ABSTRACT

TURKCAN, KEMAL. Determinants of Intra-Industry Trade in Intermediate Goods between the US and OECD Countries. (Under the Direction of Daniel Hallstrom and Charles R. Knoeber.)

The increased importance of fragmentation in world trade has created an interest among trade economists to explain the determinants of trade in intermediate goods. A substantial part of trade in intermediates between the US and OECD countries takes the form of intra-industry (IIT). I have divided total intra-industry trade into its horizontal and vertical components. Vertical IIT is defined as the exchange of intermediates which belong to the same industry but which are located at different stages on the production spectrum. Horizontal IIT is defined as the exchange of intermediate goods belonging to the same industry but differing in terms of characteristics or technological specifications, which are technologically unrelated. Hypotheses drawn from Ethier (1982) and Feenstra and Hanson (1997) are put forward to investigate the intra-industry trade in intermediates between the US and other selected OECD countries for the period of 1990-1996.To test these hypotheses, I have utilized three-way fixed effects and random effects models. The results confirm the hypothesis that the determinants of vertical and horizontal IIT in intermediates differ. Empirical results show that horizontal IIT is positively related to the size of markets and foreign direct investment, while it is negatively related to differences in human capital endowments and geographical proximity. On the other hand, vertical IIT is positively related to FDI, while it is negatively related to economies of scale.

DETERMINANTS OF INTRA-INDUSTRY TRADE IN INTERMEDIATE GOODS BETWEEN THE US AND OECD COUNTRIES

by

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To R.Z.S,

You have been truly inspiration for me throughout this doctoral study.

Thank You!

BIOGRAPHY

The Author, Kemal Turkcan, was born in Burdur, Turkey in 1970. He received his Bachelor of Arts degree in Economics from the Istanbul University at Istanbul, Turkey, in 1992. He has served as an internal revenues inspector for the Ministry of Finance during the period of 1993-1994. He was later awarded the Turkish Ministry of Education Stewardship in 1995 to pursue an academic career in economics. He left Turkey in 1995 and attended the American University, Washington, DC, and received his MA in Economics in 1997. He is currently doctoral candidate at the North Carolina State University PhD programme in economics. Upon graduation, he will take an academic position at the Osmangazi University at Eskisehir, in Turkey.

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TABLE OF CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

Chapter 1

INTRODUCTION

A distinctive feature of present economic globalization is production fragmentation, or outsourcing. Fragmentation occurs when the production of a final good requires multiple stages. Each stage in a fragmented production process may require intermediate goods of varying degree of processing. Until the early 1950s, most manufacturers had an integrated production policy: firms produced all components used to make a final good. As manufactured goods become more and more complicated, the cost of producing all components within a firm has increased significantly. This has led to the disintegration of the production process. For instance, computer chips were only used in conventional computers two decades ago. Today technological progress in computer chips enables manufacturers to use them in the production of cars, microwaves, cameras, and etc. Overall, these advances led to greater fragmentation since, for example, automobile manufacturers simply buy computer chips from computer chips producer rather than trying to produce them within their own organization. As world markets have become increasingly integrated in the last few decades due to developments in transportation and communication technologies, fragmentation of production occurs not only across regions within a country but also across countries. Grossman and Helpman (2002), citing a recent annual report of the World Trade Organization (1998), describes the production of a particular "American" car. Thirty percent of the car's value goes to Korea for assembly, 17.5 percent to Japan for components and advanced technology, 7.5 percent to Germany for design, 4 percent to Taiwan and Singapore for minor parts, 2.5 percent to the United Kingdom for advertising and marketing services, and 1.5 percent to

Ireland and Barbados for data processing. This means that only 37 percent of the production value is generated in the United States. The car example indicates that the use of foreign intermediate goods relative to locally produced intermediate goods has increased significantly. Feenstra (1998) provides another example to capture the essence of international fragmentation. The firm producing Barbie dolls, Mattel, obtains raw materials (plastic and hair) from Taiwan and Japan. The assembly activities are performed in countries such as Indonesia and Malaysia. Also it buys the molds and the paints used in decorating the dolls in the United States. Finally, China, in addition to labor, provides the cotton clothing for the dress.

Evidence suggests that a considerable amount of trade in intermediate goods between advanced nations is intra-industry trade. However, few empirical studies have been carried out to understand the determinants of intra-industry trade in intermediate goods. Intra-industry trade is defined in the theoretical literature as the simultaneous export and import of product which are close substitutes in production and consumption. In empirical studies, researchers have defined intra-industry as the simultaneous export and import of products in the same statistical product category. These goods need not be close substitutes in production and/ or consumption.

There are two possibilities that lead to intra-industry trade in intermediate goods. The first is vertical specialization. Suppose that production of a good requires three stages. The components from the first stage are exported and the components of second stage are imported. At the third stage, final goods are assembled. Both these components are technologically related because the component traded in the first stage is used primarily for the production of the second stage component. Thus, this type of exchange may appear as intra-industry trade in intermediate goods in trade statistics if the processing in the foreign country does not change the good's statistical category.

Vertical intra-industry trade in intermediate goods is consistent with the traditional Hecksher-Ohlin model. Firms engage in trade in intermediate goods since each component production requires different factor intensities and thereby firms are expected to exploit the factor cost differences across countries. In standard trade models, countries specialize in final goods in which they have comparative advantage. In the case of international fragmentation of the production process, on the other hand, a country may specialize only in the production of a single production stage. For instance, car production requires skill-intensive stages, such as research and development, designing, and manufacturing parts, and labor-intensive stages, such as assembling.

There is also horizontal intra-industry trade in intermediate goods. Countries may export and import technologically unrelated differentiated intermediate goods because of product differentiation and increasing returns to scale. Intermediate goods may have different characteristics or technological specifications but they are basically the same in terms of quality, costs, and capital/labor techniques employed in the production. Firms engage in trade in horizontally differentiated intermediate goods because some imported intermediates may fit better to their production specifications. For instance, some intermediates are often made-to order products, which may differ in terms of technical characteristics. Horizontal intra-industry trade in intermediate goods is then defined as trade in technologically unrelated inputs.

Thus, we have two models, one in which the relative factor proportions, and another in which economies of scale and product differentiation seeking to explain the extent of intra-industry trade in intermediate goods. The objective of this dissertation is to analyze the shares of bilateral intra-industry trade in intermediate goods between the US and other selected OECD countries. Hypotheses stemming from models of vertical and horizontal trade in intermediates will be tested using panel data techniques for the U.S intermediate goods trade with 25 OECD countries over the period of 1990-1996. The panel data has three dimensions: country of origin, industry, and time. Although the majority of empirical studies in finished goods employ country-specific variables, this dissertation will consider both country and industry-specific variables to test whether the determinants of horizontal and vertical intra-industry trade in intermediate goods differ.

This dissertation is organized as follows. In Chapter 2, the empirical significance of trade in intermediate goods and some potential causes of fragmentation are discussed. Chapter 3 summarizes both Ethier's (1982) model of horizontal trade and Feenstra and Hanson's (1997) model of vertical trade. Chapter 4 has two sections. The first section of Chapter 4 provides a method for distinguishing horizontal intra-industry trade from vertical intra-industry trade in intermediate goods. In addition, it discusses how to measure aggregate horizontal and vertical intra-industry trade in intermediate goods up to the industry level. The second section of Chapter 4 discusses the explanatory variables that I use to explain intra-industry trade in intermediates between the US and other OECD countries. The fifth section describes the econometric specifications and presents econometric results. Finally, the last section provides the summary and conclusions.

Chapter 2

LITERATURE REVIEW

This chapter first reviews the empirical literature measuring the importance of fragmentation in manufacturing industries. Despite the fact that these studies all used different data sources and methods to measure the degree of fragmentation, three important facts emerge. First, the level of production sharing across countries has increased. Second, the degree of fragmentation varies significantly across countries and industries and is often consistent with the Hecksher-Ohlin theorem. Finally, the degree of fragmentation is negatively correlated with the distance between trading partners. The second section of this chapter reviews theoretical literature on the causes and consequences of fragmentation in an integrated world economy. This literature looks at the differences in factor costs and technologies across countries, economies of scale, product differentiation, demand for varieties, the reduction in transportation costs, liberalization of trade and foreign direct investment policies, technical progress, and government interventions.

2.1 Empirical Significance of Trade in Intermediate Goods

Feenstra and Hanson (1996) calculated imported intermediate inputs for a given industry as the value of input purchases from each supplier industry times the ratio of imports to total consumption (imports plus shipments) in the supplier industry, summed over all supplier industries. For the US manufacturing industries between 1972 and 1990, Feenstra and Hanson (1996) found that imported intermediate goods increased from 5.3 percent of total material purchases to 11.6 percent. In some sectors, such as electric and electronic machinery, instruments, footwear, toys, jewelry, and sports equipment, the level of outsourcing is quite higher than above average value.

In another study, Feenstra (1998) employs the “end-use” categories of the Bureau of Economic analysis to construct a data series that roughly gives the magnitude of outsourcing in the US trade. The “end-use” categories record goods according to their use by buyers. By using the “end-use” categories, He splits the US exports and imports into five categories: food and beverages; industrial supplies and materials; capital goods (except autos); consumer goods (except autos); and automotive vehicles and parts. The combined share of food, and beverages and industrial supplies and materials imports in total US imports dropped from about 90 percent in 1925 to 23 percent in 1995. Note that industrial supplies and materials are not subject to additional manufacturing process. Because of that Feenstra (1998) did not include them in the measure of outsourcing. However, capital goods are not only used in investment but also as intermediate goods. For example, electrical parts and components are recorded within the capital goods category. Although, the consumer goods are finished goods, they are still subject to advertising, marketing, and product development when the US firms import them. Thus, Feenstra (1998) treats some of the consumer goods as intermediate goods. Hence, the data revealed that the share of capital goods and consumer goods in the total US imports have jumped from about 10 percent in 1925 to 60 percent in 1995. In addition, the trade data indicate that goods are being imported into the US at increasingly advanced stages of production.

Campa and Goldberg (1997) study the recent changes in the external orientation of manufacturing industries in four countries (the United States, Canada, the United

Kingdom, and Japan) in terms of industry exports share, import penetration, and imported input use in production. To calculate the share of imported to total intermediate goods, Campa and Goldberg (1997) employ input-output data series, which provide information on the weight of each industry as an input into the final output of another industry. These tables also report the usage of imported intermediate goods in production. The data indicates that the US, the UK, and Canada experienced a significant increase in the share of imported to total intermediate goods. For example, the average imported inputs share of all US manufacturing industries increased from 4.8 percent in 1974 to 8.2 percent in 1993. The U.S. figures are still low compared to the U.K and Canada figures which are 21.6 and 20.2 percent, respectively. This suggests that the US still relies on its large domestic market. However, Japan has experienced a sharp decline in the share of imported to total intermediate goods from 8.2 percent to 4.1 percent. For individual industry groups in the US, the transportation equipment industry has the largest share of imported to total intermediate goods, 15.7 percent in 1993. Industrial machinery and electrical equipment and machinery industries also have high dependency rates on foreign intermediate goods, 11.0 and 11.6 percent, respectively.

Hummels et al.(1998) examine the growing importance of trade in intermediate goods by using yet another measure of fragmentation, vertical specialization. Based on their approach, vertical specialization occurs when a country uses imported intermediate goods to produce goods it later exports. If the country does not export it later, outsourcing has occurred but vertical specialization not. On the contrary, in the case of horizontal specialization all production processes are performed in one country. By comparison, Feenstra and Hanson(1996) define outsourcing as reliance on imported inputs.[1] Hummels et al.(1998) measure of value of vertical specialized-based trade is

VS=(imported intermediates/gross output)x(exports)x(2)

or equivalently

VS=(exports/gross output)x(imported intermediates)x(2)

Vertical specialization is simply imported input content of exports. If a country does not use any imported intermediates or does not export its output, then VS takes a value of zero. They multiply by two because imported inputs are counted twice: once as imports once as a content in exports. To implement their measure, they use the OECD input-output database. The data covers ten OECD countries from 1968 to 1990. The input-output tables provide information on the interrelationships among industries, including imported intermediates usage and each industry's output exported. Aggregate vertical specialization trade is simply the sum of VS for each sector. The measured vertical trade as a share of total trade reveals two distinctive facts. First, the VS shares vary extensively across countries. The VS shares increased constantly from 1968 to 1990 for every country except Japan. The evidence indicates that the amount of vertical based trade in these countries explains more than 20 percent of total trade in 1990, and the growth in VS is around 30 percent from 1968 to 1990. The small OECD countries have the largest amount of vertical trade while large countries, such as the US, Japan, and Australia have the lowest VS shares. For instance, the VS share in the US has increased from around 4

[1]There are different types and terms of fragmentation used in the fragmentation literature. These are "outsourcing" by Feenstra and Hanson (1995,1996,1997, and 2001), "disintegration of production" by Feenstra (1998), "fragmentation" by Deardoff (1998,2001) and Jones and Kierzkowski (2000, 2001), "vertical specialization" by Hummels, Rapoport, and Ke-Mu Yi (1998), and "intra-product specialization" by Arndt (1997, 1998,2001).

percent in 1968 to 7 percent in 1990 while the VS shares in Netherlands has grown from 32 percent to 42 percent. This fact clearly suggests that large countries are generally able to produce every stage of production within their borders due to scale economies while small countries are not. Second, the VS shares vary across industries within a country. In the US, for instance, the VS shares in office and computing machinery is largest, 16.7 percent in 1990 while it was lowest in mining and quarrying, 0.8 percent. The data also suggest that the VS shares vary widely across countries within each sector. For instance, the VS share in the aircraft industry for the US is 11.6 percent while it is 34.5 percent for the United Kingdom.

