of production blocks to produce one end product lowers marginal costs but raise service link costs and hence the optimal number of fragmented production blocks rises as output level increases. On the other hand, Arndt (1997, 1998) defines "offshore sourcing" as production of components in foreign countries. As long as production of some parts takes place in a foreign country and the parts are imported, he calls it

[5] Using the micro-data of Japanese firms as well as the US BEA data, Fukasaku and Kimura (2001) conclude that the share of intra-firm trade is about 30% and stable in the past two decades.

outsourcing.

Table 5

Yi (2003) and Hummels, Ishii, and Yi (2001) focus on the wider scope of trade in intermediate goods; specifically, imported goods that are used as inputs to produce a country's export goods. Their main focus is on vertical production chains extended across countries. Yi (2003) constructs a theoretical model to demonstrate that vertical specialization can explain the non-linear relation between tariff reduction and the growth of world trade in the second half of the 20th century, which can be hardly explained by the standard trade model. On the other hand, Hummels, et al. (2001) empirically analyze how countries are connected with each other and how each country is involved in vertical production chains, using the Input-Output Table. In the sense that their main concept, vertical specialization, takes inter-industry transactions into account, the scope of Yi (2003) and Hummels, et al. (2001) is slightly different from others that put little emphasis on inter-industry aspects.

Meanwhile, Grossman and Helpman (2002a, b) and Hanson, Mataloni, and Slaughter (2003) analyze production chains from the viewpoint of firms. Grossman and Helpman (2002a, b) theoretically explain how industry characteristics affect the extent of outsourcing, while Hanson, et al. (2003) focus on trade in intermediate goods within firm groups, using firm-level micro data. Thus, we can say that their work has detailed but narrower scope of fragmentation. In any case, firms optimize their activities by the location choice of fragmented production processes and the choice of the range of internalization.

Basic forms of fragmentation we have argued so far are observed throughout the world. However, international production/distribution networks in East Asia are most developed at this point in time. Ando and Kimura (2003) claim that the international production/distribution networks in East Asia are “distinctive” in their significance in the regional economy, their geographical extensiveness, and their sophistication of both intra-firm and arm’s-length relationships across different firm nationalities.[6]

To summarize briefly, fragmentation is the result of profit-maximizing behavior of firms to take advantage of differences among countries. Firms can also separate the ownership of each block to reduce production costs, and hence various types of transactions between firms have to be taken into account. In addition, service link

[6] As for the comprehensive argument of international production networks in East Asia from the viewpoint of MNEs, see Chapter 7 of Yusuf (2003).

costs and the viewpoint of multinational enterprises (MNEs), which are much less explored in the traditional argument of international trade, should be emphasized in order to analyze fragmentation. The complicated combination of these elements formed sophisticated international production/distribution networks in East Asia. The rest of this section argues the central factors of fragmentation in detail in the context of international production/distribution networks in East Asia and discusses how each factor can be quantified in our analysis.

Income gaps

Fragmentation is the result of firms' profit maximizing behavior that takes advantage of differences in location advantages among countries. As pointed out in Jones and Kierzkowski (2001), fragmentation itself is not a new phenomenon. Fragmented production activities have long been undertaken within national economy. However, it has recently been acquiring an international dimension and more sophisticated nature. Fragmentation within local or national markets is different from international one both in terms of cost and benefit. On the one hand, necessary costs for international fragmentation are higher due to geographical distance and a variety of restrictive trade policies and domestic regulations. On the other hand, potential benefit from international fragmentation is larger than the domestic one. The reasons are as follows: first, the relationship between factor productivity and factor prices may vary in across countries—the Ricardian emphasis on technologically based differences in each country's characteristics. Second, each production process requires production factors in different proportion, and countries have different relative factor prices—the Heckscher-Ohlin basis for trade. [7] Recent advances in transportation and telecommunications technologies, and reduction in barriers to trade and investment have reduced the cost of cross-border production sharing and thus international fragmentation has proliferated. Cross-border production sharing is potentially more beneficial if service link costs are lowered and if differences among countries are larger.

The argument above is also applicable when such production sharing involves a number of countries. In the region with similar countries, firms have less incentive to deploy their production processes in each country, and hence the number of countries committing in international production/distribution networks becomes small. On the other hand, the more different each country's characteristics are and the more dispersed

[7] With no difference in location advantages among countries, fragmentation is not beneficial. Therefore, as an illustrative case, Deardorff (2001) analyzes fragmentation "across cones," meaning that two countries in different diversification cones are focused on.

factor intensity of each process becomes, the more countries tend to be involved in production networks as a result of profit-maximizing behavior of firms.

East Asian countries are of wide difference in terms of income levels. Figure 3 ranks selected countries from the left according to per capita GDP in 2001. As is apparent from this figure, East Asian countries are placed in the wide range of the diagram; starting from Japan, Singapore, and Korea to Viet Nam, Laos, and Cambodia. Even among forerunners of the ASEAN countries, the difference between the maximum and the minimum (Singapore and Indonesia) is quite large. Figure 4 shows the same statistics, with now earmarking for the European countries. As expected, EU15 countries are concentrated on the left-hand side of the figure. New EU members are also ranked on the left-hand side, and even Ukraine (the lowest in Europe) is located on the left-hand side of Indonesia. Countries such as Hungary and Slovakia, which are hosting FDI from Western European countries, are positioned on the left-hand side of Malaysia and Thailand.

Figure 3

Figure 4

Once international production/distribution networks involve many countries in a wide variety of development stages and each country specializes in narrower parts of the vertical production chain, participating countries start both exporting and importing parts and components regardless of, or rather by taking advantage of, differences in income levels.

Service Link Costs

Another important factor that determines the extent of fragmentation is service link costs. Fragmentation requires various costs including communication cost, transportation expenses to link remotely located production blocks, coordination costs, and so on. Table 6 lists notable components of service link costs. We divide the costs mainly into four categories.[8] The first category is trade costs, whose subcategories are based on Anderson and Wincoop (2004). Transportation costs and policy barriers have long been the subject of many trade economists. Other factors in subcategories, however, remained much less explored.

Table 6

[8] The remaining part of this table will be discussed later.

The second category is investment costs. A firm locates production blocks abroad and operates them through FDI. Therefore any policy barriers and problems relating to FDI adversely affect fragmentation mostly as a part of service link cost. Indeed, investment-related issues in developing countries are serious and hence seem to impede the formation of international production/distribution networks.

The other two components, communications costs and coordination costs, have been much less considered in spite of their importance. These costs are necessarily accompanied with simultaneous operation of production blocks in plural countries. Some components of these two categories have been reduced thanks to recent technological progress, while others remain due to their inherent nature.

There are thus many components in service link costs. Some are relatively easy to evaluate, while others are difficult even to identify explicitly. All the components raise transaction costs within networks and hence determine the extent of the formation of international production/distribution networks. Let us note two important points. First, components of service link costs can be divided into fixed costs and running costs though the demarcation is not always clear-cut. For example, transport costs and telecommunications costs are mostly running costs, while information costs and policy barriers to invest have strong nature of fixed costs. The former has been declining due to trade liberalization and the IT revolution. On the other hand, the latter costs would be persistent. Second, the importance of service link costs significantly varies across goods traded. If intermediate goods are traded many times within a network, trade costs become more important for trade in parts and components than trade in other goods.[9]

In the early empirical literature on international trade, either the geographical feature or the c.i.f./f.o.b. ratio is often used as a proxy for trade costs. The former is the ex ante proxy for trade costs, while the latter represents the ex post value of trade costs. Above all, economists focus on the geographical features to clarify the determinants of international trade. It is empirically confirmed that geographical features of each country matter for its export performance and income level (Redding and Venables (2003, 2004)).[10] In the context of gravity equation, distance between two countries is frequently used as a proxy for trade costs. Indeed the coefficient of distance is negative, and its statistical significance is quite robust in any kind of specification. Therefore in

[9] Yi (2003) constructs the model with multiple production stages and demonstrates that the reduction in tariff barriers has the magnified effect on world trade.

[10] Bloom and Sachs (1998) also emphasize the importance of geography in economic growth.

our analyses, we use distance as a partial proxy variable for trade costs, together with the adjacency dummy and common language dummy. With these three variables, we can capture, to some extent, the magnitude of service link costs.

Foreign Direct Investment

In the literature of international economics, distinguishing between horizontal and vertical MNEs or FDI is a popular approach. Helpman (1984) analyzes the vertical MNEs in a two-factor framework with monopolistic competition. In his model, the motivation of MNEs to set up foreign affiliate and operate abroad is to take advantage of factor price differences among the countries.[11] On the other hand, Markusen (1984, 2002) proposes the horizontal FDI framework in which firms operate in multiple countries and each plant sells its products in local market. The former is supposed to occur in the case of FDI from developed to developing countries. Fragmentation typically occurs with such vertical FDI. The latter, on the other hand, is likely to take place when both the investing and host countries are developed ones or when the host country's market is sufficiently attractive.

To analyze the role of FDI in forming networks, another distinction should be taken into account. There are two types of MNEs in developing countries; import-substituting MNEs and export-oriented or network-forming MNEs. Import-substituting MNEs are the traditional form of MNEs in developing countries and get involved with imports of parts and components. On the other hand, network-forming firms are committed to back-and-forth transactions of parts and components.

The location of fragmented production blocks critically depends on advantages and disadvantages of each location. Once the firm undertaking the fragmented block finds it economically beneficial to operate in one country, the firm carries out FDI in the country. Therefore developing countries particularly in East Asia compete with each other to attract as many network-forming firms as possible by providing firms with some location advantages.

The lower part of Table 6 summarizes important components of location advantages. Production cost is the primary component that affects location choice of firms. On top of that, accessibility to imported intermediate goods with low tariff rate should be noted because it is quite important for network-forming firms.

[11] In the context of East Asia, Fukao, Ishido, and Ito (2003) empirically show that in East Asia FDI played an important role in the rapid increase in vertical IIT, which is likely to be driven by differences in factor prices.

Agglomeration is also an important component of location advantages. Through increasing returns, externality, and availability of abundant suppliers, an industrial cluster makes the region more attractive. Moreover, agglomeration simultaneously plays an important role in reducing service link costs, as discussed below. Consequently, service link costs and location advantages have certain intersection. In our analysis of gravity equations for FDI flows, after controlling for some geographical features, the magnitude of coefficients for country/regional dummies quantify the remaining part of service link costs and location advantages not represented by income level in the lump-sum fashion.