Lovely and Richardson (1998) divided the US trading partners into three broad categories based on their level of industrialization: the industrialized countries (I-countries), newly industrialized countries (NICs), and the primary producers (P-countries). For each group of trading partners, they classified products into two sub categories: producer and consumer goods. Next, they divided producer goods into durables and non-durables because they argue that nondurable goods, such as raw materials, mineral, and agricultural products are used in manufacturing as inputs while durables, such as machines, are used in manufacturing industries as capital goods. With the help of these classifications, the US trade data indicates that the US mainly trades inputs not outputs. The data also show that the trade volume of producer goods is three to four times as large as that of consumer goods. Focusing on the trading partners, they found that intra-industry trade in producer goods in 1994 is mostly with I-countries and NICs but the US still had net exports (inter-industry trade) with NICs. The data suggest that the US trade with P-countries is relatively one-way (inter-industry) trade. The US has net imports in oil, food, apparel, and footwear goods while it has net exports in manufactured intermediate goods and capital goods.

Using these empirical facts, Lovely and Richardson (1998) draw several important conclusions. Although the skill intensities within a group at the two-digit level are roughly similar, industry classification for each group at the more disaggregated level suggests that each product requires different factor contents. U.S trade in intermediate goods with NICs is more concentrated in the labor-intensive sub-products and processes than is trade with I-countries. Intra-industry trade in producer inputs between the U.S and industrialized countries is entirely in horizontally differentiated and skill intensive products while intra-industry trade between the US and NICs is the vertical exchange of labor-intensive intermediates for skill-intensive producer inputs or final manufactures.

Gorg (2000) analysis the determinants of the inward processing trade (IPT) in the European Union for the period of 1988-1994. IPT is the duty relief procedure allowing goods to be imported into the EU for processing and subsequent export outside the EU without payment of duty. Thus, Gorg (2000) argues that IPT could be good proxy for fragmentation in trade. Gorg (2000) concentrates on the US IPT as a source for IPT since the US is a major trading partner of 12 EU countries' imports from the US in 1994. The data on IPT also revealed that the share of US IPT for 12 EU countries increased slightly from 17.7 percent in 1988 to 19.8 percent in 1994. The growth share in periphery countries is significantly higher than core countries, i.e from 13.7 to 23.7 percent in periphery while from 18.1 to 18.9 in core countries.[2]

[2] In his study, periphery countries are Greece, Ireland, Portugal, and Spain while the core countries are Belgium, Denmark, France, Germany, Italy, Luxembourg, and the UK.

Yeats (2001) evaluates the magnitude and growing importance of global production sharing in international trade by simply looking at 1995 OECD trade statistics. Yeats argues that the Standard International Trade Classification system (SITC Revision 1) fails to differentiate between final goods and components: about 10 out of 800 industry groups at the five-digit level in the SITC Revision 1 are identified as components. Since the late 1970s, many countries, mostly OECD members, have adopted the SITC Revision 2 system, which consists of more components industry groups. Yeats (2001) focuses only on Machinery and transport equipment group which SITC 7 (Rev. 2) group accounts for more than 50 percent of all trade in manufactures. Items classified as components and parts in the SITC 7 group are used to measure the growing importance of trade in components in international trade. The machinery and transport equipment group (SITC 7) has at least 50 individually identified components items at three, four, and five-digit levels. His results show that in 1995, about 30 percent of all OECD trade in the machinery and transport equipment (SITC 7) is components trade. In the United States, the share of parts and components in total imports, in manufactured goods imports, and in transport and machinery equipment imports are 12.3 percent, 15.6 percent, and 26.5 percent, respectively. The share of parts and components in total U.S exports, manufactured goods exports, and in transport and machinery equipment exports are 18.7 percent, 24.4 percent, and 39.8 percent respectively. The component export share in total SITC 7 trade is significantly higher in the US than in European countries. The trade data also indicates that the share of component trade in total OECD SITC 7 trade grew faster than total SITC 7 trade from 1978 to 1995. Thus, the data clearly suggests that the companies in machinery and transport equipment sectors are becoming increasingly dependent on foreign intermediate producers.

2.2 Causes of Fragmentation

The fragmentation of production could occur for a variety of reasons. In the newly emerging fragmentation literature, the following factors are suggested to explain the recent surge of the fragmentation.

2.2.1 Differences in Production Technologies and Factor Endowments

Most of the traditional trade models have mainly focused on explaining the pattern of specialization in final goods. According to the Heckscher-Ohlin (H-O) and the Ricardian models, each country specializes in goods in which they have comparative advantage and exchanges these products for those in which other countries enjoy a comparative advantage. In the Ricardian model, there are two commodities and one factor of production and comparative advantage is solely the result of international differences in the productivity of labor. In the H-O model, there are two commodities and two factors and comparative advantage is determined by the interaction between countries' factor endowments and commodities' factor intensities.

A typical finished good consists of many intermediate goods. These traditional trade models, however, ignore the possibility of trade in intermediate goods. In other words, if a country specializes in the production of TV sets, these models assume that production of all TV sets parts are produced within that country. In the past, fragmentation of production has mainly occurred within the country borders. Thus, there was no need to modify these traditional models to include international fragmentation of production. In the present, countries, however, not only exchange final goods but also intermediates. A question arises ,then, whether the prediction of these models regarding the pattern of specialization in intermediates continues to hold or not. Similar to trade in finished goods, the majority of trade economists have attempted to explain the determinants of trade in intermediates using either the Ricardian or the H-0 model or a combination of both. These explanations particularly work well to explain the causes of fragmentation between developed and developing countries.[3]

A number of studies, such as by Sanyal (1983), Hummels et al. (1998), and Deardoff (1998), have employed the Ricardian model to explain the pattern of specialization in the case of trade in intermediates. The first model that explicitly tackles vertical specialization along the spectrum of a good is developed by Sanyal (1983). His model applies the Ricardian model with the concept of a continuum of goods which is first introduced for final goods by Dornbusch, Fischer, and Samuelson (1977). As noted earlier, the simplest version of the Ricardian model has only two final products. With a large number of products, solutions to this model become impossible. Dornbusch et al. (1977) developed a Ricardian model with large number of finished goods. To establish the pattern of specialization, they order finished goods in decreasing order of home country's comparative advantage by comparing each good's unit labor requirements across countries.

Introduction of fragmentation into the Ricardian model complicates investigation of the pattern of specialization in intermediates because a typical finished product consists of many parts from raw materials to semi-finished goods to final good. Sanyal (1983) has overcome this problem by applying the method initially developed by

[3] In some studies, researchers attempt to incorporate both the Ricardian and the H-O features into one model. For instance, Cheng et al. (2001) examine the relationship between FDI and production

Dornbusch et al. (1977). The only difference between these two models is that Sanyal (1983) considers the continuum of semi-finished stages along the vertical spectrum whereas Dornbusch et al. (1977) have worked with the continuum of finished products. In Sanyal's model, there are two countries producing one final good with a single factor of production, labor. Each final good consists of many stages along its vertical spectrum. Similar to Dornbusch et al. (1977), Sanyal (1985) indexed each stage on an interval, $[0,1]$. In addition, he assumed that the amount of labor required to produce each stage increases as we move towards final stage 1 and it varies across countries. The model predicts that if the labor requirements up to stage, say x, in country 1 is lower than that of country 2, then country 1 will specialize in the production of parts (from stage 0 to x) while country 2 specializes in the late stages (from stage x to 1). Hence, the comparative advantage in this model is determined by comparing relative unit labor requirements across countries. Hummels et al. (1999) developed an extension of the Dornbusch-Fischer-Samuelson Ricardian model to explain vertical specialization. Deardoff (1998) also developed a Ricardian type of fragmentation model though he does not employ the method in Dornbusch et al. (1977). The specialization in this model is also determined by differences in relative unit labor requirements across countries.

Feenstra and Hanson (1995,1996,1997, and 2001), Arndt (1997, 1998, and 2001), Deardoff (1998, 2001), Jones and Kierzkowski (2000,2001), use the H-O model to explain the effects of fragmentation on the pattern of specialization and especially on factor returns. Like in the final goods case, in the H-O fragmentation models, countries try to exploit differences in factor prices across countries. In Deardoff (1998), the model

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fragmentation by combining both models' features.

consists of two small countries, two final goods, X and Y, and two factors, labor and capital. Before the introduction of fragmentation, the model assumes that the home country is relatively capital abundant and has a comparative advantage in the relatively capital-intensive final good X. Suppose that fragmentation is possible in the production of final good X and it is costless. The model also assumes that there are two stages in the production of good X. In the first stage, intermediate good Z is produced via labor and capital factors while in the second stage the intermediate good, labor, and capital factors are combined to produce final good X. Thus, assuming that the intermediate good is capital-intensive relative to the production of the final good X, the home country will have a comparative advantage in the production of intermediate good Z. Since there will be no complete specialization in any goods or parts, the home country will continue producing a combination of intermediate good Z, final good X, and other final good Y but it will employ more resources in the production of capital-intensive intermediate good Z. Overall, Deardoff (1998) argues that the introduction of fragmentation will enlarge the diversification cone because fragmentation will enable firms to participate in the production of a good in which they initially have no comparative advantage.

Feenstra and Hanson (1997) present a model of vertical specialization in a H-O framework with a continuum of intermediate goods. They use this model to study the effects of outsourcing on the rising wage-inequality in the US and Mexico. Though there are some similarities between Feenstra and Hanson's outsourcing model and Sanyal's vertical specialization model, there are some notable differences. Unlike the Sanyal model, the outsourcing model has three factors, capital, skilled labor, and unskilled labor. In addition, each stage along the vertical spectrum is indexed in terms of skill intensity not in terms of unit labor requirements. In this model, developed countries locate unskilled stages to underdeveloped countries where labor is cheap, while skilled-labor abundant countries specialize in intermediates which employ intensively the skilled labor factor in the production of intermediate goods. Therefore, the pattern of trade in both models is determined by the differences in factor endowments across countries.

2.2.2 Economies of Scale, Product Differentiation, and Demand for Varieties

The Ricardian and the H-O models are often used to explain the phenomenon of fragmentation and its effects on wages between developing and developed countries. However, the empirical evidence reviewed above reveals that there is a considerable amount of trade in intermediate goods among developed countries. This occurs despite the fact that they are similar in terms of factor endowments and production technologies. It has been argued that the exchange of intermediate goods among advanced nations may be the result of economies of scale, product differentiation, and demand for varieties. In the trade literature, a number of new models have been developed to explain trade in intermediate goods. These models are extensions of new trade models that were specifically developed to explain the trade in horizontally differentiated finished goods. These new trade models of trade in horizontally differentiated final goods can be classified into two types: neo-Chamberlinian models of monopolistic competition developed by first Dixit and Stiglitz (1977) in the context of a closed economy and then modified to include international trade by Krugman(1979,1981, and1982) and neo-Hotelling models of monopolistic competition developed by Lancaster (1979,1980) and improved by Helpman (1981). These new trade models emphasize the economies in which markets have product differentiation, consumers love for variety, increasing returns to scale and imperfect competition. There are numerous similarities between the neo-Chamberlinian models and the neo-Hotelling models regarding the supply side of the economy but there are some differences considering demand side of the economy. The neo-Chamberlinian models uses a “love of variety” approach while the neo-Hotelling models employ an “ideal variety” approach. In the case of the love of variety approach, a consumer may prefer to consume all types at different times since they want variety. In the case of the ideal variety approach, a consumer may value a specific brand of a good more than any other available brands.