2.3 Supporting economic logic (2): agglomeration

Another important force paralleling with fragmentation is industrial clustering or "agglomeration." In his classic paper, Marshall (1920) emphasizes potential benefits of agglomeration and claims that some sort of externality with forward and backward linkage plays an important role in forming agglomeration. In the 1980s, his work stimulated lots of researchers trying to formalize agglomeration in formal economic models. Krugman (1991), for instance, is the seminal one that treats the factors of geography in the context of international economics. Since then, many researchers have tried to introduce agglomeration in international trade models.[12] However, the relationship between agglomeration and fragmentation remains mostly unexplored in spite of its importance.[13]

Let us argue the background logics of agglomeration of three kinds. The first is the standard type of agglomeration where fragmentation is irrelevant. This type is represented by the case treated in the standard version of the core-periphery model.[14] In the model, labor force is mobile between two regions, with workers moving according to nominal wages and price indices. By the magnitude of transport cost and initial allocation of labor force between two regions, whether all manufacturing activities are concentrated in one region or not is determined. For example, with moderate transport cost and either a sufficiently high or sufficiently low initial value of labor share in one region, all manufacturing activities cluster in one area of the country. In this type of agglomeration, neither externality nor vertical production chain

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[12] Fujita, Krugman, and Venables (1999) review important seminal works on the related issues.

[13] Jones and Kierzkowski (2003) provide an illustration of framework in which they can explicitly analyze both fragmentation and agglomeration.

[14] The "core and periphery framework" is the special case of the multi-regional model. See Chapter 5 of Fujita, et al. (1999).

(fragmentation) is relevant. In addition, transport cost has no monotonic relation with the extent of agglomeration. Such type of industrial cluster is widely observed in EU where developed countries are engaging in horizontal intra-industry trade.[15]

The second is the concentration of firms in the particular area of the country because of transport costs and externality. In this case, firms engaging in the similar activity form an industrial cluster to reduce transport costs and to take advantage of the benefit from externality. Therefore transport cost and agglomeration are both sides of one coin. The benefit to make a cluster tend to be larger, the higher transport costs become. One important point here is that the geographical scope of agglomeration is smaller than a nationwide phenomenon. Some literature treats agglomeration as a nationwide phenomenon and hence measures the extent of an industrial cluster by calculating how large labor force is absorbed in one industry. If, in this method, labor share of one industry in a country's macro economy is larger than that of the whole world, agglomeration is considered to be formed in the industry of the country. However, our second aspect of agglomeration has more "local" features.

Of particular importance is that the relationship between agglomeration and fragmentation is sometimes complementary against our intuition. Fragmentation seems to adversely affect a geographical concentration. However, with increasing returns in service link costs, fragmentation may accelerate the formation of agglomeration. When externalities such as spillovers or increasing returns in service link costs exist, firms have incentive to make a cluster or to come closer to each other to reduce total production costs, rather than spreading broadly. Such type of agglomeration is often observed in East Asian countries such as Malaysia; firms producing parts of electrical machinery are concentrated in the particular area of the country.

The third is the case in which agglomeration and fragmentation work in the opposite directions, according to the type of products. If the product in question requires frequent changes in spec or strict just-in-time delivery, proximity to the customer is crucial.[16] Customized chips are the examples. On the other hand,

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[15] A similar type of agglomeration is observed in Tsubame City in Japan. In the city, a lot of firms that undertake the production of similar parts are concentrated in the particular area, mainly because they can easily find skilled workers there.

[16] Harrigan and Venables (2004) argue that time costs are qualitatively different from direct monetary costs and demonstrate that if two final assemblers locate in different places and technology of component production exhibits constant returns to scale, then component producers have incentive to cluster around just one of the two assemblers, because the delay in delivery of one component results in the delay of the completion of final products.

standardized parts such as random access memories tend to be fragmented because proximity to the customer is not necessarily required.

For any of these three logics, to quantitatively evaluate the relationship between agglomeration and fragmentation by our gravity model approach is difficult because our trade data is national level data. However the coefficient for distance may show a systemic pattern. Although there are possibly various types of relationship between agglomeration and fragmentation as discussed above, distance is likely to be more important for machinery parts and components than for other products if the international production/distribution networks have been formed and hence parts and components are more intensively traded within the networks than with countries outside the networks.

Lastly, we must point out the importance of FDI in forming agglomeration. In developing countries, foreign firms have strong competitiveness vis-a-vis local indigenous firms in terms of technological capability and access to credit and market. In addition, the entry of foreign assemblers is accompanied with the entry of parts suppliers. Moreover, the entry and the operation of one foreign firm lower the threshold for subsequent potential investors to enter the country's market.[17] As such, FDI plays an important role in the early stage of agglomeration. As a cluster becomes large, local indigenous firms begin to be involved in the agglomeration. Finally a large industrial cluster that includes both foreign firms and local indigenous firms is formed in a particular area of a country or region. And then such clusters in turn form international production/distribution networks in the region. This is what we observe in East Asia at present.

3. Gravity equation approach for parts and components trade

To empirically examine the mechanics of international production/distribution networks, we estimate gravity equations and check whether the results are consistent with our intuition or not.[18] The basic model is specified as

[17] This effect has been analyzed in a series of studies beginning with Head, Ries, and Swenson (1995).

[18] As for the micro foundation of the gravity equation, see Anderson (1979), Bergstrand (1989), and Deardorff (1998). There recently emerge many papers that apply gravity equations to the analysis of determinants of disaggregated data rather than total trade data (e.g. Feenstra, Markusen, and Rose (2001)).

$$EX_{ij} = \alpha * DIS_{ij}^{\beta_1} * EXGDP_i^{\beta_2} * EXPERGDP_i^{\beta_3} * IMGDP_j^{\beta_4} * IMPERGDP_j^{\beta_5} * \varepsilon_{ij}$$

where EX_{ij} denotes country *i*'s export of parts and components to country *j*, and DIS_{ij} stands for the distance between *i* and *j*. $EXGDP_i$, $EXPERGDP_i$, $IMGDP_j$, and $IMPERGDP_j$ are GDP and per capita GDP of i and j, respectively. ε_{ij} represents the error term that follows lognormal distribution. β s are estimated coefficients.

Taking natural logarithm and introducing some dummy variables yields

$$\ln EX_{ij} = \ln\alpha + \beta_1 \ln DIS_{ij} + \beta_2 \ln EXGDP_i + \beta_3 \ln EXPERGDP_i + \beta_4 \ln IMGDP_j$$
$$+ \beta_5 \ln IMPERGDP_j + \mathrm{B} * Dummy + \ln\varepsilon_{ij}$$

where *Dummy* denotes a matrix of dummy variables and *B* is a vector of coefficients for them. Various kinds of regional dummies are introduced so as to identify the characteristics of each region. Besides regional dummies, we introduce the adjacency dummy and the common language dummy, which are often used in the usual gravity equation approach. In our analysis, however, the common language dummy is a bit more important. The coefficient for the common language dummy partially captures service link costs. The definition and data source of these variables are summarized in Table 7.

Table 7

Table 8 presents the results of basic estimations. The dependent variables of Models 1 to 4 are total exports, exports of total manufactured goods, final goods of machinery, and machinery parts and components, respectively. In every equation, the estimated coefficients for economic size and distance have expected signs and are statistically significant. The coefficients for the common language dummy are also positive.[19] Common languages facilitate trade among people who speak them. Regional dummies are mostly statistically significant, meaning each region has some

[19] A subtle, but interesting point here is that the magnitude of the common language dummy in Model 3 is larger than that in Model 4. This is consistent with Hutchinson (2001), which finds that language distance had a larger impact on trade in consumer manufactures than it did on trade in producer manufactures.

distinctive characteristics.

On top of that, three points are worth being noted. First of all, the elasticity of distance varies greatly across the equations. In the estimate with total trade, the elasticity is around -1, which means the 1% increase in distance between trading countries reduces trade by 1%. With manufactured goods, the corresponding figure is -1.34. Machinery goods are more sensitive to distance. Parts and components have the largest elasticity in absolute form, meaning that distance discourages trade in parts and components the most.

Table 8

There are three possible explanations for the difference. First, the elasticity of substitution can be different across commodities. The commodity with high elasticity of substitution is more sensitive to price changes. Since distance is proxy for trade costs, the coefficient of distance is likely to be larger for the equation of parts and components if the elasticity of substitution for those products is high. Second, timeliness can matter. If timeliness for parts and components is more important than for other goods, the coefficient for distance becomes larger, as remote countries tend to take a long time to trade goods.[20] The third explanation, probably relating to the previous two and the most important of the three, is the existence of international production/distribution networks across the world. As stated in Section 2, one end product has to go through several steps before completed. If each block is concentrated on the particular area of the world, the product passes through national borders many times as each country specializes in narrower parts of the vertical production chain, and hence intermediate goods are traded within such networks much more intensively than final goods. Yi (2003) claims that vertical specialization in which countries specialize only in particular stages of the production chain explains the magnification impact of tariff reduction on the growth of world trade. This means that trade in parts and components as a whole are more severely affected by service link costs than final-goods trade. Such characteristics of intermediate goods generate the principal motivation to form international production/distribution networks.

The coefficients for distance also vary across subcategories of parts and components. We disaggregate parts and components into general machinery (HS-84), electrical machinery (HS-85), transportation equipment (HS-86 to 88), and others. Table 9 summarizes the estimate results. The fact that the absolute value of the

[20] See the footnote 12.

coefficient is the largest in the equation for transportation equipment may be due to the bulky nature of parts and components of the industry.

Table 9

The second noticeable point in Table 8 is that the coefficient for EU15 dummy shows a systemic pattern across equations. The coefficients for EU15 dummy are negative all the way, meaning that EU countries trade less than predicted by the gravity equations. Although they are trading a lot in absolute values, the equations predict larger values than they actually trade, since the former EU members are large economies and locate closely to each other. While the negativity of EU15 dummy in the first equation is moderate, the absolute magnitudes of negative coefficients for EU15 dummy are getting larger in the other estimations. Above all, the coefficient for EU15 dummy in the equation for parts and components is quite high. EU countries trade much less parts and components within the region than in the case of total trade, total manufactures, or final goods of machinery, in comparison with the normal two countries with the standard economic size and distance between them.