Like in the case of trade in horizontally differentiated finished goods, we can also classify the horizontally differentiated intermediates trade models into two types: the neo-Chamberlinian models developed by Ethier(1982) and later by Helpman and Krugman (1985) and the neo-Hotelling models modeled by Helpman and Krugman (1985) and extended by Luthje (2000a, 2000b).[4] Ethier (1982) was the first to develop a model of intra-industry trade in horizontally differentiated intermediate goods. The starting point of Ethier’s (1982) model of international division of labor is Dixit and Stiglitz’s (1977) “love of variety” approach. Like consumers, Ethier (1982) argues that firms also benefit from an increasing in number of varieties of intermediates. In his paper, the international division of labor is built upon two important fundamentals: increasing returns to scale in the production of components and the greater market size possible with free trade. Intermediate goods are produced at increasing returns to scale related to the plant size. This type of economies of scale is termed “national” returns. The Intermediate goods market is characterized by monopolistic competition. In other words, production of each

[4] Helpman and Krugman (1985) separately employed Dixit and Stiglitz’s love of variety approach and Lancaster’s ideal variety approach and concluded that both led to similar results.

variety will be undertaken by only one intermediate goods producer since a potential entrant can always do better by introducing a new variety than by sharing in the production of an existing variety. Beside the national returns in the production of intermediate goods, there are external economies of scale in finished goods production with respect to the number of varieties of intermediate goods. The external economies of scale in finished goods production arise from an Adam Smith type of the division of labor. Adam Smith's concept of division of labor is initially applied to the trade in final goods. Ally Young (1928) argues that not only final goods but also intermediate goods can be diversified. In autarky, the division of labor is greatly limited by the extent of the market. Foreign trade, however, generates a larger market and thereby an increase in the supply of available varieties of intermediates. Thus, the producers of finished goods have more options to choose among varieties of components in the international market and at lower prices. This result of Ethier's model is sometimes referred as "love of variety for inputs" paralleling "love of variety of final goods" in Dixit and Stiglitz's paper.

Luthje (2000a, 2000b) employed Lancaster's "ideal variety approach" to formalize intra-industry trade in horizontally and vertically differentiated goods.[5] Luthje argues that the use of the "love of variety approach" in the study of intermediate goods trade is not appropriate because the final goods producer will not enjoy having more intermediate varieties but will put more effort to purchasing the variety that satisfies specific production requirements. In other words, the final goods producer uses one specific variety of the intermediate good, called the "ideal intermediate good", in the production of one specific variety of final good. Like in Lancaster's model, Luthje

[5] Luthje used Helpman and Krugman's (1985) approach to model trade in horizontally differentiated intermediate goods.

applied the compensation function to trade in inputs. If the available varieties of inputs in the market do not satisfy the requirements of the specific final goods production, then firms should use more capital and labor to adapt them into the production of final goods. The cost of adaptations is large if the number of input varieties are small. Thus, by increasing the number of intermediates, we should expect that the productivity in final goods production to increase and unit costs to decline. In autarky, firms incur large adaptation costs since the number of input varieties is small. With the opening of trade, there will be more options for final goods producers to select since foreign trade increases the number of input varieties. Thus, the final goods producers get closer to their ideal intermediate good. Since foreign trade provides a larger market for their products, the increasing returns to scale in intermediate goods production also raised considerably. Hence, by using Lancaster's "ideal variety approach", Luthje has reached the same conclusion as Ethier (1982) did.

2.2.3 Technological Improvements, Institutional and Policy Changes

Another set of explanations is based on developments in transportation and communication technologies, technological progress in the production process, reductions in trade barriers, liberalization in foreign direct investment, and government interventions in the market. Jones and Kierzkowski (2000) claim that technological progress in production could be a major force behind the recent surge of fragmentation. Due to technological progress, manufacturers may employ newly developed methods and production techniques to combine inputs to produce final goods. For instance, computer chips were only used in conventional computers two decades ago but today technological progress in computer chips enables manufacturers to use them in the production of cars, microwaves, cameras, etc. Overall, these advances lead to a greater volume of fragmentation since, for example, automobile manufacturers simply buy computer chips from computer chips producer rather than trying to produce them within their own organization.

Technical progress in the service sector is another cause of the fragmentation of production. For instance, lets assume that the production of a final good requires two production blocks, i.e two different stages. If these blocks are both domestically available, then the need for service would not be much, but if the production of a final good requires combining of one domestic production block with a foreign production block, then the role of services would be very important. Outsourcing helps companies to reduce marginal costs of the entire production, but it also generates extra costs of service links between the production blocks: links in the form of communication, transportation, coordination and accounting. Small changes in transportation costs have a major effect on fragmentation decisions since these costs are a significant fraction of total costs if the intermediate goods cross multiple borders.[6] Thus, the decision to fragment production depends on a tradeoff between its extra service costs and the cost saving that can be achieved by outsourcing some of the production stages into countries where factor prices are cheaper. Due to recent development in service links, companies find it profitable to outsource more production processes to developing countries where labor costs are low.

Harris (2001) developed a more formal model of the effects of recent improvements in communication technologies on the fragmentation of production. He emphasizes a different type of fixed costs in the production of components: fixed network

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[6] See Krugman and Venables (1995) for the role of transportation costs within the framework of fragmentation.

costs. Ethier (1982) focused on fixed costs in the production of intermediate goods to generate increasing returns to scale in his model. Harris (2001) includes both network costs and traditional fixed costs at the plant level into an Ethier type components cost function to generate economies of scale. As suggested by Jones and Kierzkowski (2000), service links between production blocks are a very important part of the fragmentation process. Harris (2001) claims that communication costs are different from transportation costs become that communication services are kind of a quasi-public good. Once a communication networks is established, every company will be able to use it at average cost. The total cost of providing the entire network system depends on the number of markets and the number of components. Hence, as the number of component producer increases, the average costs will decline, and thereby companies earn higher profits. Therefore, international trade will lead to increasing returns to scale in component production due to emergence of global network systems. High profits lead to additional entry of component producers into the market. In sum, Harris pointed out that the recent developments in communication technologies, such as the internet, have lowered the average network costs per users, and ultimately led to a surge in the intermediate goods trade.

Liberalization of FDI and reductions in trade barriers for the last two decades are also cited as major factors behind the recent surge in fragmentation. The most notable paper to explicitly develop a fragmentation model with FDI is Cheng et al. (2001). The majority of FDI is carried out by MNEs from developed countries, which establish an affiliate in a developing country to produce labor-intensive intermediate goods, which are then re-exported back to its home base for assembly. The decision to establish an affiliate in a developing country depends on the profitability of FDI. FDI leads to a technology transfer from an advanced home country to an underdeveloped foreign country. Due to the availability of managerial skills in the foreign country, there will be some efficiency loss for home firms when the new technology is adopted into the foreign country. The model's solution reveals that the minimum price level for positive supply of intermediate goods is negatively related to the efficiency loss variable, and is positively related to tariffs, transportation costs, and wages. Hence, the efficiency variable has negative effects on the foreign country's comparative advantage in intermediate goods production. If the efficiency loss is small or moderate, then home firms make FDI in foreign country, the intermediate goods supply in this country increases and its price declines. If the efficiency loss is large, no FDI is made and there will be no fragmentation in intermediate goods. Cheng et al. (2001) applies the model implications to the relationship between Hong Kong and Guangdong, a province of China that is close to Hong Kong. They found that as the share of Hong Kong FDI in Guangdong increases from 61 percent in 1988 to 68 percent in 1996, the share of processing trade in Guangdong's total exports rose from 5.4 percent to 27.2 percent. Moreover, the share of Guangdong's exports by foreign-funded enterprises jumped from 16 to 51 percent. These figures clearly suggest that production fragmentation induced by FDI has generated a large volume of trade between Hong Kong and China. However, as Hong Kong moves its manufacturing activities into mainland China, the share of employment in Hong Kong's manufacturing sector, especially in intermediate goods production, drops significantly from 34.7 in 1986 to 11.4 percent in 1996 while the employment in trade-related services, such as transport, storage, and communication, rose from 8.2 to 11 percent since China exports goods to the world market through Hong Kong.

Although tariff and non-tariff trade barriers worldwide are now quite low, especially among the advanced countries, further tariff liberalization can increase the gains from production fragmentation since intermediate goods may cross borders more than once. In addition, the trade gains from fragmentation can be greater when countries eliminate FDI restrictions. The stylized facts indicate that multinationals invest in foreign countries for two reasons. First, by investing in foreign countries MNEs are able to avoid tariff and non-trade barriers. Second, vertically organized MNEs invest in countries where they can take advantage of factor price differences. Fragmentation has enhanced the close relationship between foreign direct investment policies and trade policies since multinationals do play a major role in the fragmentation of production in international trade. Markusen (1997) performs a simulation to see whether trade liberalization and investment liberalization policies are substitutes or complements. In a trade liberalization simulation, trade costs become zero while foreign direct investment is not allowed. In the case of an investment liberalization scenerio, the ban on investment is removed but trade costs remain high. In the last simulation, a combination of both trade and investment liberalization is studied. The simulations show that the combination of the two performs better than either alone. As a result, Markusen (1997) argues that governments should implement both trade liberalization and foreign direct investment liberalization at the same time because both policies are complementary to achieve greater national welfare gains.

Complimentary to these developments, it is also often cited in the development literature that government policies have a major impact on the location of manufacturing plants between developed and developing countries. When the investment conditions in developing countries such as insufficient infrastructure systems are discouraging, the companies in developed countries avoid shifting their low-skilled production process into developing countries since the tradeoff between its the extra costs due to these unpleasant conditions and the cost savings due to cheap labor is not favorable. During the 1960s, East Asian countries launched several programs. These programs increased the volume of trade in intermediate goods between developed countries and East Asian countries. Since other developing countries observed the rapid development of East Asian countries, they also adapted similar programs. Therefore, we can argue that indirect government policies, such as improvement of education, higher literary rates, the development of adequate transportation, financial and communications systems, providing technical training to work force, and eliminating the risks such as, political risks, social unrest, nationalization without adequate compensation, exchange rate risks, strikes, and so forth, would certainly increase the fragmentation of production between developed and developing countries.

Chapter 3

THEORY OF INTERMEDIATE GOODS TRADE

Intra-industry trade (IIT) is defined as the simultaneous export and import of products, which belong to the same statistical product category. According to Kol and Rayment (1989), three types of IIT may occur at any industry level: the exchange of final goods against final goods, the exchange of final goods against intermediates, and the exchange of intermediates against intermediates. The first section of this chapter describes two types of IIT in intermediates observed in trade statistics: horizontal IIT and vertical IIT. Horizontal IIT in intermediates is defined as the exchange of intermediate goods belonging to the same industry but differing in terms of characteristics or technological specifications, and technologically unrelated. Vertical IIT in intermediates, however, is defined as the exchange of intermediate goods which belong to the same industry but which are located at different stages on the production spectrum. Consequently, in the second section of this chapter, I have briefly summarized Ethier's model to explain horizontal IIT and Feenstra and Hanson's model for vertical IIT.

3.1 Trade in Intermediate Goods

Trade data used in this dissertation are published according to an agreed international system of classification known as the Harmonized System (HS Rev.1). These trade statistics are published at various different levels of aggregation. The level of aggregation is shown by the number of digits in the number used in the product classification. The highest level of aggregation is the two-digit level, which is followed by the fourth, sixth and tenth-digit levels representing successively higher levels of disaggregation. These published trade statistics employ methods of classification based on statistical convenience rather than economic meaningfulness. In economic theory, IIT is defined as the simultaneous export and import of products, which are close substitutes in production and consumption. In empirical studies, researchers, on the other hand, define IIT as the simultaneous export and import of products, which belong to the same statistical product category. Here is an example of a hierarchy from HS (Rev. 1):

85	Electrical machinery equipment parts thereof; sound recorder etc
8501	Electric motors and generators (excluding generating sets)
8528	Television receivers (including video monitors & video projectors)
8534	Printed Circuits
8540	Thermionic, cold cathode valves & tube (ex vac/ga filld, tv camera tubes)
854011	Cathode-ray television picture tubes, inc video monitor tubes, color
854012	Cathode-ray TV picture tube incl video monitor tube,
854020	Television camera tubes, image converter and other photocathode tubes
854030	Cathode-ray tubes, nes
854041	Magnetron tubes
854042	Klystron tubes
854049	Microwave tubes, nes
854081	Receiver or amplifier valves and tubes
854089	Valve and tubes, nes
854091	Parts of cathode-ray tubes
854099	Parts of valve and tubes, nes

The reported exchange of final goods against final goods in trade statistics may be result of categorical aggregation. An aggregation problem arises when a researcher employs higher level of aggregation to measure the extent of IIT, such as at two-digit level. In empirical studies, researchers argue that the four-digit level is the closest level of statistical industry groupings to economically meaningful industry groupings. Consider a case where a researcher chooses the two-digit level of HS to measure the level of IIT in Electrical machinery equipment parts industry HS (85). IF HS (8501) and HS (8540) require different resources or technologies in their production, then calculated IIT in HS (85) industry group is purely the result of grouping together essentially different products and treating them as belonging to the same industry. However, since all of these products are aggregated into one export/import category at two-digit level of aggregation, HS (85), it could show up as IIT in HS (85), when in actuality there would be no IIT in this industry. In empirical studies, researchers called this problem “aggregation bias”. Even at the four-digit level, an aggregation problem could be present. In this case, the solution would be to employ six or even ten-digit level industry groups.

Apart from aggregation bias, the exchange of final goods against final goods may be an exchange of differentiated goods.[7] In the trade literature, differentiated goods are classified into two groups: horizontally differentiated and vertically differentiated goods. In the case of horizontal differentiation, goods differ because of style, appearance, and one or more characteristics but they are basically the same in terms of quality, costs, and capital/labor techniques employed in the production. Most of the non-durable consumer goods, such as wine, textile products, beauty products, and etc, are considered to be horizontally differentiated commodities. In the literature, the exchange of horizontally differentiated finished goods is often called as horizontal IIT.

When it comes to vertical differentiation, goods differ in terms of qualities but they are no longer the same in terms of unit production costs and factor intensities. Vertical differentiation is more common in durable consumer goods, such as TV sets, automobiles, washing machines, and etc. In the case of horizontal differentiation, consumers have no clear consistent ranking of goods. For example, some prefer French wine to Californian wine while some prefer Australian wine over French and Californian wine. On the other hand, especially in durable goods cases, everybody would agree that a particular brand is considered to be best. For instance, a Sony television set is generally considered to be superior to any other available television set in the market. In the trade literature, the exchange of vertically differentiated finished goods is often termed as vertical IIT.[8]

In addition to IIT in horizontally differentiated final goods or vertically differentiated final goods, Kol and Rayment (1989) also consider that countries may exchange final goods for intermediates. This type of trade also shows up IIT if both are classified within the same industrial category. The exchange of final against intermediates may be result of foreign assembly activities. The color television industry trade between the US and Mexico could be good example of final goods exchanged for intermediates case. In the early periods, the television sets industry had an integrated production policy, in other words, production of all parts within the firm. At the beginning of the 1960s, firms realized that the cost of producing all parts within the firm increased considerably due to managerial costs because the television sets were becoming more and more complicated and the number of stages required to produce a television set drastically increases. In addition, the US firms had to compete with the cheap television sets imported from East Asia. They begin outsourcing the labor-intensive activities to developing countries where wages are relatively low since each production stage requires different factor intensities. For now, suppose that production of a television set requires two production stages: production of Cathode-ray tubes and assembly of the television set. The production of Cathode-ray tubes requires substantial capital and research and development expenditures (R&D) while the assembly activities are mostly labor-intensive

[7] Although the evidence suggests that IIT mainly occur in differentiated goods, IIT could also take place in homogenous or identical goods for a variety of reasons, such as cross-border trade, seasonal goods, entrepot trade, and reciprocal dumping.
[8] Falvey (1981) and Falvey and Kierzkowski (1984) are the first to developed a model in which they achieved to explain the determinants and directions of the IIT in final goods within H-O-S frameworks: the IIT in vertically differentiated goods occurs because of factor endowment differences across countries.

activities. American firms produce the Cathode-ray tubes in the first stage. The Cathode-ray tubes are then exported to Mexico where labor costs are low, and the assembled finished television sets are imported from that country. This is typical two-stage vertical specialization. Firms engage in trade to exploit differences in comparative advantage. Thus, two-stage vertical specialization in this case is consistent with the traditional H-O model.

Since IIT is defined as the exchange of similar products at the same industry level, two-stage vertical specialization will clearly not generate intra-industry trade in goods. Take for example product group HS (85). If an empirical researcher employs a two-digit level of HS (85), then the exchange of exported Cathode-ray tubes HS (8540) and imported television receivers (sets) HS (8528) may show up as IIT in trade statistics between the US and Mexico. It is obvious that the categorical aggregation problem is more severe in the case of exchange of final against intermediate goods although trade indeed actually takes inter-industry form. In addition, the number of stages required to produce a good is often more than two. Since this dissertation employs six-digit level of HS, the share of intra-industry trade of two-stage vertical specialization is expected to contribute little to the observed IIT in intermediates.[9]

Finally, countries may exchange intermediate goods for intermediate goods, both within the same industry classification. There are two possibilities that lead to the two-way exchange in intermediate goods: multi-stage vertical trade and horizontally differentiated intermediates trade. Multi-stage vertical trade involves the exchange of technologically linked intermediates. Lets again focus on the production of television sets example. In reality, the production of television sets involves more than two steps, each of which uses a different mix of capital, R&D, labor, and skill. Television sets consists of following major components: picture tube with its flyback transformer and deflection yoke, printed circuit board, transformer, wire harness, tuner, plastic and metal parts, and various small parts. The color picture tube itself consists of many production stages and components, such as front panel assemblies, deflection coils and various small parts. All these parts are recorded under the product group of HS (854091). Suppose that some of the components which are part of the front panel are imported into Mexico from the US under the product group of HS (854091). This is not surprising assumption because the production of front panel components is relatively capital intensive and the US is relatively capital abundant nation while the assembly of front panel is highly labor intensive and Mexico is low-wage country. As shown in Figure 3.1, at the first stage, American firms produce the components of front panels and export these components to Mexico under the product group of HS (854091). At the second stage, the assembly of parts of front panels bound for the US market take place in one of Mexico's maquiladoras. At final stage, the assembled front panels are imported from Mexico under the product group of HS (854091) are used in the production of color picture tubes, and subsequently in the production of television sets in the US manufacturing plants. Thus, this type of exchange appears as IIT in intermediate goods in trade statistics since the processing in Mexico does not change the good's statistical category. Thus, vertical IIT in intermediates is defined as the trade in inputs belonging to the same industry but located at different stages on the production spectrum. Like in the case of two-stage

[9] Notice that all the exchange of final goods against intermediates does not necessarily represent a two-stage vertical specialization type trade. Imported final goods and exported intermediates could be

vertical specialization, multi-stage vertical specialization stems from the differences in factor costs across countries.

Beside vertical IITin intermediate goods, there is also horizontal IIT in intermediate goods. Countries simultaneously export and import technologically unrelated differentiated intermediate goods. Unlike vertical trade, there is no link between the exports of particular intermediates to imports of particular intermediates, both classified under the same product by HS. Intermediate goods may have different characteristics or technological specifications but they are basically the same in terms of quality, costs, and capital/labor techniques employed in production. Firms engage in trade in horizontally differentiated intermediate goods because some imported intermediates fit their production specifications better. For instance, intermediates are often made-to order products, which may differ in terms of technical characteristics. Suppose that there are two types of picture tubes available in the market and they differ in terms of screen sizes. In addition, assume that the US firms specialize in the production of large size color picture tubes while the Japanese firms focus on the small sizes. It should be noted that some of the television sets producers in the US may continue to require small sized color picture tubes, which are produced in Japan. Similarly, some of the Japanese television producers would be still in search of large sized picture tubes, which are produced in the US. Hence, the simultaneous export and import of color picture tubes recorded under the product group of HS (854011) will definitely show up as IIT as shown in Figure 3.2. In this case, the IIT in intermediates originates from economies of scale, product differentiation, and love of inputs varieties.

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technically unrelated to each other though they are classified within the same two-digit level of HS.

3.2 Theoretical Model of Horizontal Trade

This section summarizes Ethier's (1982) model of horizontal trade. In the model, there are two countries: a home country h and a foreign country f. Each country is industrialized so they are similar in terms of tastes, factor endowments and technologies. We assume that there are two primary factors, capital and labor, and they are perfectly mobile between two sectors but immobile between the two countries. Let (k,l) and (k^*,l^*) denote home and foreign country's factor endowments, respectively. Home country can produce two final consumption goods: wheat (w) and manufactures (y), and similarly (w^*) and (y^*) for foreign country.[10] In addition, it is assumed that the markets for primary factors, wheat, and manufactures are perfectly competitive. Further wheat is numeraire good and produced under constant returns to scale. Two primary factors and intermediate goods are combined to produce manufactures that are then consumed by consumers. Production of final manufactures exhibits constant returns to scale with respect to quantity of intermediate goods and the primary factors used in production, but increasing returns with respect to the number of varieties of intermediate goods. It is further assumed that there are economies of scale in the production of the differentiated intermediate goods due to inclusion of fixed costs into production functions, and the market structure is the Chamberlinian monopolistic competition type. In addition, production functions are the same for all intermediate varieties.

3.2.1 Final Goods Sector

To determine the transformation curve between wheat and final manufactures, let $y = SY$, where S an index of scale economies, Y is defined as an index of scale operations.[11] With the help of this definition, the endowments of capital and labor, (k,l) and (k^*,l^*), determine transformation functions between wheat and manufactures bundles in both countries as:

$$w = t(Y) \qquad \text{and} \qquad w^* = t(Y^*) \tag{3.1}$$

Note that the transformation functions are governed by the standard Heckscher-Ohlin-Samuelson (H-S-O) assumptions.

Following Ethier (1982) and Lovely and Nelson (2000), it is assumed that final manufactured goods are costlessly assembled from intermediate manufactured goods. In addition, suppose that there n domestic firms and n^* foreign firms producing the intermediate goods. Since we intend to model IIT trade in intermediate goods, the production functions for final manufactures take the form in home and foreign country, respectively:[12]

$$y = \left[\sum_{i=1}^{n} z_i^\theta + \sum_{j=1}^{n^*} z_j^\theta\right]^{\frac{1}{\theta}} \qquad \text{and} \qquad y^* = \left[\sum_{i=1}^{n} z_i^\theta + \sum_{j=1}^{n^*} z_j^\theta\right]^{\frac{1}{\theta}} \tag{3.2}$$

where z_i denotes the quantity of component i produced at home and z_j is the quantity of component j produced in foreign country. θ is a parameter, $1 > \theta > 0$. As the value of θ gets bigger, then components can be more easily substituted for each other. Thus, we expect that product differentiation fall with rising θ within the manufacturing sector. The elasticity of substitution between any pair of intermediate goods, (i, j), is given by

[10] From on, I denote foreign country's variables with astericks.

[11] Note that y denotes the output of manufactures while S is related to both home and foreign manufacturing activities.

[12] This equation is borrowed from Lovely and Nelson (2000) and is slightly different from that of Ethier (1982). The reason we prefer this version is that (3.2) explicitly shows the source of inputs whether they are

CES, $1/(1-\theta)$. According to (3.2), there are constant returns to scale with respect to output of each variety of component, but increasing returns to scale with respect to the number of varieties, n and n^*. The elasticity of output with respect to home and foreign varieties, n and n^*, respectively, is $1/\theta$.

It is assumed that all intermediate goods have the same cost functions and are produced from capital and labor via identical production functions in both countries. Under this symmetry assumption, all component varieties z_i are produced in equal amounts, and then a common z represents the output of each component. Intermediate goods producers could sell their products to either domestic final goods producers or export them to foreign final goods producers. Equation (3.3) gives the total output level of each input variety produced both at home and abroad, z and z^*, respectively.

$$z = z_{hh} + z_{hf} \quad \text{and} \quad z^* = z_{ff} + z_{fh} \tag{3.3}$$

Using equation (3.2), equation (3.3) reduces to following simple form:

$$y = \left[nz_{hh}^{\theta} + n^* z_{fh}^{\theta}\right]^{\frac{1}{\theta}} \quad \text{and} \quad y^* = \left[nz_{hf}^{\theta} + n^* z_{ff}^{\theta}\right]^{\frac{1}{\theta}} \tag{3.4}$$

where z_{hh} is the usage of a home produced component variety by the home final manufactures producers, z_{fh} is the usage of a foreign produced component variety by the home final manufactures producers, z_{ff} is the usage of a foreign produced component variety by the foreign final manufactures producers, and z_{hf} is the usage of a home produced component variety by the foreign final manufactures producers. Equation (3.4) simply implies that the final manufacturing sectors whether at home or in foreign country

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bought from local markets or world markets such that we can easily derive the intra-industry index for trade in intermediate goods.

will use all varieties of components produced either by home or by foreign intermediate goods producers.

3.2.2 Intermediate Goods Sector

Where the final good is produced under external economies of scale, production of intermediates is characterized by internal economies of scale.[13] As mentioned above that the market for components is described as monopolistically competitive. Intermediate goods producers use primary factors, (k, l). Suppose that the scale variable Y is an index of the number of bundles of factors devoted to manufacturing production. We assume that each variety is produced with the same cost function. Hence, the number of bundles required to produce z units of any intermediate part is $az + b$, for some $a, b > 0$. Because of the symmetry assumption, the production costs and the quantity of component production are identical across firms. Thus, the technology of component production is defined according to following relation:

$$Y = n(az + b) \qquad \text{and} \qquad Y^* = n^*(az^* + b) \tag{3.5}$$

where a is a constant marginal costs parameter and b is a fixed costs parameter. Both types of costs are paid in bundles and are assumed constant across firms in the intermediate goods sector.