As discussed in Section 2, trade within EU countries tends to be horizontally differentiated. Meanwhile, trade in parts and components within EU are expected to be relatively small since firms have little incentive to conduct division of labor within the region where wage gaps and other differences in location advantages are small. To reinforce this statement, we analyze the change in coefficients for EU dummies with various country grouping. Table 10 shows estimates of such attempt. The dependent variables are trade in parts and components in all equations. EU7 denotes a dummy variable that takes 1 if both the importer and the exporter are the United Kingdom, Germany, France, Italy, Spain, Netherlands, or Belgium. Similarly, EU3 takes 1 if both are the United Kingdom, Germany, or France. As the coverage of the dummy variable becomes narrower, income gaps, differences in technological capability and factor proportions are to be small. The results indicate, as expected, that the magnitude of coefficients is streamlined in the descending order.

Table 10

The third point that we would like to emphasize is that East Asia presents a completely different picture. Although intra-industry trade is rapidly growing within the region as well as EU, economic factors behind the increase are not the same. As we discussed in the previous section, the division of labor or cross-border (global) production sharing is the prominent form of trade in East Asia. Fragmentation of production blocks is accompanied by flows of parts and components among each block. The coefficients for AFTA dummy in Table 8 prove our claim, presenting a sharp contrast with EU15 dummy. That is, AFTA dummy changes in the ascending order, opposite to EU15. The coefficient for AFTA dummy in the equation for parts and components is much higher than in the equations for total trade and total manufactures. AFTA countries intensively trade machinery parts and components with each other. This observation implies the formation of international production networks.

This finding is very robust even when we alter the coverage of dummy variables. Table 11 provides the results of similar estimations with various kinds of dummy variables for the East Asian countries. The coefficients for both JKAPCH dummy and APCH dummy are positive and statistically significant. The positive value for JKAPCH dummy indicates that APCH countries import parts and components a lot from Japan and Korea, which is consistent with the traditional argument of outsourcing, i.e., indicating trade flows of intermediate goods from developed countries to developing countries. In addition, the positive coefficient of APCH dummy means that in East Asia there is active trade in parts and components even between developing countries.

Table 11

Table 12 lists the magnitude of coefficient for each country dummy to further focus on differences among countries. The table provides the coefficients for both importer and exporter dummies. The figures in Table 12 confirm the distinctiveness of East Asian countries, particularly in term of exports of parts and components. In the case of East Asia, this finding is not consistent with the viewpoint of Ng and Yeats (2003) in which production processes are dichotomized into production of intermediate goods and assembly of them. They explicitly assume that countries that specialize in exporting parts and components have competitive disadvantage in assembling because wage rates in those countries are high. On the contrary, importers of them have comparative disadvantage in production of some components with high skill or capital intensity. They further advance their reasoning such that the sign and size of trade balance in intermediate goods show each country's competence for production of parts and components, or for assembly of them. This argument has the possibility to convey a misleading picture for actual vertical production chains. It is true that developing countries tend to import more parts and components than they export, but this rule of thumb is not applicable to East Asian countries. As we presented in Table 1, they export as large amount of parts and components as they import. Remember that income levels of those countries are broadly scattered in Figure 3. Coupled with the results obtained in this section, it means that both high income and low income countries actively trade parts and components within the region. This phenomenon is totally different from intra-industry trade prevalent in EU, and even different from the traditional view of production sharing in which developed countries export parts and components to developing countries for further assembly and import them back as final consumer products.

Table 12

4. FDI

Major players in international production/distribution networks are MNEs. As discussed in Section 2, countries joining international production/distribution networks attract large amount of FDI. To show that East Asia has distinctive features in terms of such networks, we apply the gravity equation technique to evaluate bilateral FDI flows. Due to data availability, source countries of FDI are limited to OECD members. To distinguish the motivation of each FDI, we further divide the dataset into vertical and horizontal FDI. As discussed in Section 2, vertical FDI (export-oriented or networked FDI) plays a role in forming international production/distribution networks. Therefore we define FDI flows from OCED to Non-OECD countries as vertical FDI and compile them in one sample set. Although applying the gravity equation to FDI data is not so common, the results are expected to be similar to cases of trade data. Since the sample set includes many observations with zero value, we provide both Tobit and OLS estimators.[21]

Table 13 provides the estimate results of gravity equations. As expected, economic size and distance have the same signs as the case of trade; that is, the former is positively correlated and the latter is negatively associated with bilateral FDI flows. The estimated coefficients for regional dummy variables, i.e., EUROPE, EAST ASIA, and AMERICA, indicate that these regions are hosting more FDI than other regions such as Africa. To understand which countries actually attract many MNEs, we introduce country dummies. Table 14 summarizes the coefficient for each country

[21] In the case of OLS estimation, observations with zero value are excluded from the sample to avoid estimation biases.

dummy. These figures indicate that most of East Asian countries are hosting relatively many MNEs after controlling for economic size and geographical characteristics.

Table 13

Table 14

The interesting question here is how income or wage level matters in attracting vertical FDI. Of course, other things equal, countries with low wage level attract larger vertical FDI than high income countries. However, Figures 3 and 4 suggest that other factors are also important. If wage level is a dominant determinant, countries like Ethiopia and Cambodia must perform the best in attracting vertical FDI. Meanwhile, Singapore and Malaysia should accept a few vertical MNEs due to their high income levels. Nevertheless, very poor countries perform worse, and countries like Singapore and Malaysia are actually hosting many FDI.[22] Notice that the East Asian countries with positive dummy coefficients have a wide variety of income, from Singapore to Indonesia. This finding indicates that factors other than income level play important roles in attracting vertical FDI. We claim international production/distribution networks are the major factor behind this observation.

To conclude, the fact that vertical FDI is attracted to East Asia where income level varies significantly across the countries implies the MNEs' involvement in the formation of international production/distribution networks.

5. Conclusion

The formation of international production/distribution networks in East Asia was one of the most noticeable and important phenomena in the recent 10-15 years. The fragmentation theory has a great potential to shed light on such ongoing trend of global economy. However, there is paucity of both theoretical and empirical analysis on this subject. Specifically, its empirical relevance has remained largely unexplored. This paper investigates the importance of the fragmentation theory using gravity equations for trade in machinery parts and components and vertical FDI, focusing on the East Asian context.

Detailed examinations on the coefficients for distance indicate that service link

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[22] FDI to Singapore or Malaysia doesn't seem to be horizontal FDI because their small population, which results in relatively small market size, gives investors little incentive to engage in horizontal FDI.

costs matter particularly for trade in parts and components, which is consistent with both our argument and findings in the earlier literature. Our estimates also present a sharp contrast among regions. The amount of trade in parts and components based on the vertical division of labor is relatively small within the core members of EU in which trade in horizontally differentiated products is prominent. In East Asia, by contrast, the significance of parts and components trade is much larger, meaning that global production sharing is actively conducted in this region.

We present some additional evidences to reinforce our argument. A clear pattern of country dummies in gravity equations for vertical FDI indicates that the East Asian countries are distinctive in the sense that they are accepting more vertical FDI than the gravity equation predicts. Coupled with the wide dispersion of income levels and intensive back-and-force transactions of parts and components in this region, we can confirm the formation of international production/distribution networks where many countries with a wide range of income levels are involved and each country specializes in narrow part of vertical production chain.

Our finding leaves some unanswered questions. Unobserved part of service link costs, location advantages not represented by income level, and agglomeration effects were just quantified in lump sum as the magnitude of coefficients for country/regional dummies. To what extent are these elements important? Moreover, the link between fragmentation and vertical FDI has not been fully clarified. Further exploration to answer these questions will provide valuable insights.

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Table 1 Trade in Machinery Goods and Parts and Components in East Asian Countries

	Exports		Imports	
	1996	2000	1996	2000
Japan				
Value (US$1000)				
Total	410,944,244	479,244,574	349,185,062	379,661,760
Machinery (HS84-92)	307,646,521	358,833,056	98,088,775	121,601,005
Parts and components in machinery goods	145,594,106	173,334,390	42,244,407	61,066,645
Share				
of machinery goods in total	74.9%	74.9%	28.1%	32.0%
of parts and components in total	35.4%	36.2%	12.1%	16.1%
of parts and components in machinery goods	47.3%	48.3%	43.1%	50.2%
Korea				
Value (US$1000)				
Total	129,696,331	172,264,221	150,320,064	160,477,507
Machinery (HS84-92)	70,265,289	102,656,292	61,430,373	66,402,184
Parts and components in machinery goods	31,300,305	50,000,665	31,107,314	42,506,546
Share				
of machinery goods in total	54.2%	59.6%	40.9%	41.4%
of parts and components in total	24.1%	29.0%	20.7%	26.5%
of parts and components in machinery goods	44.5%	48.7%	50.6%	64.0%
Singapore				
Value (US$1000)				
Total	122,882,738	137,803,198	131,337,708	134,544,130
Machinery (HS84-92)	86,464,800	98,882,015	82,698,546	87,923,302
Parts and components in machinery goods	45,255,689	62,969,704	51,240,888	61,854,808
Share				
of machinery goods in total	70.4%	71.8%	63.0%	65.3%
of parts and components in total	36.8%	45.7%	39.0%	46.0%
of parts and components in machinery goods	52.3%	63.7%	62.0%	70.4%
Malaysia				
Value (US$1000)				
Total	78,308,476	98,224,808	77,901,213	81,287,187
Machinery (HS84-92)	44,883,017	63,267,346	48,816,398	53,650,999
Parts and components in machinery goods	26,416,051	41,143,650	33,052,487	42,676,537
Share				
of machinery goods in total	57.3%	64.4%	62.7%	66.0%
of parts and components in total	33.7%	41.9%	42.4%	52.5%
of parts and components in machinery goods	58.9%	65.0%	67.7%	79.5%
Thailand				
Value (US$1000)				
Total	55,672,988	68,780,636	72,311,216	61,445,996
Machinery (HS84-92)	22,414,630	31,390,017	36,457,745	28,930,835
Parts and components in machinery goods	12,095,832	19,715,977	21,896,420	20,888,062
Share				
of machinery goods in total	40.3%	45.6%	50.4%	47.1%
of parts and components in total	21.7%	28.7%	30.3%	34.0%
of parts and components in machinery goods	54.0%	62.8%	60.1%	72.2%

	Exports		Imports	
	1996	2000	1996	2000
Philippines				
Value (US$1000)				
Total	20,537,617	38,072,479	34,697,094	33,802,416
Machinery (HS84-92)	12,058,695	29,466,121	18,657,072	18,289,222
Parts and components in machinery goods	9,543,414	23,197,724	12,381,556	14,666,666
Share				
of machinery goods in total	58.7%	77.4%	53.8%	54.1%
of parts and components in total	46.5%	60.9%	35.7%	43.4%
of parts and components in machinery goods	79.1%	78.7%	66.4%	80.2%
Indonesia				
Value (US$1000)				
Total	49,811,786	62,117,778	42,923,875	33,509,943
Machinery (HS84-92)	5,305,267	11,216,465	18,128,354	9,621,840
Parts and components in machinery goods	2,216,286	5,747,222	9,311,469	5,250,261
Share				
of machinery goods in total	10.7%	18.1%	42.2%	28.7%
of parts and components in total	4.4%	9.3%	21.7%	15.7%
of parts and components in machinery goods	41.8%	51.2%	51.4%	54.6%
China				
Value (US$1000)				
Total	151,046,318	249,201,432	138,831,036	225,091,657
Machinery (HS84-92)	40,190,931	90,297,514	58,949,579	99,658,137
Parts and components in machinery goods	15,050,765	38,202,227	26,684,923	63,312,444
Share				
of machinery goods in total	26.6%	36.2%	42.5%	44.3%
of parts and components in total	10.0%	15.3%	19.2%	28.1%
of parts and components in machinery goods	37.4%	42.3%	45.3%	63.5%
Hong Kong				
Value (US$1000)				
Total	27,426,223	23,531,493	201,282,410	214,039,820
Machinery (HS84-92)	10,178,998	7,793,123	83,881,726	101,939,603
Parts and components in machinery goods	7,360,808	6,465,171	40,664,744	61,409,399
Share				
of machinery goods in total	37.1%	33.1%	41.7%	47.6%
of parts and components in total	26.8%	27.5%	20.2%	28.7%
of parts and components in machinery goods	72.3%	83.0%	48.5%	60.2%

Source：Ando and Kimura (2003).

Table 2 Trade in Machinery Goods and Parts and Components in Advanced Countries

	Export 1996	Export 2000	Import 1996	Import 2000
USA				
Value (US$1000)				
Total	622,784,152	780,331,713	817,627,136	1,258,080,174
Machinery (HS84-92)	341,335,537	458,588,175	394,823,236	605,181,215
Parts and components in machinery goods	184,914,392	267,566,343	172,463,240	249,496,869
Share				
of machinery goods in total	54.8%	58.8%	48.3%	48.1%
of parts and components in total	29.7%	34.3%	21.1%	19.8%
of parts and components in machinery good:	54.2%	58.3%	43.7%	41.2%
Canada				
Value (US$1000)				
Total	202,262,544	277,113,405	170,605,560	240,090,677
Machinery (HS84-92)	80,047,150	115,829,500	93,047,276	134,298,200
Parts and components in machinery goods	30,507,777	43,994,145	51,419,028	73,620,806
Share				
of machinery goods in total	39.6%	41.8%	54.5%	55.9%
of parts and components in total	15.1%	15.9%	30.1%	30.7%
of parts and components in machinery good:	38.1%	38.0%	55.3%	54.8%
Germany				
Value (US$1000)				
Total	524,165,841	549,637,063	458,699,670	500,814,479
Machinery (HS84-92)	271,116,439	295,527,544	165,481,417	195,002,968
Parts and components in machinery goods	106,913,021	118,020,282	73,116,710	93,064,447
Share				
of machinery goods in total	51.7%	53.8%	36.1%	38.9%
of parts and components in total	20.4%	21.5%	15.9%	18.6%
of parts and components in machinery good:	39.4%	39.9%	44.2%	47.7%
United Kingdom				
Value (US$1000)				
Total	253,622,092	276,438,188	282,720,141	330,196,943
Machinery (HS84-92)	125,753,202	143,680,532	131,076,314	165,573,450
Parts and components in machinery goods	59,487,847	72,227,840	64,427,938	77,873,235
Share				
of machinery goods in total	49.6%	52.0%	46.4%	50.1%
of parts and components in total	23.5%	26.1%	22.8%	23.6%
of parts and components in machinery good:	47.3%	50.3%	49.2%	47.0%

	Export 1996	Export 2000	Import 1996	Import 2000
France				
Value (US$1000)				
Total	283,901,198	302,247,936	274,913,755	310,896,689
Machinery (HS84-92)	123,208,008	144,364,420	109,083,797	132,085,773
Parts and components in machinery goods	57,133,032	63,436,784	47,692,116	62,858,920
Share				
of machinery goods in total	43.4%	47.8%	39.7%	42.5%
of parts and components in total	20.1%	21.0%	17.3%	20.2%
of parts and components in machinery good:	46.4%	43.9%	43.7%	47.6%

Data source: Authors' calculation, based on UN Comtrade.

Table 3 Trade in Machinery Goods and Parts and Components in Central and Eastern European Countries

	Export		Import	
	1996	2000	1996	2000
Czech Republic				
Value (US$1000)				
Total	21,907,321	29,052,824	27,717,294	32,242,545
Machinery (HS84-92)	7,674,854	13,418,362	11,556,218	13,879,811
Parts and components in machinery goods	4,340,137	7,961,987	5,261,175	7,430,985
Share				
of machinery goods in total	35.0%	46.2%	41.7%	43.0%
of parts and components in total	19.8%	27.4%	19.0%	23.0%
of parts and components in machinery goods	56.6%	59.3%	45.5%	53.5%
Hungary				
Value (US$1000)				
Total	12,632,794	28,091,793	16,042,644	32,079,454
Machinery (HS84-92)	3,483,419	17,175,019	5,294,353	17,384,257
Parts and components in machinery goods	2,482,204	9,585,773	2,279,978	11,832,455
Share				
of machinery goods in total	27.6%	61.1%	33.0%	54.2%
of parts and components in total	19.6%	34.1%	14.2%	36.9%
of parts and components in machinery goods	71.3%	55.8%	43.1%	68.1%
Poland				
Value (US$1000)				
Total	24,389,859	31,613,456	36,990,042	48,834,216
Machinery (HS84-92)	5,948,443	11,103,789	13,183,609	19,233,053
Parts and components in machinery goods	2,439,726	5,359,196	5,585,356	8,264,701
Share				
of machinery goods in total	24.4%	35.1%	35.6%	39.4%
of parts and components in total	10.0%	17.0%	15.1%	16.9%
of parts and components in machinery goods	41.0%	48.3%	42.4%	43.0%
Slovakia				
Value (US$1000)				
Total	9,633,902	11,884,531	11,726,974	12,774,094
Machinery (HS84-92)	2,888,924	4,868,718	4,555,580	4,877,620
Parts and components in machinery goods	1,386,658	1,837,283	2,129,070	2,963,933
Share				
of machinery goods in total	30.0%	41.0%	38.8%	38.2%
of parts and components in total	14.4%	15.5%	18.2%	23.2%
of parts and components in machinery goods	48.0%	37.7%	46.7%	60.8%

	Export		Import	
	1996	2000	1996	2000
Slovenia				
Value (US$1000)				
Total	8,309,796	8,732,125	9,420,645	10,114,646
Machinery (HS84-92)	3,007,703	3,370,692	3,433,512	3,682,296
Parts and components in machinery goods	1,112,153	1,436,879	1,489,309	1,606,450
Share				
of machinery goods in total	36.2%	38.6%	36.4%	36.4%
of parts and components in total	13.4%	16.5%	15.8%	15.9%
of parts and components in machinery goods	37.0%	42.6%	43.4%	43.6%
Estonia				
Value (US$1000)				
Total	2,077,993	3,829,940	3,223,891	5,052,229
Machinery (HS84-92)	442,455	1,444,594	1,024,393	2,189,439
Parts and components in machinery goods	256,643	537,948	426,773	1,281,340
Share				
of machinery goods in total	21.3%	37.7%	31.8%	43.3%
of parts and components in total	12.4%	14.0%	13.2%	25.4%
of parts and components in machinery goods	58.0%	37.2%	41.7%	58.5%
Latvia				
Value (US$1000)				
Total	1,671,602	1,869,263	2,720,941	3,190,803
Machinery (HS84-92)	192,572	148,597	808,164	984,728
Parts and components in machinery goods	91,348	66,425	255,353	299,781
Share				
of machinery goods in total	11.5%	7.9%	29.7%	30.9%
of parts and components in total	5.5%	3.6%	9.4%	9.4%
of parts and components in machinery goods	47.4%	44.7%	31.6%	30.4%
Lithuania				
Value (US$1000)				
Total	3,862,456	3,809,197	5,643,366	5,455,945
Machinery (HS84-92)	825,386	704,946	1,808,741	1,415,572
Parts and components in machinery goods	292,608	325,506	488,407	481,590
Share				
of machinery goods in total	21.4%	18.5%	32.1%	25.9%
of parts and components in total	7.6%	8.5%	8.7%	8.8%
of parts and components in machinery goods	35.5%	46.2%	27.0%	34.0%

Data source: Authors' calculation, based on UN Comtrade.