Two types of economies of scale exist in this intermediate goods production technology. First, it has the traditional type of economies of scale due to firm's plant production level x and fixed costs b. Ethier (1982) terms this type of economies of scale as "national returns to scale". Component producers internalize these economies of scale by increasing their plant sizes. The second one is external economies of scale to final

[13] In the model, "components" and "intermediates" words are used interchangeably.

manufacturing producers. In the final manufacturing sector, the model assumes that production is subject to constant returns to scale for a given number of varieties of components, $n + n^*$. On the other hand, output is an increasing function of the number of both home and foreign varieties. These economies of scale are the result of greater division of labor rather than increasing plant sizes. The greater division of labor is achieved through either horizontal specialization or vertical specialization. As in Ethier (1982), this type of economies of scale is assumed to be external to the final manufactures producers and is called as "international returns to scale".[14]

3.2.3 Equilibrium in Closed Economy

In this part, a closed economy is considered to determine components' demand, supply, price, and number of varieties for both home and foreign countries. The most important aspect of the closed economy is that we can not distinguish international returns to scale from national increasing returns to scale. The final goods are produced to according to equation (3.4). Taking wheat as the numeraire, let q and q^* denote the common price of a pair of intermediates in terms of wheat while z_{hh} and z_{fh} denote the output levels in each country. As in Ethier (1982), cost minimization by an individual final good producer subject to equation (3.4) generates a demand curve faced by the intermediate goods producer of z_{hh} and z_{ff} :

$$z_{hh} = z_{fh}\left(\frac{q^*}{q}\right)^{1/1-\theta} \quad \text{and} \quad z_{ff} = z_{hf}\left(\frac{q}{q^*}\right)^{1/1-\theta} \tag{3.6}$$

[14] Increasing returns to the variety of components in the final manufacturing sector can be seen with the following simple mathematical formula: $\frac{\partial y}{\partial n} = \frac{1}{\theta} n^{\frac{1-\theta}{\theta}} z > 1$. Since z is constant across firms, θ variable is

where $1/(1-\theta)$ is the elasticity of the demand curve faced by the producer of z_{hh}. This condition is assured by the fact that n is sufficiently large so that the components markets stay competitive and actions by any intermediate goods producer will not affect intermediate goods prices.

Giving the fact that the markets for primary factors and wheat are competitive, a representative intermediate goods producer has the following cost function:

$$-t^{'}(Y)[az+b] \qquad \text{and} \qquad -t^{'}(Y^{*})[az^{*}+b] \tag{3.7}$$

where $t^{'}(Y)$ is the relative price of factor bundles for intermediate goods production and exogenous to the individual firm in the home country. Suppose that the transformation function, $t(Y)$, between manufactures and wheat is assumed to be strictly concave transformation function of the H-O-S model, in other words, $t^{'}(Y)<0$ and $t^{''}(Y)<0$. Furthermore, the total revenue function for a representative intermediate goods producer is expressed as

$$tr = qz \qquad \text{and} \qquad tr^{*} = q^{*}z^{*} \tag{3.8}$$

Since this firm maximizes its profit by equating its marginal revenue to marginal cost, the common price of components in both countries can be derived as:

$$q = \frac{-t^{'}(Y)a}{\theta} \qquad \text{and} \qquad q^{*} = \frac{-t^{'}(Y^{*})a}{\theta} \tag{3.9}$$

This is the profit maximizing choice of price for the component producer. Note that the firm takes the choices of other firms as given when setting its price. [15]

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between 0 and 1, and the manufacturing production, y, is homogenous of degree $\frac{1}{\theta}>1$. This is also true for foreign firms.

[15] The derivation of the equation (3.9) is provided in Appendix A.

Remember that each variety of the intermediate good is produced by monopolistically competitive firms while the final goods are produced by competitive firms. The profit of each representative component producer is then given by:

$$\pi = qz + t^{'}(Y)\left[az + b\right] \quad \text{and} \quad \pi^{*} = q^{*}z^{*} + t^{'}(Y^{*})\left[az^{*} + b\right] \tag{3.10}$$

Since we assumed that the intermediate goods are produced by the monopolistically competitive firms, the profits of those firms are driven to zero in the long run due to free entry and exit of firms. Only one firm in equilibrium produces each variety since each firm has a monopoly power over its product. Using equation (3.10), we can derive the component output function as:[16]

$$z = \frac{b\theta}{a(1-\theta)} \quad \text{and} \quad z^{*} = \frac{b\theta}{a(1-\theta)} \tag{3.11}$$

Equation (3.11) indicates that both home and foreign component output levels are identical, which is again the result of symmetry assumptions.

In an autarky equilibrium, the number of varieties of components is given by the following equation:[17]

$$n = \frac{(1-\theta)Y}{b} \quad \text{and} \quad n^{*} = \frac{(1-\theta)Y^{*}}{b} \tag{3.12}$$

The intersection of the supply curve of final manufactures and the demand curve of final goods, finished manufactures and wheat, determines the relative prices and quantities of each good in a closed economy. In autarky, the production of manufactures is subject to increasing returns to scale since the shifting resources from wheat industry to the manufacturing industry increases the number of varieties of intermediates which eventually leads to productivity gains in finished manufactured goods production.

[16] The derivation of the equation (3.11) is provided in Appendix B.

Remember that intermediate goods producers prefer to produce new varieties rather than increase the output levels of an existing variety when they decide to enter the market. Thus, the most important aspect of the closed economy is that we can not distinguish international returns to scale from national returns to scale when the domestic firms increase number of varieties without engaging in trade.

3.2.4 Equilibrium in Free Trade

Lets include international trade in horizontally differentiated intermediate goods into the model we developed so far. In free trade, we assume that both home and foreign economies have an identical production technology as in autarky, except that factor endowments differ across countries. If the countries trade freely without barriers, they constitute a single market for horizontally differentiated intermediate goods. Note that we suppose that there are no trade barriers or transportation costs. Hence, the market for the horizontally differentiated intermediate goods has the same properties as each economy in autarky, while the number of intermediate varieties will increase. In autarky equilibrium, we have reached to a conclusion that each firm will produce only one component variety. A single firm will be better off choosing a variety that is not already being produced by another firm. With our assumptions, the international market for the intermediate goods will be again monopolistically competitive as in autarky. Therefore, in free-trade equilibrium, each variety of the component will be produced in only one of the countries, but used in the final production in both countries. Since equation (3.6) representing the demand curve faced by the producer of an intermediate good and equation (3.11) representing the output of component in either country still holds true for free trade, then

[17] The derivation of the equation (3.12) is provided in Appendix C.

the number of varieties of intermediates produced globally is given by:

$$n_w = n + n^* = \frac{(1-\theta)}{b}\left(Y + Y^*\right) \tag{3.13}$$

Equation (3.13) clearly shows that foreign trade in comparison with autarky generates an increase in the supply of varieties of the intermediate good. Hence, the single producer of a component in either country can utilize increasing returns to scale, and thereby produces a larger amount of each variety than autarky case. Consequently, the division of labor is achieved through trade in intermediate goods. This is called the "international" division of labor by Ethier (1982). Thus, the producers of the final good will have more options to choose among varieties of the intermediates in the international market at lower prices. The result of Ethier's model is sometimes referred as **"**love of variety for inputs**"** as the love of variety of final goods in Dixit and Stiglitz's paper. We should be careful that national increasing returns to scale determined by an increase in the production level of a given number of component varieties must not be mistaken for the international increasing returns to scale determined by an increase in the number of component varieties by an international division of labor. We could find national increasing returns to scale both in autarky and in free trade while international increasing returns to scale can be found only in free trade.

With the help of the allocation-curve technique, Ethier (1982) is able to predict the volume of IIT between two economies, the volume of world output of final manufactures, the volume of world components production, and the relative intermediate and final goods prices. The international equilibrium is determined by the intersection of the two allocation curves. However, the model fails to predict the pattern of intra-industry trade. In other words, we are not sure which country specializes in which specific varieties of components.

3.2.5 The Derivation of Intra-Industry Trade Index in Ethier's Model

Recall the assumption that finished manufactures are costlessly assembled from bundles of all components. It is also assumed that there is no finished manufactures trade in the model. Thus, international trade entirely consists of exporting or importing the intermediate goods and wheat. Under the assumption of symmetry, Ethier's model predicts that in equilibrium foreign and home firms produce the same amount of intermediate good, in other words, $z = z^*$, where $z = z_{hh} + z_{hf}$ and $z^* = z_{ff} + z_{fh}$.

Consequently, using (3.6), we can easily define a zero profit condition for the final manufactures producers in the free-trade equilibrium as:

$$py = qnz_{hh} + q^* n^* z_{fh} \quad \text{and} \quad p^* y^* = qnz_{hf} + q^* n^* z_{ff} \tag{3.14}$$

where py represents the total sales of final manufactures producers while $qnz_{hh} + q^* n^* z_{fh}$ is the total costs in the production of final manufactures.

The final goods producer has an option to use either home or foreign inputs or combination of both in the production of final manufactures. The domestic national income is then defined as:

$$G = py + w \quad \text{and} \quad G^* = p^* y^* + w^* \tag{3.15}$$

where w and w^* denote the incomes from wheat productions and while p and p^* are the final manufactures prices. Remember that wheat prices are normalized in the model. While intermediate goods are used as inputs in the production of final goods, and only wheat and finished manufactures are consumed.

Consequently, using (3.15), we can drive the intra-industry trade index. Following Ethier (1982), the volumes of exports and imports in the differentiated component between the two countries can be written as:

$$X_c = nzg^* \qquad \text{and} \qquad M_c = n^* z^* g \tag{3.16}$$

where g represents the domestic national income as a fraction of world income, i.e., $g = py + w/\left[p\left(y + y^*\right) + w + w^*\right]$. They can be also considered as the relative market size of two countries. Suppose that the home country is the relatively capital abundant nation and has slightly higher net exports of components, i.e., $nzg^* \geq n^* z^* g$. If both countries' factor endowments are assumed to be identical, i.e, $k = k^*$ and $l = l^*$, each country will be sufficient in the production of wheat, and then there will be no inter-industry trade in wheat. Thus, the level of IIT in intermediate goods will reach its maximum point. Each country specializes in the production of specific varieties of components. On the other hand, if both countries' endowments differ sufficiently, then we expect that there will be no IIT in components and all trade will be inter-industry trade in wheat and components.

Several theoretical measures of IIT have been suggested in the literature. The common way to define and measure IIT is by the Grubel-Lloyd index:

$$IIT = 1 - \frac{|X - M|}{X + M} \tag{3.17}$$

If we plug (3.16) into (3.17), we get the following IIT index:

$$IIT = 1 - \frac{\left|nzg^* - nz^* g\right|}{nzg^* + nz^* g} \tag{3.18}$$

This result thus shows that the degree of IIT depends both on country $\left(g, g^*\right)$ and on industry characteristics $\left(n, n^*, z, z^*\right)$. Note that a and b that give the economies of scale indirectly appear in the index. Hence, (3.18) implies that the number of foreign varieties or the quantity of each foreign variety used by home producers has a positive relationship with the IIT index. On the contrary, the IIT index falls when the number of varieties produced at home or the quantity of each home variety used by foreign producer increases. The intuition behind this result is simple. This is clearly in line with the direct relationship between similarity of factor endowments and the IIT. Recall that we already assume that the capital rich home country is the net exporter of the manufactured intermediate goods, which is a capital-intensive good. As the capital endowments increase favorably for the home country, we expect that the number of component varieties produced at home will also rise. Therefore, the home finished goods producers begin to rely on locally produced intermediate goods. At the same time, the foreign finished manufactures producers benefit from the availability of home components varieties at cheap prices due to improvements in the productivity in the home country. That will lead to an increase in the imports of components from the home country. Eventually, the IIT index falls. If the capital endowments in the foreign country, the net importer of components, increase relatively, then IIT index rises. However, if we plug (3.11) and (3.12) into (3.18), we get:

$$IIT = 1 - \frac{\left| g^* \frac{b\theta}{(1-\theta)} \frac{(1-\theta)}{b} Y - g \frac{b\theta}{(1-\theta)} \frac{(1-\theta)}{b} Y^* \right|}{g^* \frac{b\theta}{(1-\theta)} \frac{(1-\theta)}{b} Y + g \frac{b\theta}{(1-\theta)} \frac{(1-\theta)}{b} Y^*}$$

$$IIT = 1 - \frac{\left| g^* Y - g Y^* \right|}{gY + gY^*} \qquad (3.19)$$

This is the most controversial result in Ethier's model: the degree of IIT depends on the relative size of the two countries (g, g^*) and factor endowments (Y, Y^*).[18] In the IIT literature, product differentiation and economies of scale can be seen as the most important factors to explain the existence of IIT; Dixit and Stiglitz (1977), Krugman (1979), and Lancaster (1980). Despite this implication, none of the parameters related to the degree of product differentiation, n and n^*, directly appears in the IIT index though the market size indirectly represents these parameters. The degree of product differentiation is clearly important for the existence of IIT but not for the degree of IIT. Ethier (1982) explains this controversial result with the following reasoning. As the number of components rise, the output of each component will drop because of fixed costs since a country has limited factor endowments. Thus, the total volume of IIT declines due to the higher degree of product differentiation. Likewise, other technological parameters, such as θ from (3.2) and a and b from (3.5), that give the economies of scale do not affect the degree of IIT since changes in those parameters will not change the allocation of resources devoted the components production.