Table 4 Trade in Machinery Goods and Parts and Components in Latin American Countries

	Export		Import	
	1996	2000	1996	2000
Mexico				
Value (US$1000)				
Total	95,661,171	166,191,645	89,355,035	190,790,435
Machinery (HS84-92)	53,437,981	103,137,370	44,261,091	101,558,151
Parts and components in machinery goods	23,387,592	43,288,925	30,472,260	66,845,212
Share				
of machinery goods in total	55.9%	62.1%	49.5%	53.2%
of parts and components in total	24.4%	26.0%	34.1%	35.0%
of parts and components in machinery goods	43.8%	42.0%	68.8%	65.8%
Colombia				
Value (US$1000)				
Total	10,647,555	13,114,976	13,680,470	11,538,473
Machinery (HS84-92)	325,851	607,093	5,558,200	3,990,493
Parts and components in machinery goods	104,705	164,346	1,753,242	1,421,539
Share				
of machinery goods in total	3.1%	4.6%	40.6%	34.6%
of parts and components in total	1.0%	1.3%	12.8%	12.3%
of parts and components in machinery goods	32.1%	27.1%	31.5%	35.6%
Venezuela				
Value (US$1000)				
Total	23,072,342	30,948,104	8,902,212	14,584,165
Machinery (HS84-92)	502,080	371,981	3,632,179	6,480,104
Parts and components in machinery goods	195,261	256,581	1,477,780	2,236,902
Share				
of machinery goods in total	2.2%	1.2%	40.8%	44.4%
of parts and components in total	0.8%	0.8%	16.6%	15.3%
of parts and components in machinery goods	38.9%	69.0%	40.7%	34.5%
Chile				
Value (US$1000)				
Total	16,678,189	18,214,492	18,110,804	16,619,696
Machinery (HS84-92)	462,162	524,318	8,344,305	6,199,085
Parts and components in machinery goods	172,667	201,886	2,101,819	1,824,395
Share				
of machinery goods in total	2.8%	2.9%	46.1%	37.3%
of parts and components in total	1.0%	1.1%	11.6%	11.0%
of parts and components in machinery goods	37.4%	38.5%	25.2%	29.4%

	Export		Import	
	1996	2000	1996	2000
Peru				
Value (US$1000)				
Total	5,671,804	6,866,038	8,220,256	7,415,018
Machinery (HS84-92)	161,338	80,120	3,287,618	2,587,529
Parts and components in machinery goods	113,519	43,651	1,000,290	878,653
Share				
of machinery goods in total	2.8%	1.2%	40.0%	34.9%
of parts and components in total	2.0%	0.6%	12.2%	11.8%
of parts and components in machinery goods	70.4%	54.5%	30.4%	34.0%
Guatemala				
Value (US$1000)				
Total	2,344,079	2,699,355	3,851,918	4,882,355
Machinery (HS84-92)	55,109	70,317	1,246,476	1,674,022
Parts and components in machinery goods	8,289	17,328	420,619	490,754
Share				
of machinery goods in total	2.4%	2.6%	32.4%	34.3%
of parts and components in total	0.4%	0.6%	10.9%	10.1%
of parts and components in machinery goods	15.0%	24.6%	33.7%	29.3%
Ecuador				
Value (US$1000)				
Total	4,889,831	4,821,865	3,733,027	3,445,908
Machinery (HS84-92)	88,340	92,556	1,395,217	982,133
Parts and components in machinery goods	20,558	21,255	425,143	366,066
Share				
of machinery goods in total	1.8%	1.9%	37.4%	28.5%
of parts and components in total	0.4%	0.4%	11.4%	10.6%
of parts and components in machinery goods	23.3%	23.0%	30.5%	37.3%
Honduras				
Value (US$1000)				
Total	1,445,698	1,077,565	2,147,370	2,914,873
Machinery (HS84-92)	25,890	24,522	641,870	864,222
Parts and components in machinery goods	8,497	8,934	166,163	214,486
Share				
of machinery goods in total	1.8%	2.3%	29.9%	29.6%
of parts and components in total	0.6%	0.8%	7.7%	7.4%
of parts and components in machinery goods	32.8%	36.4%	25.9%	24.8%

Data source: Authors' calculation, based on UN Comtrade.

Table 5 Definition and Coverage of Each Terminology

terminology	paper	note	types
• Fragmentation	Jones and Kierzkowski (1990)	spatial dispersion of production blocks	A, B, C, D
• Fragmentation	Jones and Kierzkowski (2001)	spatial dispersion of production blocks	B, D
• Vertical specialization	Yi (2003), Hummels, Ishii, and Yi (2001)	vertical division of production processes (imported goods that are used as inputs to produce a country's export goods)	B, D, E
• Outsourcing	Grossman and Helpman (2002a, b)	production of components by different firms	C, D
• Disintegration of production	Feenstra (1998)	vertical division of production processes	B, D
• Vertical production networks	Hanson, Mataloni, and Slaughter (2003)	vertical link of production activity within one firm	B
• External orientation	Campa and Goldberg (1997)	increase in export share and import penetration (including import in parts)	B, D, E
• Offshore sourcing	Arndt (1997, 1998)	production of components in foreign countries	B, D
• Global production sharing	Yeats (2001)	vertical division of production processes	B, D

Note: Alphabet in the last column corresponds to that in Figure 2.
: "E" indicates a broader relation with international economy.

Table 6 Components of Service Link Costs

	Category	Subcategory	Details
Service Link Costs	trade costs	transportation costs	shipment charge, freight charge
		policy barriers	tariff barriers (ad valorem tariff, specific tariff), non-tariff barriers (quatos, other
		information costs	search cost for sellers or buyers, research cost for preference of foreign people
		contract enforcement costs	direct and indirect costs to make sure
		costs associated with the use of different currencies	costs of exchange rate volatility, risk hedge, and uncertainty
		legal and regulatory costs	direct and indirect costs to deal with legal and regulatory issues and procedures
		local distribution costs	costs to utilize local infrastructure, and to efficiently deliver goods to local consumers
	investment costs	policy barriers	indirect costs due to prohibition to entry, absence of national treatment, and other FDI discriminating measures
		information costs	search cost for suppliers
		contract enforcement costs	direct and indirect costs to make sure
		legal and regulatory costs	direct and indirect costs to deal with legal and regulatory issues and procedures
	communications cost		telecommunications costs, internet fee
	coordination costs	timeliness	indirect costs due to inadequateness of timely delivery
		uncertainty	indirect costs due to uncertainty regarding coordination of a series of activities from production to shipment of end proeucts
	agglomeration	networking	IT networking, business networking
		cluster of suppliers	accessibility to suppliers due to agglomeration effects
Location Advantages		cluster of homogeneous firms	externality
		distribution costs	reduction of distributionn costs due to its nature of increasing returns
		concentration of similar types of labor (i.g. skilled labor)	availability of workers thanks to agglomeration effects
	low production costs	running costs	low level of wage, factor abundance (natural resources, land), accessibility to imported intermediate with low tariff rate
		fixed costs	accessibility to public utility (condition of infrastructure), availability of productive workers
	proximity to large markets		proximity to large markets in which there are many consumers or customers
	other geographical features		e.g. there is a suitable port for transit trade

Note: Agglomeration is a part of location advantages, and at the same time affects service link costs.
Source: Components of trade cost are drawn from Anderson and Wincoop (2004).

Table 7

Definition and Source of Data

Variable	Definition	Source
EX	*i*'s Export of parts and components to *j* (US $)	Authors' calculation, based on UN Comtrade.(*)
DIS	Distance between capital cities of *i* and *j* (km)	Fitzpatrick and Modlin (1986).
EXGDP	GDP of country *i* (US $ million)	World Development Report 2003.
EXPERGDP	Per capita GDP of country *i* (US $)	World Development Report 2003.
IMGDP	GDP of country *j* (US $ million)	World Development Report 2003.
IMPERGDP	Per capita GDP of country *i* (US $)	World Development Report 2003.
ADJ	Adjacency dummy	1 if both countries have a common national border, 0 otherwise.
LAN	Common language dummy	1 if both countries use at least one common language, 0 otherwise.
EU15	Intra EU15 dummy	1 if both countries are members of EU15, 0 otherwise.
NAFTA	Intra NAFTA dummy	1 if both countries are members of NAFTA, 0 otherwise.
AFTA	Intra AFTA dummy	1 if both countries are members of AFTA, 0 otherwise.
MERCOSUR	MERCOSUR dummy	1 if both countries are members of MERCOSUR, 0 otherwise.
EU7	Intra EU7 dummy	1 if both countries are members of EU7, 0 otherwise. (*)
EU3	Intra EU3 dummy	1 if both countries are members of EU3, 0 otherwise. (**)
JKAFTA	JK-AFTA dummy	1 if exporter is Japan or Korea, and importer is one of AFTA
EA	Intra EA dummy	1 if both countries are members of EA, 0 otherwise. (‡)
APCH	Intra AFTA plus CH dummy	1 if both countires are members of AFTA, China, or Hong Kong.
JKAPCH	JK-APCH dummy	1 if exporter is Japan or Korea, and importer is one of APCH.
EEC7	Intra EEC7 dummy	1 if both countries are Czech, Hungary, Poland, Slovakia, Slovenia, Bulgaria, or Romania.
EU7EEC7	EU7-EEC7 dummy	1 if exporter is one of EU7, and importer is one of EEC7.
EEC7EU7	EEC7-EU7 dummy	1 if exporter is one of EEC7, and importer is one of EU7.
FDI	FDI flows from *i* to *j*	International Direct Investment Statistics

Note:

(*) EU7 includes Germany, the United Kingdom, France, Italy, Spain, Netherlands, and Belgium.
(**) EU3 includes Germany, the United Kingdom, and France.
(‡) EA includes ASEAN5 plus China, Hong Kong, Vietnam, Korea, and Japan.
EX, DIS, EXGDP, EXPERGDP, IMGDP, IMPERGDP, and FDI are log form.

Countries in the sample

OECD(27)	Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States
Non-OECD (46)	Algeria, Argentina, Bolivia, Brazil, Bulgaria, Cameroon, Chile, China, Colombia, Costa Rica, Dominican Republic, Ecuador, Egypt, Ethiopia, Ghana, Hong Kong, India, Indonesia, Iran, Israel, Ivory Coast, Jamaica, Kenya, Kuwait, Malaysia, Mongolia, Morocco, Nigeria, Pakistan, Panama, Paraguay, Peru, Philippines, Romania, Russia, Saudi Arabia, Singapore, Slovak Republic, Slovenia, South Africa, Sri Lanka, Thailand, Tunisia, Uruguay, Venezuela, Viet Nam

Note: Algeria, Cameroon, Dominican Republic, Ecuador, Egypt, Ethiopia, Ghana, Ivory Coast, Jamaica, Kenya, Kuwait, Mongolia, Morocco, Nigeria, Pakistan, Panama, Paraguay and Viet Nam are included only as importers.

Table 8 Estimate Results of Basic Equations

model	1	2	3	4
dependent variable	total trade	total manufactures	completed machinery goods	machinery parts and components
Constant	-0.97 *	-2.42 ***	-12.78 ***	-12.52 ***
	(0.58)	(0.64)	(0.90)	(0.88)
Distance	-1.09 ***	-1.34 ***	-1.69 ***	-1.83 ***
	(0.04)	(0.05)	(0.07)	(0.07)
EXGDP	1.16 ***	1.34 ***	1.76 ***	1.74 ***
	(0.03)	(0.03)	(0.04)	(0.04)
EXPERGDP	0.15 ***	0.21 ***	0.74 ***	0.68 ***
	(0.03)	(0.03)	(0.05)	(0.05)
IMGDP	1.07 ***	1.10 ***	1.12 ***	1.27 ***
	(0.03)	(0.03)	(0.05)	(0.04)
IMPERGDP	0.08 **	0.07 **	0.20 ***	0.16 ***
	(0.03)	(0.03)	(0.06)	(0.05)
ADJ	0.51 ***	0.25	0.08	-0.03
	(0.16)	(0.17)	(0.25)	(0.25)
LAN	1.01 ***	1.05 ***	1.55 ***	1.35 ***
	(0.12)	(0.13)	(0.16)	(0.17)
EU 15	-0.41 ***	-0.69 ***	-1.11 ***	-1.64 ***
	(0.11)	(0.12)	(0.17)	(0.16)
NAFTA	-1.16 **	-1.50 **	-2.07 *	-2.32 **
	(0.47)	(0.60)	(1.11)	(0.94)
AFTA	2.69 ***	2.83 ***	3.51 ***	4.78 ***
	(0.16)	(0.17)	(0.24)	(0.27)
MERCOSUR	0.92 *	0.80	1.34 *	0.56
	(0.52)	(0.52)	(0.73)	(0.72)
Adjusted R-squarec	0.615	0.593	0.533	0.548
No. of Observations	3960	3960	3960	3960

Note:
- **Figures in parentheses are robust standard errors.**
- *****: significant at 1% level **: 5% **: 10%.**

Table 9 Estimate Results (Subcategory of machinery parts and components)

dependent variable	machinery parts and components					
	general machinery		electrical machinery		transportation equipments	
Constant	-16.57	***	-15.08	***	-17.85	***
	(0.93)		(1.03)		(1.10)	
Distance	-1.86	***	-2.04	***	-2.22	***
	(0.07)		(0.08)		(0.09)	
EXGDP	1.80	***	1.81	***	2.47	***
	(0.04)		(0.05)		(0.05)	
EXPERGDP	0.92	***	0.79	***	0.07	
	(0.05)		(0.06)		(0.06)	
IMGDP	1.33	***	1.30	***	1.43	***
	(0.04)		(0.05)		(0.05)	
IMPERGDP	0.11	*	0.23	***	0.11	*
	(0.05)		(0.06)		(0.06)	
ADJ	0.17		0.02		0.15	
	(0.27)		(0.29)		(0.36)	
LAN	1.33	***	1.39	***	1.46	***
	(0.19)		(0.21)		(0.22)	
EU 15	-1.61	***	-1.69	***	-0.84	***
	(0.17)		(0.19)		(0.24)	
NAFTA	-2.70	***	-2.64	**	-1.85	
	(1.02)		(1.11)		(1.16)	
AFTA	4.93	***	5.70	***	5.01	***
	(0.32)		(0.31)		(0.35)	
MERCOSUR	0.62		0.60		0.98	
	(0.83)		(0.92)		(1.18)	
Adjusted R-squared	0.566		0.511		0.551	
No. of Observations	3960		3960		3960	

Note:
- Figures in parentheses are robust standard errors.
- ***: significant at 1% level **: 5% **: 10%.

Table 10 Estimate Results of Gravity Equations with Various EU Dummies

model	1	2	3	4	5
dependent variable	machinery parts and components				
Constant	-12.52 ***	-12.88 ***	-12.88 ***	-3.72	-5.09 ***
	(0.88)	(0.88)	(0.89)	(2.87)	(1.68)
Distance	-1.83 ***	-1.74 ***	-1.70 ***	-2.24 ***	-1.61 ***
	(0.07)	(0.06)	(0.06)	(0.08)	(0.06)
EXGDP	1.74 ***	1.75 ***	1.74 ***	1.76 ***	1.16 ***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
EXPERGDP	0.68 ***	0.64 ***	0.63 ***	0.65 ***	0.50 ***
	(0.05)	(0.05)	(0.05)	(0.05)	(0.16)
IMGDP	1.27 ***	1.28 ***	1.27 ***	1.25 ***	1.28 ***
	(0.04)	(0.04)	(0.04)	(0.08)	(0.03)
IMPERGDP	0.16 ***	0.12 **	0.11 **	-0.34	0.18 ***
	(0.05)	(0.05)	(0.05)	(0.29)	(0.04)
ADJ	-0.03	0.11	-0.02	-0.48 *	0.46
	(0.25)	(0.25)	(0.26)	(0.25)	(0.29)
LAN	1.35 ***	1.41 ***	1.42 ***	0.92 ***	1.92 ***
	(0.17)	(0.17)	(0.17)	(0.18)	(0.18)
NAFTA	-2.32 **	-2.23 **	-1.99 **	-2.41 ***	-1.11
	(0.94)	(0.93)	(0.90)	(0.93)	(1.30)
AFTA	4.78 ***	4.86 ***	4.94 ***	3.16 ***	1.64 ***
	(0.27)	(0.26)	(0.26)	(0.37)	(0.32)
MERCOSUR	0.56	0.60	0.80	-0.31	2.56 ***
	(0.72)	(0.70)	(0.69)	(0.84)	(0.96)
EU15	-1.64 ***			-2.15 ***	-1.86 ***
	(0.16)			(0.19)	(0.15)
EU7		-2.72 ***			
		(0.24)			
EU3			-3.54 ***		
			(0.38)		
Country dummy (EX)	NO	NO	NO	NO	YES
Country dummy (IM)	NO	NO	NO	YES	NO
Adjusted R-squared	0.548	0.547	0.546	0.567	0.731
No. of Observations	3960	3960	3960	3960	3960

Note:

- Figures in parentheses are robust standard errors.
- ***: significant at 1% level **: 5% **: 10%.

Table 11 Estimate Results of Gravity Equations with Various Dummies

Model	1	2	3	4	5	6
dependent variable	total trade	total manufactures	completed machinery goods	machinery parts and components	machinery parts and components	machinery parts and components
Constant	-1.92 **	-3.58 ***	-14.70 ***	-14.47 ***	-14.55 ***	-14.71 ***
	(0.62)	(0.69)	(0.97)	(0.95)	(0.94)	(0.95)
Distance	-1.00 ***	-1.22 ***	-1.50 ***	-1.61 ***	-1.56 ***	-1.57 ***
	(0.04)	(0.05)	(0.07)	(0.07)	(0.07)	(0.07)
EXGDP	1.17 ***	1.36 ***	1.79 ***	1.77 ***	1.75 ***	1.76 ***
	(0.03)	(0.03)	(0.04)	(0.04)	(0.04)	(0.04)
EXPERGDP	0.15 ***	0.21 ***	0.73 ***	0.65 ***	0.67 ***	0.67 ***
	(0.03)	(0.03)	(0.05)	(0.05)	(0.05)	(0.05)
IMGDP	1.08 ***	1.10 ***	1.12 ***	1.28 ***	1.24 ***	1.26 ***
	(0.03)	(0.03)	(0.05)	(0.04)	(0.04)	(0.04)
IMPERGDP	0.07 **	0.06 *	0.17 ***	0.12 **	0.13 ***	0.14 ***
	(0.03)	(0.03)	(0.05)	(0.05)	(0.05)	(0.05)
ADJ	0.51 ***	0.27 *	0.10	0.02	0.14	0.09
	(0.15)	(0.16)	(0.24)	(0.24)	(0.23)	(0.24)
LAN	1.08 ***	1.14 ***	1.69 ***	1.51 ***	1.45 ***	1.40 ***
	(0.12)	(0.13)	(0.16)	(0.17)	(0.17)	(0.17)
NAFTA	-1.05 **	-1.35 **	-1.84 *	-2.04 **	-1.91 **	-1.94 **
	(0.46)	(0.58)	(1.10)	(0.91)	(0.90)	(0.89)
MERCOSUR	1.10 **	1.02 **	1.70 **	0.94	0.96	1.00
	(0.50)	(0.49)	(0.69)	(0.67)	(0.66)	(0.65)
AFTA	2.85 ***	3.03 ***	3.83 ***	5.12 ***		
	(0.16)	(0.17)	(0.24)	(0.26)		
JKAFTA	1.80 ***	1.79 ***	1.42 ***	2.37 ***		
	(0.27)	(0.34)	(0.56)	(0.50)		
EA					3.59 ***	
					(0.25)	
APCH						4.40 ***
						(0.23)
JKAPCH						1.90 ***
						(0.50)
EU7	-0.78 ***	-1.18 ***	-1.71 ***	-2.40 ***	-2.25 ***	-2.31 ***
	(0.16)	(0.18)	(0.25)	(0.24)	(0.24)	(0.23)
EEC7	1.64 ***	1.81 ***	2.83 ***	2.77 ***	2.82 ***	2.82 ***
	(0.15)	(0.17)	(0.24)	(0.22)	(0.22)	(0.22)
EU7EEC7	0.27 **	0.08	-0.35 *	-0.14	-0.06	-0.09
	(0.12)	(0.13)	(0.19)	(0.20)	(0.19)	(0.19)
EEC7EU7	0.56 ***	0.99 ***	2.20 ***	1.85 ***	1.97 ***	1.92 ***
	(0.13)	(0.15)	(0.21)	(0.20)	(0.20)	(0.20)
Adjusted R-squared	0.618	0.595	0.537	0.551	0.553	0.553
No. of Observations	3960	3960	3960	3960	3960	3960

Note:
- Figures in parentheses are robust standard errors.
- ***: significant at 1% level **: 5% **: 10%.