Note that (g, g^*) gives the relative size of two countries while (Y, Y^*) is the number of factor bundles devoted to production of intermediate goods in home and foreign countries, respectively. To see the relationship between the share of IIT and these parameters, let us assume that the home country is relatively capital abundant nation, i.e., $k/l > k^*/l^*$ and manufactured components are relatively capital-intensive goods. Hence,

[18]This causes very important empirical consequences in the IIT literature. For instance, Harrigan (1994) argues that the scale economies have no effect on the Grubel-Lloyd index since any change in the technological parameters affects proportionally the import and export flows in a given sector. Consequently, he focuses on the volume of trade in intermediate goods instead of studying the relation between the share of IIT in intermediate goods and the degree of product differentiation.

we expect that the number of component varieties in the home country will be relatively larger than that in foreign country given a condition that the larger country is relatively capital abundant, in other words, $n/n^* > g/g^*$ when $Y/Y^* > g/g^*$. The intuition behind this condition is simple: the greater market increases the number of component varieties produced in the domestic market. This is true if a nation allocates relatively more of its resources toward the manufacturing sector. Consequently, the nation which allocates more of its resources into manufacturing production ends up having larger domestic national income, i.e., $g > g^*$. In the end, the number of component varieties produced in that country will be greater than in the other country. Thus, an increase in the home country endowments relatively to the foreign country will decrease the share of the IIT index:

$$\frac{\partial IIT}{\partial\left(Y/Y^*\right)} < 0 \text{ if } \frac{Y}{Y^*} > \frac{g}{g^*} \tag{3.20}$$

In other words, as differences in factor endowments escalate, the IIT in intermediate goods decline. However, if the country's trade is mostly inter-industry type, then any increase in the capital endowments generates higher share of IIT in total trade:

$$\frac{\partial IIT}{\partial\left(Y/Y^*\right)} > 0 \text{ if } \frac{Y}{Y^*} < \frac{g}{g^*} \tag{3.21}$$

In this case, the country previously concentrated on wheat production. As the capital endowments rise, that country produces more intermediate varieties, which increase the share of IIT.

3.3 Theoretical Model of Vertical Trade

The third section of this chapter summarizes the outsourcing model developed by Feenstra and Hanson (1997). There are two countries, a home country and foreign country. Each country is endowed with three factors of production: capital (K), skilled labor (H), and unskilled labor (L). There is a single final good produced in each country, Y, which is assembled from a continuum of intermediate goods, indexed by $z \in [0,1]$. At the plant level, production of a final good generally requires N stages of processing, from raw materials to intermediate goods, then to more advanced intermediates, and so on.[19] Production of intermediate goods at stage $N-1$ uses all previously produced intermediate goods, either domestically produced or imported from the foreign country. Rather than indexing these stages in their production order, the production stages in the outsourcing model are defined in terms of skill intensity. This indexing places the least skill-intensive stage, such as assembly, at the upstream end and the most skill-intensive stage, such as R&D, at the downstream end. The production of each unit of z requires skilled labor, unskilled labor, and capital. Let $a_h(z)$ and $a_l(z)$ represent the amount of skilled and unskilled labor to produce one unit of the intermediate good z. Thus, intermediates with high z's are relatively skill intensive goods and intermediates with low z's are unskill intensive goods. Consequently, the ratio $a_h(z)/a_l(z)$ is non-decreasing in z, which can be shown as:

$$\frac{\partial[a_h(z)/a_l(z)]}{\partial z} \geq 0 \tag{3.28}$$

Given these assumptions, the intermediate production function is:

$$x(z) = A_i\left[\min\left\{\frac{L(z)}{a_L(z)}, \frac{H(z)}{a_H(z)}\right\}\right]^{\theta}[K(z)]^{1-\theta} \tag{3.29}$$

[19] The number of stages varies for each final good.

where $x(z)$ is the quantity of intermediate good z, and $H(z)$, $L(z)$, and $K(z)$ denote the total amount of skilled labor, unskilled labor, and capital, respectively, used in the production of intermediate good z. The parameter, A_i, represents the efficiency or the productivity parameter in the two economies, the home country and the foreign country, $(i = h, f)$.[20] The model assumes that the efficiency parameter is neutral across all the intermediate goods. θ gives the share of overall labor costs in the production of intermediate good z. The intermediate good production function in (3.29) has a Leontief technology between two types of labor while it has a Cobb-Douglas technology between overall labor and capital, K. The model assumes that the degree of substitution between capital and either type of labor is the same.

At the last stage, the final good, Y, is costlessly assembled from all the individual intermediate goods which can be either domestically produced or imported from the foreign country. Final good production function in either country is then given by:

$$\ln Y = \int_0^1 \alpha(z) \ln x(z) dz \quad , \quad \text{where} \int_0^1 \alpha(z) dz = 1 . \qquad (3.30)$$

Note that labor is not included as an input into equation (3.29) because the model assumes that final good is costlessly assembled from all the intermediate goods. In other words, the model assumes the assembly activity at the last stage will not add any value into the total value of final good. By assuming this, there is no need to know the location or the country in which the assembly activity is performed.

[20] The intermediate good production function is assumed to be the same in each country except that the efficiency parameter can differ across countries.

Rather than using the production functions for the inputs in (3.29), it will be more suitable to use the unit-cost function to determine the pattern of specialization in intermediates between the home and the foreign country:

$$c_i\left(w_i, q_i, r_i; z\right) = B_i\left[w_i a_L\left(z\right) + q_i a_H\left(z\right)\right]^{\theta} r_i^{1-\theta} \tag{3.31}$$

where $c_i\left(w_i, q_i, r_i, z_i\right)$ is the minimum cost of producing one unit of x in the home country. The unit-cost function is a function of factor prices and the skill intensity of the intermediate good z. In addition, w, q, and r denote the wage of unskilled labor, the wage of skilled labor, and the rental on capital. B is a constant and defined as:

$$B_i \equiv \theta^{\theta}\left(1-\theta\right)^{-(1-\theta)} A_i^{-1} \tag{3.32}$$

To maximize its profits, firms should buy the intermediates from the minimum cost location, either from domestic markets or from international markets. To determine the pattern of specialization, the model will make the following assumptions regarding factor endowments:

$$\frac{H_h}{L_h} > \frac{H_f}{L_f} \quad \text{and} \quad K_h > K_f \tag{3.33}$$

The assumptions on factor endowments immediately imply the following relation of factor prices between the two countries:

$$\frac{q_h}{w_h} < \frac{q_f}{w_f} \quad \text{and} \quad r_h < r_f \tag{3.34}$$

Based on these assumptions, we expect that the home country will specialize in the production of relatively skill-intensive intermediates while the foreign country will have comparative advantage in relatively less-skill-intensive intermediates. Figure 3.3 shows minimum cost location for each intermediate good. In Figure 3.3, $c_h c_h$ and

$c_f c_f$ are the locus of minimum unit-costs for the home and the foreign country, respectively. The locus of unit-costs are graphed as a function of the skilled intensity, z. We assume that both curves intersect at least once so that there could be some global production sharing between two countries. The point at which minimum cost curves intersect, $c_h(w_h, q_h, r_h; z^*) = c_f(w_f, q_f, r_f; z^*)$, is called as the dividing production stage and denoted by z^*. As shown in Figure 3.3, the foreign country's unit-costs are initially drawn above the home country's unit costs. To see why, as z increases, the ratio $a_h(z)/a_l(z)$ also increases. Thus, the unskilled labor requirements are relatively higher in the production of intermediate goods, which fall in the range $[0, z^*)$. The foreign country has comparative advantage in the production of goods in this range of inputs since the cost of unskilled labor is relatively cheaper in the foreign country than at home. On the other hand, the home country is a relatively skilled labor abundant nation. The cost of producing relatively skill-intensive good is thus cheaper in the home country than abroad. In equilibrium, the model predicts that foreign unit costs will be less than those at home until the cutoff intermediate good so that the foreign country specialize in the intermediates $z \in [0, z^*)$, while the home country unit-costs will be less than those after the cutoff intermediate good such that the home country specializes in the intermediates $z \in (z^*, 1]$. Given the pattern of specialization in equilibrium, the production function for the final good in the home country can then be rewritten as:

$$\ln Y = \int_0^{z^*} \alpha(z) \ln x(z) dz + \int_{z^*}^{1} \alpha(z) \ln x(z) dz \qquad (3.35)$$

The first term on the right hand side of the equation gives the share of final output due to intermediate inputs produced in the foreign country while the second term expresses the output share due to intermediates produced in the home country.

Given this information, we will study two comparative statics results that will be used later as hypotheses in the empirical analysis. The first is the effect of capital movement from the home country to the foreign country on the volume of intermediate goods trade between two countries, while the second is the effect of a change in the ratio of skilled labor/unskilled labor endowments in the foreign country on the volume of intermediate goods trade. The model predicts that there will be capital movement from the home country to the foreign country since the return to capital in the foreign country is higher than that of the home country, $r_h < r_f$. Thus, the capital stock in the home country falls while it increases in the foreign country. The initial impact of the capital movement on the returns to capital will be explained by employing the intermediate goods function from equation (3.29). The home country's national income equals the sum of the factor payments used in the production of all intermediate goods, which is given by:

$$\left(w_h L_h + q_h H_h + r_h K_h\right) \tag{3.36}$$

Since overall labor will earn the fraction θ of national income, equation (3.36) can restated as:

$$\left(w_h L_h + q_h H_h\right)/\theta \tag{3.36'}$$

and multiplying national income by the capital share provides the total capital earnings in the manufacturing industry:

$$r_h K_h = \left[w_h L_h + q_h H_h\right]\left(1-\theta\right)/\theta \tag{3.37}$$

Equation (3.37) shows that capital movements from the home country to the foreign country will increase the returns to the capital in the home country, assuming that wage rates are not changed in the short-run. The impact of inward capital movements, however, will reduce the returns to capital in the foreign country. The effect of the capital movement on the cutoff intermediate good is illustrated in Figure 3.4.

In the short-run, the increase in the returns to capital in the home country will shift the home country's minimum cost curve up from $c_h c_h$ to $c'_h c'_h$ while the reduction in the foreign country's rental rate on capital will shift the foreign country's minimum cost curve down from $c_f c_f$ to $c'_f c'_f$. Assuming that wages are fixed in the short-run, the movement of capital causes the value of the cutoff intermediate good to increase from z^* to z'. Thus, the range of inputs produced in the foreign country increased from $[0, z^*)$ to $[0, z')$ while the home country will now specialize in a smaller range of production inputs, $(z', 1]$. The increase in z^* implies an increase in foreign outsourcing. The activities that have been outsourced from the home country, i.e. (z^*, z'), are still less skilled-intensive than the remaining activities in the home country, i.e. $(z', 1]$. At the same time, the new activities, i.e. (z^*, z'), carried out in the foreign country will be more skill-intensive than any activities initially performed there.

The outsourcing model initially supposed that wages are fixed in both countries in the short-run. However, outsourcing has some effects on the wages in both countries in the long-run. For the home country, the relative demand for skilled labor increases since the remaining activities that are carried out are more skill-intensive than those activities previously performed there. Thus, outsourcing from the home country to the foreign country that raises the value of z^* will increase the relative wage of skilled labor in the home country:

$$\frac{\partial(q_h/w_h)}{\partial z^*} > 0 \qquad (3.38)$$

It is widely believed that manufacturing plants in developing countries owned by developed countries' companies employ relatively more skilled labor than the plants owned by the local companies. This will in turn increase the relative wage of skilled labor in the foreign country. The model then predicts that the outsourcing will increase the relative wage of skilled labor in the foreign country:

$$\frac{\partial(q_f/w_f)}{\partial z^*} > 0 \qquad (3.39)$$

The following question arises: will the value of z^* still increase after the changes in wage costs in both countries? The answer is yes. The increase in the relative wage of skilled labor in the both countries will shift their minimum cost curves up because it will be more costly to produce the intermediates in both countries. Yet the negative impacts of the wage changes on the cutoff intermediate input z^* will not be as big as the positive effects of the capital movement from the home country to the foreign country. The intuition is quite clear. The cost share of skilled labor used in the range $(z',1]$ in the home country is still higher than the range (z^*, z'), which was outsourced to the foreign country. Likewise, the cost share of skilled labor used in the range $[0, z^*)$ in the foreign country is less than the range (z^*, z'). Since the majority of activities performed in the foreign country is still relatively less skill-intensive, the increase in the wage of skilled labor will not undermine the foreign country's comparative advantage in less skill-intensive goods. Thus, the capital movement will still shift the foreign country's minimum cost curve down despite the changes in wages. On the other hand, the increase in the wage of skilled labor further reduces the comparative advantage of the home country along with the increased returns to capital. Therefore, the home country's minimum cost curve definitely shifts up. Feenstra and Hanson (1997) prove that the increase in the relative wage of skilled labor in both countries raises the price index of the home country's intermediates more than that of the foreign country. Overall, the home companies will continue outsourcing some of the activities to the foreign country to remain competitive in the global markets. Feenstra and Hanson (1997) concluded that the capital flow will still increase the cutoff intermediate good z^* despite the fact that the relative wage of skilled labor in both countries increases. The increase in z^* therefore leads to an increase in intermediates trade between home and foreign countries. It can be seen from the final goods production function that the share of the first term on the right hand side, the usage of imported intermediate goods, will increase in the total production of the home companies. [21]

Let us study our second comparative static experiment. Since companies seek the cheapest inputs in the global markets, what will happen to the value of z^* when the relative ratio of skilled labor to unskilled labor changes between two countries. Suppose that the foreign country experienced an increase in the number of unskilled workers. For example, the foreign country may get relatively unskilled workers as a result of immigration from the other countries. The effect of the change in the ratio of skilled labor

[21] The effects of the increase in the productivity and the growth of the capital stock in the foreign country on the value of the cutoff intermediate input will be the same as the effects of the capital movement from the home country to the foreign country, namely the FDI. In all cases, the value of the cutoff intermediate good grows. The proofs are provided in Feenstra and Hanson (1996).

to unskilled labor in the foreign country on the value of z^* and thereby on the amount of intermediate trade can be analyzed using the Figure 3.5 and 3.6. In Figure 3.5, S_f represents the relative supply for skilled labor while $D_f\left(z^*\right)$ is the relative demand for skilled labor in the foreign country. Recall that the assembly activities at the last stage, i.e. combining the inputs to produce the final good, require no additional labor. Thus, the relative demand for both types of labors can be found by using the foreign country's unit costs function. The relative demand for skilled and unskilled labor in the foreign country is then given by:

$$D_f\left(z^*\right)=\frac{\int_0^{z^*}\frac{\partial c_f}{\partial q_f}x(z)dz}{\int_0^{z^*}\frac{\partial c_f}{\partial w_f}x(z)dz} \tag{3.40}$$

Feenstra and Hanson (1997) prove that any increase in the relative wage rate will reduce the relative demand for skilled labor:

$$\frac{\partial D_f}{\partial\left(q_f/w_f\right)}<0 \tag{3.41}$$

On the other hand, the supply of the skilled labor is an increasing function of the relative wage rate while the supply of the unskilled labor is a decreasing function of the relative wage in the foreign country:

$$\frac{\partial H_f}{\partial\left(q_f/w_f\right)}>0 \text{ and } \frac{\partial L_f}{\partial\left(q_f/w_f\right)}\leq 0 \tag{3.42}$$

Hence, the relative supply for skilled labor S_f is upward-sloping curve.[22] Suppose that the ratio of skilled labor to unskilled labor in the foreign country drops due to sudden immigration of unskilled labor into the country. This will shift the curve of the relative supply of skilled labor from S_f to S_f'. Thus, we expect that the relative wage of skilled labor increases in the foreign country. In other words, the wage of unskilled labor in the foreign country drops. Companies will substitute the relatively cheap unskilled laborers in place of the skilled laborers.

The unit-cost function (3.31) shows that changes in the relative wage affects the prices of the inputs, which in turn change the equilibrium demand for each input. Figure 3.6 shows the effect of a change in the relative wage induced by a sudden increase in the unskilled labor supply in the foreign country on the cutoff intermediate good. As shown in the Figure 3.6, assuming that there are no changes in the unit-costs in the home country, the increase in the relative wage of skilled labor in the foreign country will shift the foreign country's unit-cost curve down from $c_f c_f$ to $c_f'' c_f''$. The graph shows that the value of the cutoff intermediate good increases from z^* to z'' assuming that the home country's unit costs are unchanged. For the home country, the range of activities is reduced from $(z^*, 1]$ to $(z'', 1]$ while the foreign country increases the number of activities from $[0, z^*)$ to $[0, z'')$. As mentioned earlier, Feenstra and Hanson (1997) proved that the increase in the relative wage of skilled labor in both countries causes the price index of the home country's inputs to rise relative to that of the foreign country. In this

[22] Given the fixed labor endowments, it is expected that any increase in relative wages also motivates the unskilled labors to become more skilled workers through training or education. In addition to these responses, the government could initiate a program that provides free education and other job related training activities to the initially unskilled labor, which in turn increases the skilled labor endowment.

comparative statistics, however, we have assumed that the only change is the increase in the relative wage of skilled labor in the foreign country due to sudden increase in the supply of unskilled labor. The foreign country's inputs price relative to that of the home country thus drops less than when the increase in the relative wage skilled labor in both countries is due to FDI. In that case, we expect that the home country firms increasingly use the cheap imported foreign inputs in the production of final goods to remain competitive in the international markets. Thus, the impact of the increase in the unskilled labor in the foreign country will be to raise the level of global production sharing between the home and foreign countries. Overall, we predict an increase in the volume of intermediate goods trade between the home and foreign country as long as the costs of fragmentation are not prohibitive.