Table 12 Summary of Each Country Dummy (based on model 4 and 5 of Table 10)

	Importer		Exporter				Importer		Exporter	
Czech Rep.	-1.75	**	0.97	***		Jamaica	-1.30		—	
Hungary	-0.15		0.50			Kenya	-1.53		—	
Mexico	0.06		-3.12	***		Kuwait	-0.84	*	—	
Poland	-2.43	***	-1.04	**		Malaysia	1.37	**	1.94	***
Turkey	-1.56	**	-0.20			Mongolia	-2.42	*	—	
Algeria	-3.07	***	—			Morocco	-2.16	**	—	
Argentina	-0.14		-2.65	***		Nigeria	-1.54		—	
Bolivia	-1.33		-5.35	***		Pakistan	-2.23	*	—	
Brazil	0.38		0.26			Panama	1.11		—	
Bulgaria	-1.88	**	-0.72			Paraguay	-1.11		—	
Cameroon	-2.68	**	—			Peru	-0.42		-6.76	***
Chile	0.89		-4.69	***		Philippines	-0.31		0.70	
China	-0.91		2.20	***		Romania	-2.59	***	-0.50	
Colombia	-0.35		-6.45	***		Russia	-3.10	***	-1.75	***
Costa Rica	-0.02		-3.47	***		Saudi Arabia	-0.95	*	-6.46	***
Dominican Rep.	-1.51	*	—			Singapore	2.43	***	2.11	***
Ecuador	0.44		—			Slovakia	-2.90	***	-0.68	
Egypt	-1.59	*	—			Slovenia	-1.82	***	-0.77	**
Ethiopia	-2.67	*	—			South Africa	0.84		0.28	
Ghana	-1.35		—			Sri Lanka	-1.42		-2.92	***
Hong Kong	1.43	***	1.64	***		Thailand	-0.11		2.56	***
India	-2.09	*	0.88			Tunisia	-2.44	***	-5.39	***
Indonesia	-1.13		1.50	**		Uruguay	0.40		-8.07	***
Iran	-1.72	**	-7.38	***		Venezuela	-0.05		-6.85	***
Israel	-1.02		-0.15			Viet Nam	-1.94		—	
Ivory Coast	-2.70	**	—							

Note: This table summarizes the coefficient and its significance of each country dummy.
Exporter dummy takes 1 if the country is exporter.
Importer dummy takes 1 if the country is importer.
***: significant at 1% level **: 5% **: 10%.

Table 13 Estimate Results of Gravity Equations of Foreign Direct Investment

expoter-importer	OECD-NONOECD	OECD-NONOECD	OECD-ALL	OECD-ALL
estimator	OLS	TOBIT	OLS	TOBIT
Constant	-23.16 ***	-55.20 ***	-26.35 ***	-48.72 ***
	(3.11)	(4.84)	(1.86)	(2.85)
Distance	-0.52 ***	-1.82 ***	-0.97 ***	-1.61 ***
	(0.18)	(0.27)	(0.10)	(0.15)
EXGDP	0.96 ***	1.67 ***	0.89 ***	1.50 ***
	(0.11)	(0.17)	(0.07)	(0.11)
EXPERGDP	0.67 ***	1.20 ***	1.36 ***	1.44 ***
	(0.31)	(0.38)	(0.16)	(0.22)
IMGDP	0.71 ***	2.48 ***	0.76 ***	1.81 ***
	(0.13)	(0.19)	(0.07)	(0.11)
IMPERGDP	0.42 **	0.93 ***	0.40 ***	0.67 ***
	(0.12)	(0.17)	(0.08)	(0.11)
ADJ	0.73	1.28	0.18	-0.46
	(0.91)	(1.49)	(0.35)	(0.59)
EUROPE			0.29	2.80 ***
			(0.29)	(0.44)
EAST ASIA			1.11 ***	2.84 ***
			(0.27)	(0.42)
AMERICA			1.20 ***	1.54 ***
			(0.27)	(0.39)
Sigma		4.16 ***		3.82 ***
		(0.22)		(0.12)
Ratio of Samples with Zero	0.00	0.78	0.00	0.65
Adjusted R-squared	0.388		0.552	
Log Likelifood		-902.159		-2068.130
No. of Observations	269	1104	650	1728

Note:

- Figures in parentheses are robust standard errors.
- ***: significant at 1% level **: 5% **: 10%.
- Data on FDI is for 2000, other explanatory variables are for 1999.
- EUROPE is a dummy variable that takes 1 if the host country belongs to EEC7.
- EAST ASIA is a dummy variable that takes 1 if the host country belongs to APCH.
- AMERICA is a dummy variable that takes 1 if the host country is developing country in Latin America.
- Samples with zero FDI are excluded from the data set for OLS estimation.
- "Sigma" denotes the estimated value of standard deviation in the log likelifood function.

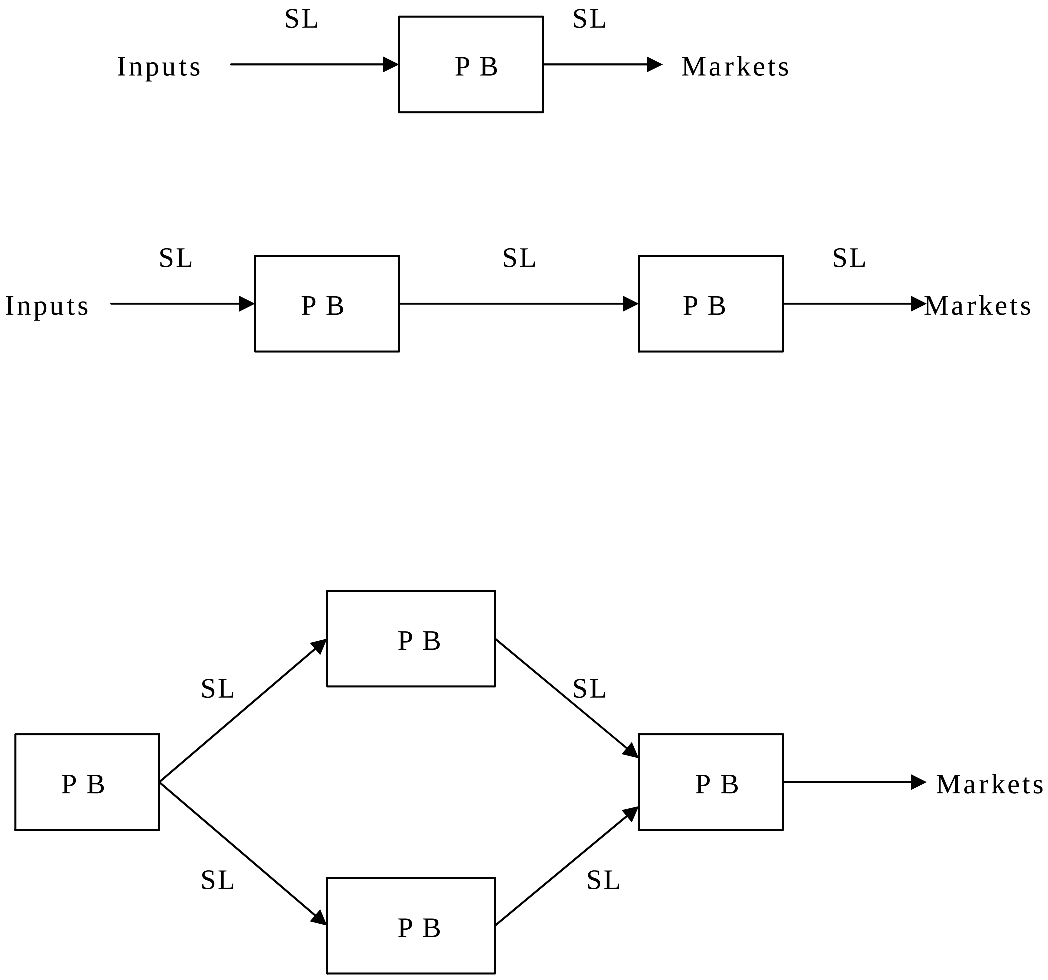
Table 14 Summary of Each Country Dummy (based on equations in Table 13)

OECD → NONOECD			OECD + NONOECD→ OECD + NONOECD			OECD → OECD + NONOECD		
No. of Observations	1104		No. of Observations	3960		No. of Observations	1728	
Ratio of Samples with zero	78.4%		Ratio of Samples with zero	84.8%		Ratio of Samples with zero	65.2%	
Argentina	1.28		Argentina	2.63	***	Argentina	2.44	***
Algeria	-5.13	***	Algeria	-5.99	***	Algeria	-5.24	***
Bolivia	-21.35		Bolivia	-24.96		Bolivia	-22.21	
Brazil	-0.66		Brazil	1.62	*	Brazil	1.42	
Bulgaria	3.86	***	Bulgaria	1.79		Bulgaria	2.03	*
Cameroon	-20.31		Cameroon	-24.06		Cameroon	-21.51	
Chile	2.30	**	Chile	2.39	**	Chile	2.15	**
China	0.26		China	1.66	*	China	1.59	*
Colombia	0.99		Colombia	1.04		Colombia	0.86	
CR	1.82		Costa Rica	-0.07		Costa Rica	0.24	
Dominica Rep.	-25.40		Dominican Rep.	-28.13		Dominican Rep.	-25.10	
Ecuador	-24.26		Ecuador	-26.99		Ecuador	-24.19	
Egypt	1.66		Egypt	1.45		Egypt	1.50	
Ethiopia	-17.74		Ethiopia	-22.72		Ethiopia	-20.10	
Ghana	-19.76		Ghana	-23.89		Ghana	-21.25	
Hong Kong	-0.74		Hong Kong	1.45		Hong Kong	0.88	
India	-0.17		India	0.57		India	0.44	
Indonesia	2.39	**	Indonesia	2.04	*	Indonesia	1.92	*
Iran	-27.09		Iran	-28.36		Iran	-26.02	
Israel	-1.73		Israel	-0.03		Israel	-0.38	
Ivory Coast	-21.42		Ivory Coast	-24.85		Ivory Coast	-22.25	
Jamaica	-23.07		Jamaica	-26.65		Jamaica	-23.54	
Kenya	-19.97		Kenya	-23.82		Kenya	-21.33	
Kuwait	-5.13	**	Kuwait	-5.14	**	Kuwait	-4.67	**
Malaysia	2.40	**	Malaysia	2.14	**	Malaysia	2.22	**
Mongolia	-15.12		Mongolia	-21.43		Mongolia	-18.36	
Morocco	2.15	*	Morocco	1.18		Morocco	1.18	
Nigeria	-23.95		Nigeria	-26.55		Nigeria	-24.05	
Pakistan	-24.77		Pakistan	-26.98		Pakistan	-24.56	
Panama	2.71	*	Panama	0.92		Panama	0.93	
Paraguay	-21.24		Paraguay	-24.68		Paraguay	-22.03	
Peru	-26.79		Peru	-28.37		Peru	-25.77	
Philippines	3.62	***	Philippines	2.80	***	Philippines	2.84	***
Romania	2.98	***	Romania	2.09	**	Romania	2.12	**
Russia	-3.56	***	Russia	-1.12		Russia	-1.42	
Saudi	-7.41	***	Saudi Arabia	-6.63	***	Saudi Arabia	-6.25	***
Singapore	2.91	***	Singapore	3.59	***	Singapore	3.54	***
Slovakia	3.06	***	Slovakia	2.14	**	Slovakia	2.28	**
Slovenia	-1.64		Slovenia	-1.45		Slovenia	-1.21	
South Africa	2.39	**	South Africa	2.86	***	South Africa	2.58	***
Sri Lanka	-21.84		Sri Lanka	-24.94		Sri Lanka	-22.45	
Thailand	1.66		Thailand	1.75	*	Thailand	1.70	*
Tunisia	-25.20		Tunisia	-27.00		Tunisia	-24.62	
Uruguay	-24.60		Uruguay	-26.46		Uruguay	-23.99	
Venezuela	1.89	*	Venezuela	2.22	**	Venezuela	2.16	**
Vietnam	-23.43		Viet Nam	-26.50		Viet Nam	-23.78	

Note:

- ***: significant at 1% level **: 5% **: 10%.
- Each coefficient is Tobit estimator.

Figure 1 Fundamental Concept of Fragmentation

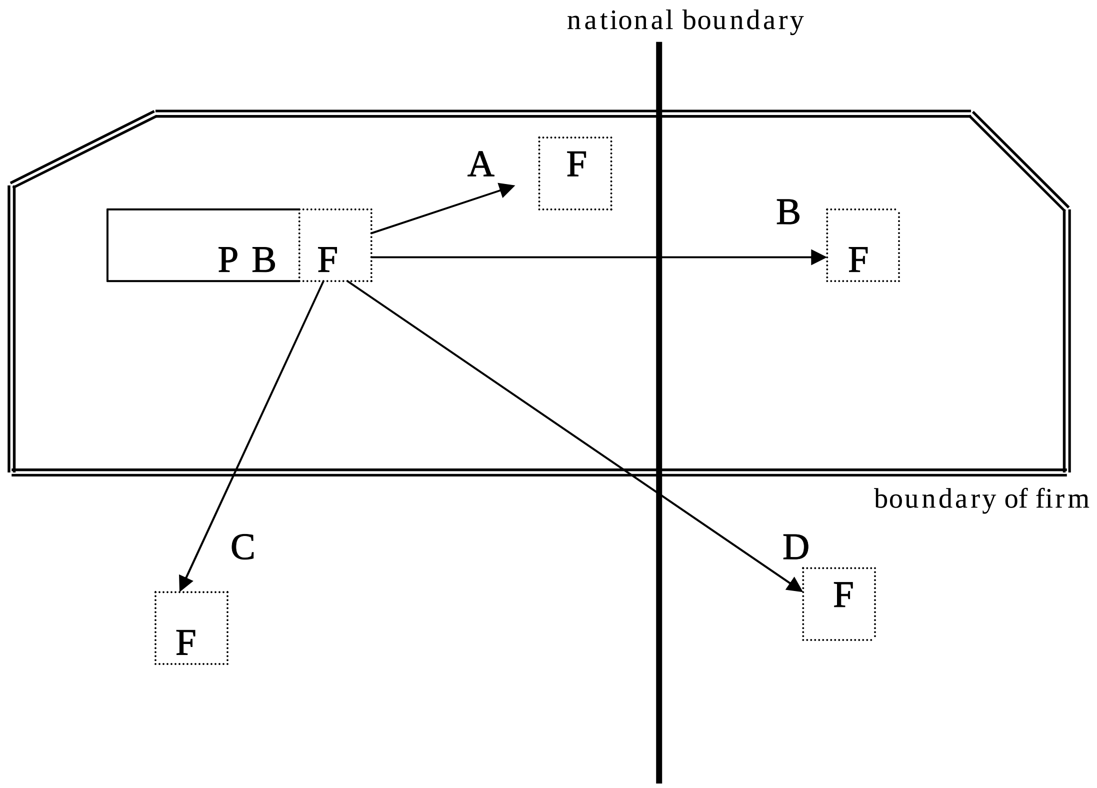


PB: production block

SL: service link cost

Source; Jones and Kierzkowski (1990).

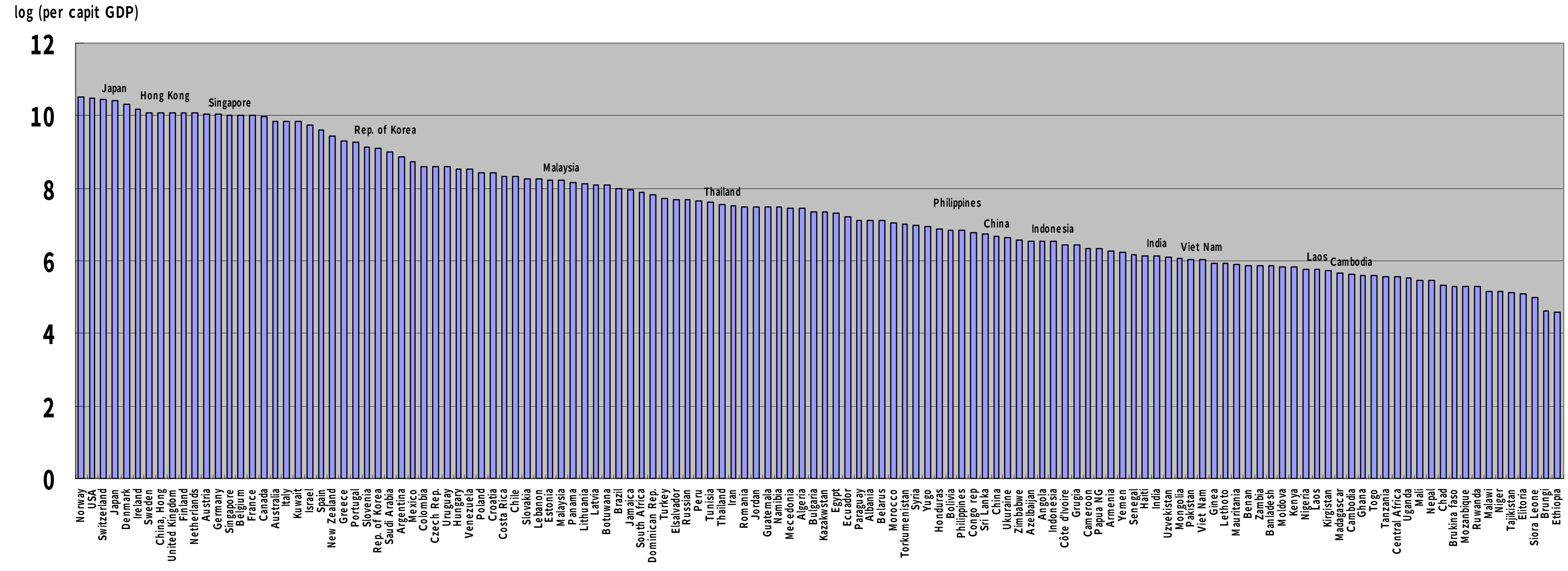
Figure 2　Types of Fragmentation (in Wider Sense)



PB: production block
F: fragment
A: domestic fragmentation (in narrow sense)
B: international fragmentation (in narrow sense)
C: domestic outsourcing
D: international outsourcing

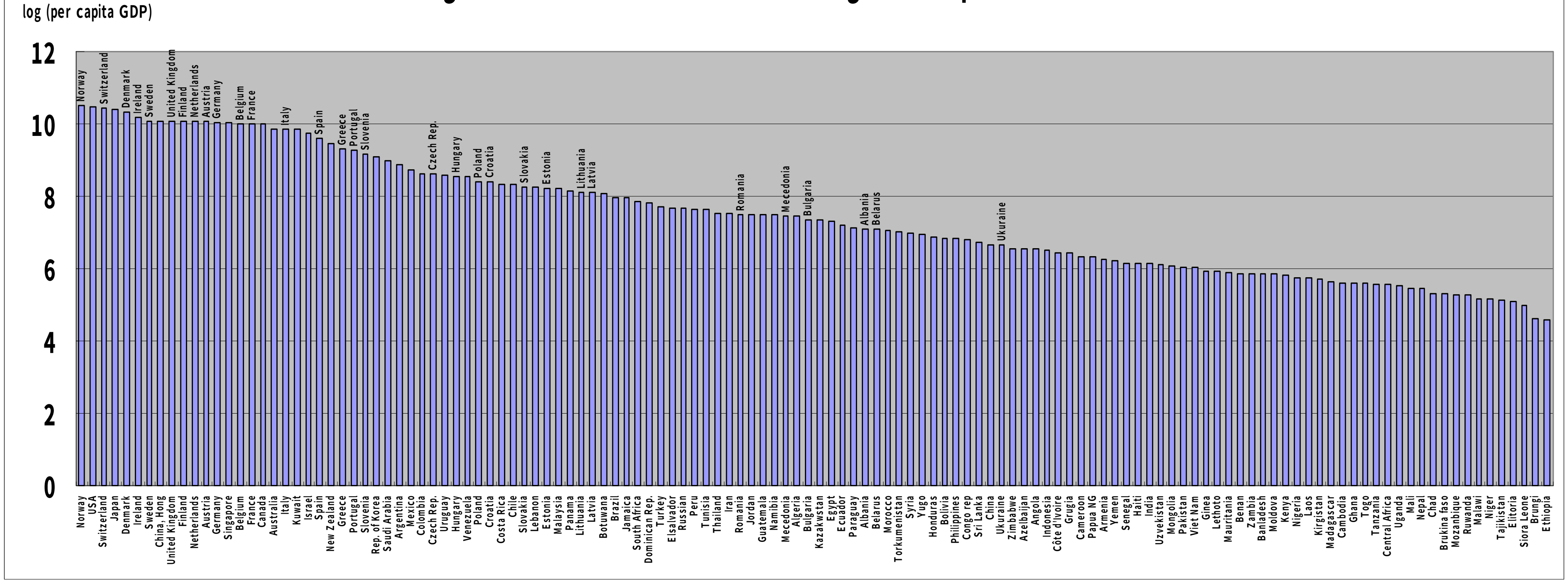
・ Only B and D are captured by trade data.

Figure 3 Income Level: Positioning of East Asian Countries



Source: World Development Report 2003.

Figure 4 Income Level: Positioning of European Countries



Source: World Development Report (2003).