Figure 3.1: Vertical Trade in Intermediates between Home and Foreign Country

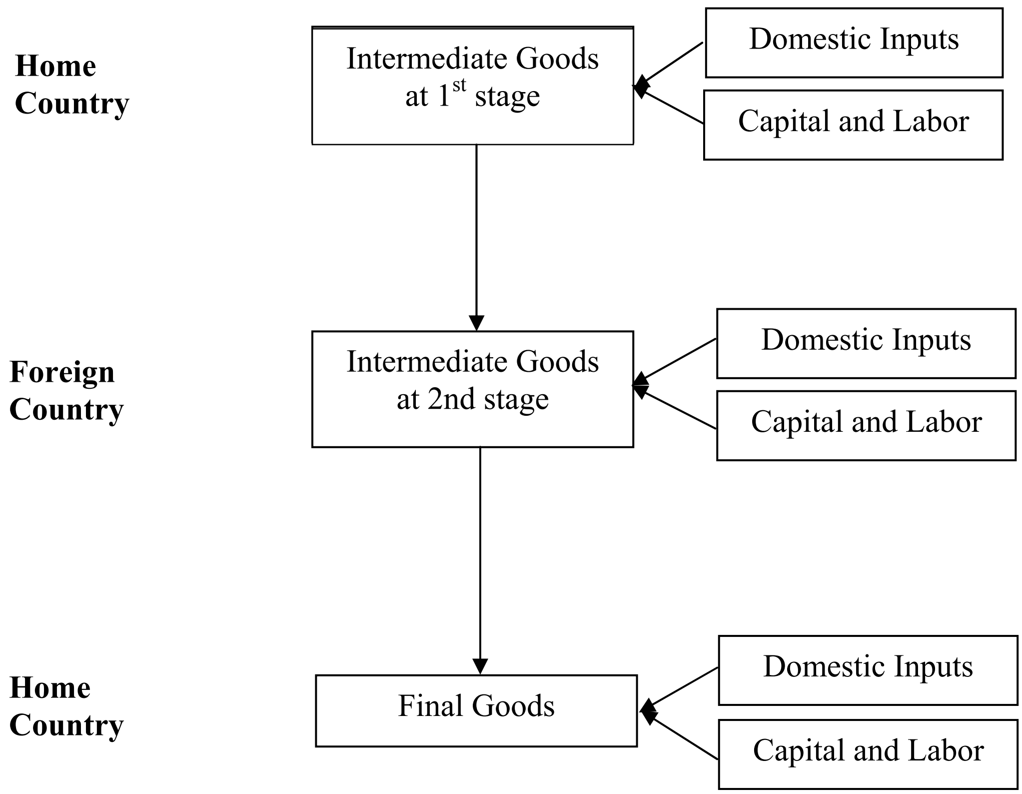


Figure 3.2: Horizontal Trade in Intermediates between Home and Foreign country

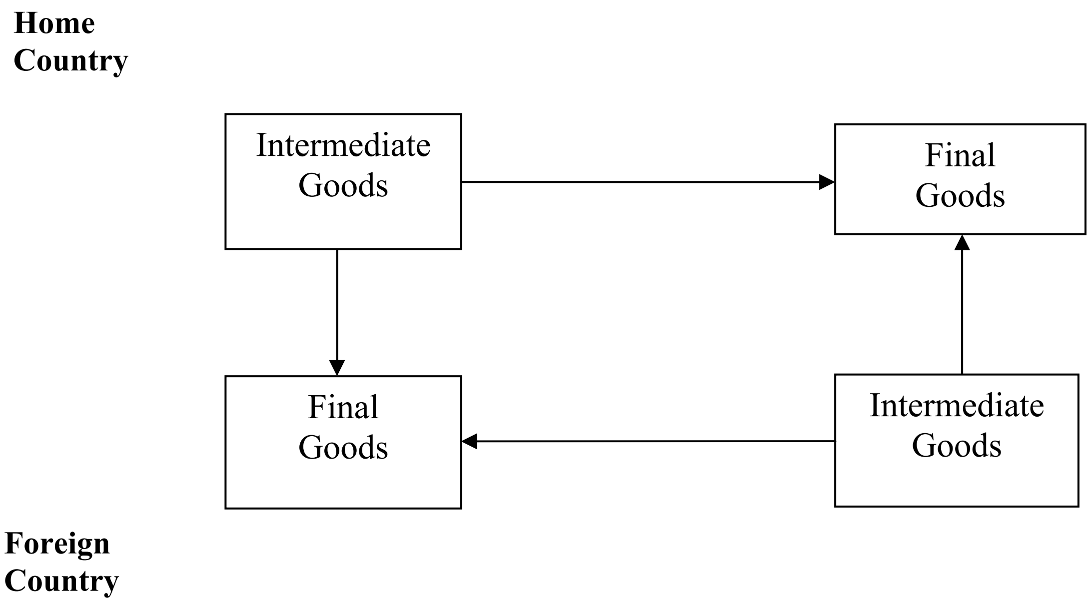


Figure 3.3: The Determination of Cutoff Intermediate Input z^*

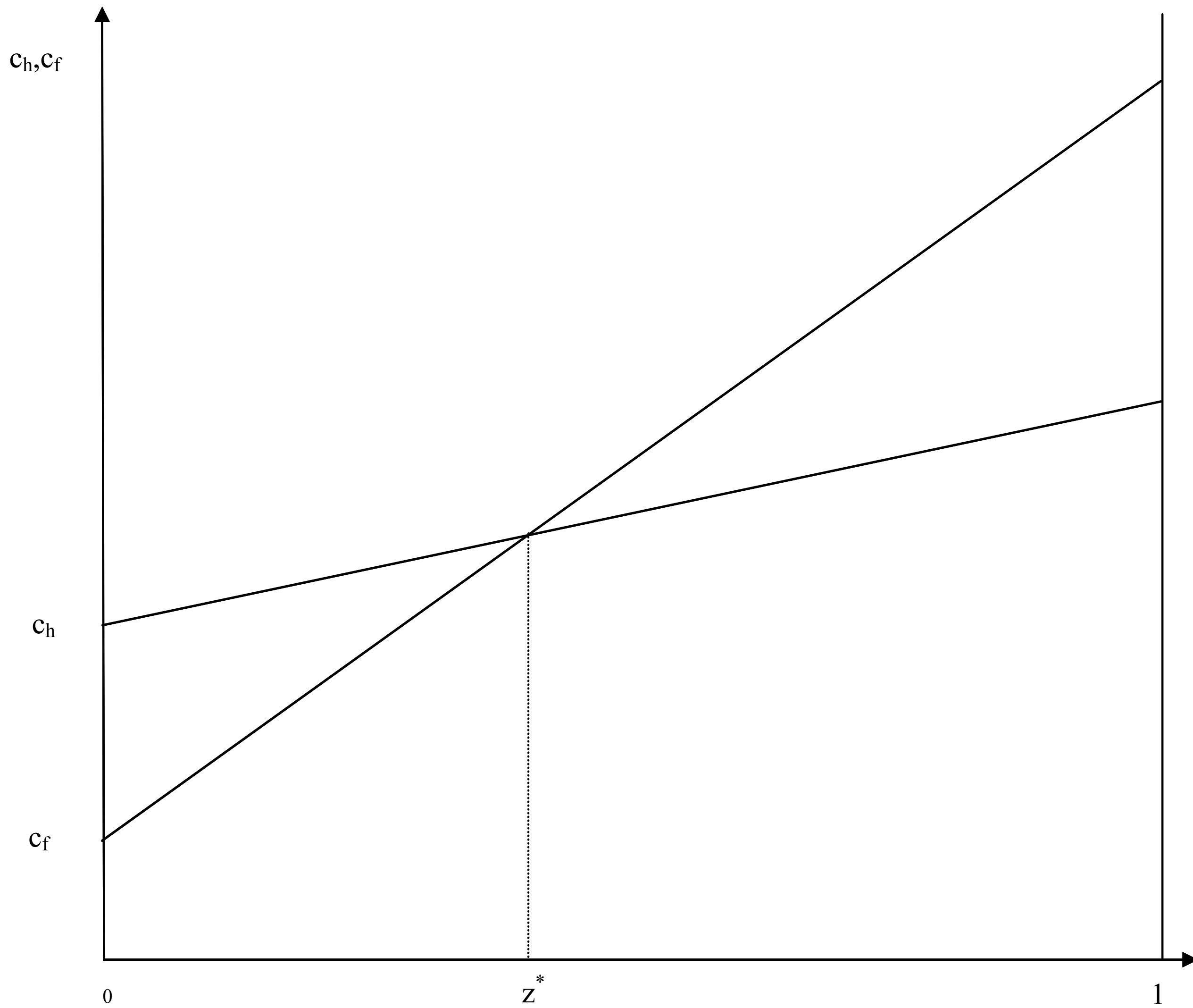


Figure 3.4: The Effect of Capital Flows from Home to Foreign Country

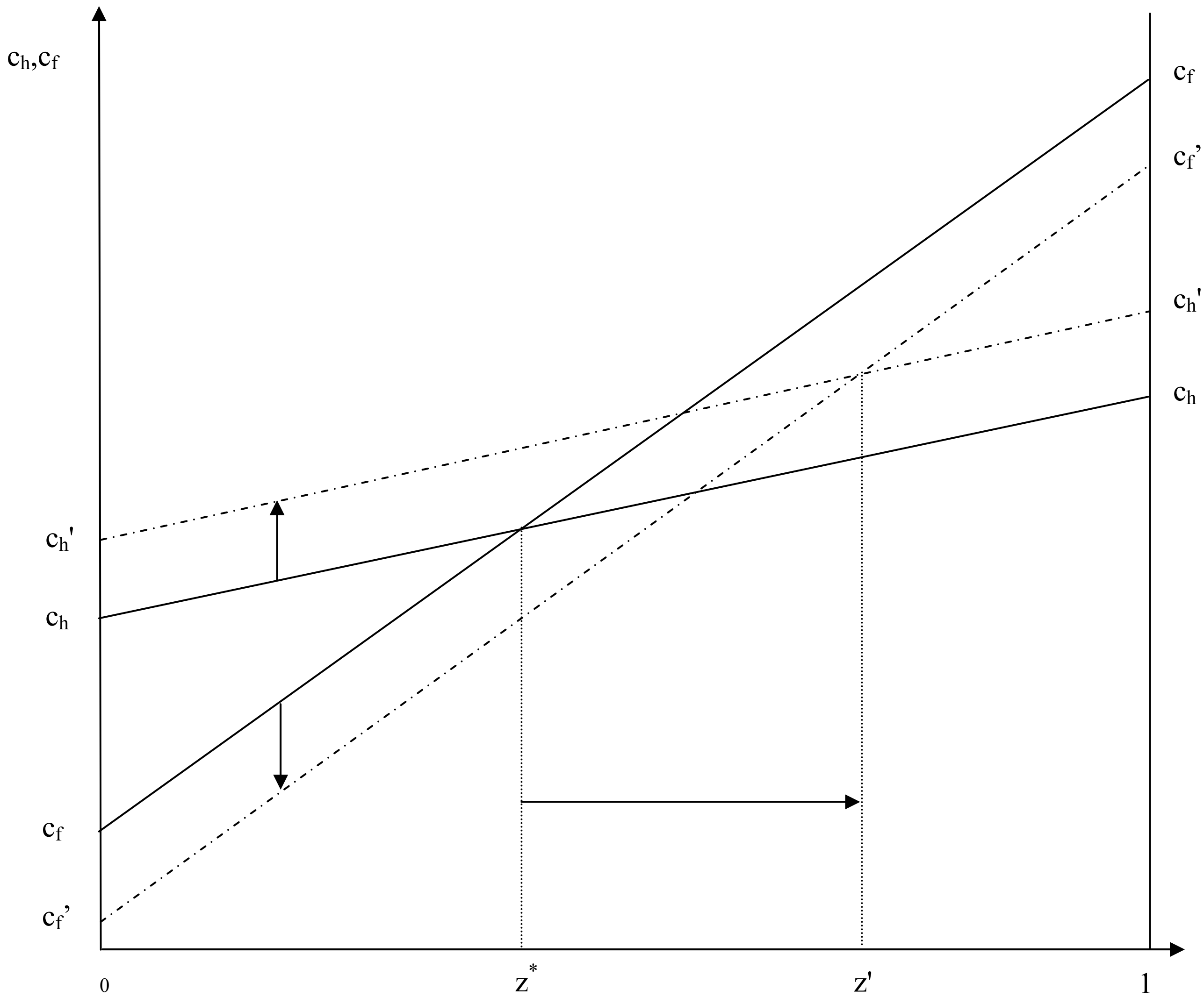


Figure 3.5: The Effect of Increase in the Relative Supply of Skilled Labor on the Foreign Country's Relative Wages

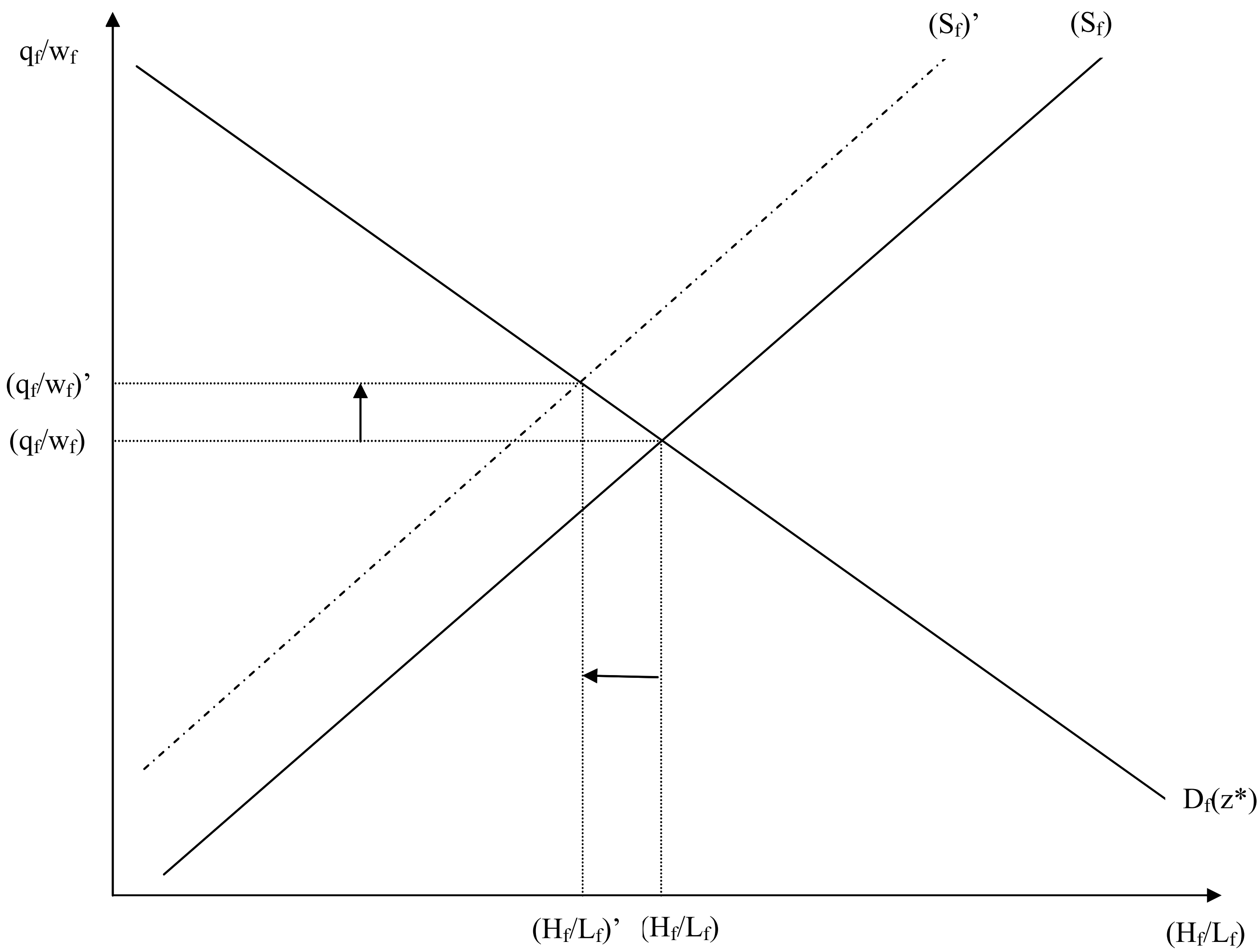
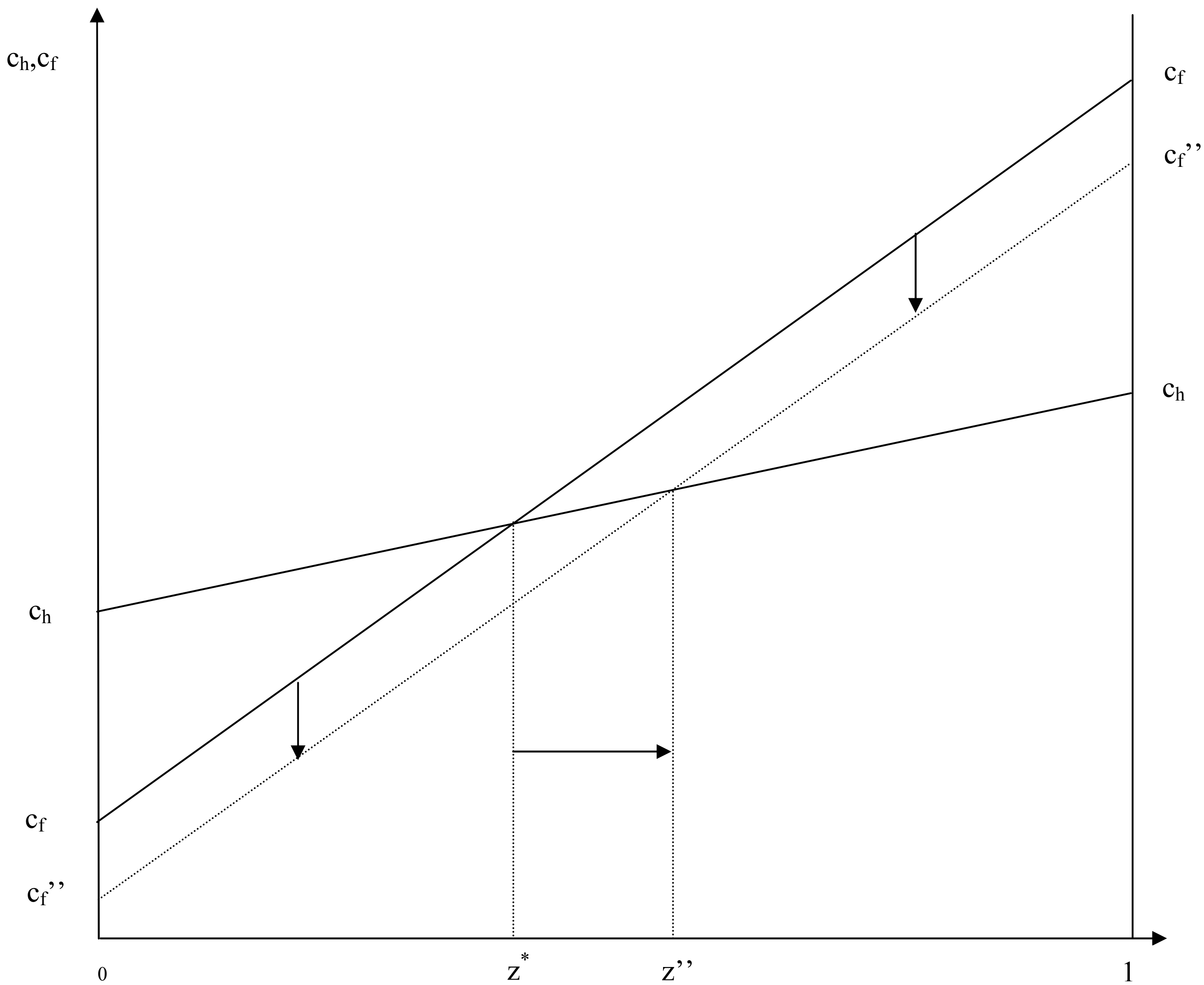


Figure 3.6: The Effect of Increase in the Relative Supply of Foreign Country's Labor on the Cutoff Intermediate Good



Chapter 4

DATA

The first section of this chapter describes the calculation of the dependent variables used in the econometric analysis. The second section of this chapter discusses the explanatory variables that I use to explain intra-industry trade in intermediates between the US and other OECD countries. The explanatory variables have either two dimensions (country-time) or three dimensions (country-industry-time).

4.1 Dependent Variables

The dependent variables are bilateral total, vertical, and horizontal intra-industry indices of intermediate goods trade between the US and OECD countries. In order to find out whether Ethier's (1982) model of horizontal trade or Feenstra's (1997) model of vertical trade explains the data on intermediate goods, I calculate the shares of vertical and horizontal intra-industry at the 3-digit level of the ISIC, Rev 2. The first step to calculate trade shares is to select the intermediate goods in the bilateral trade data. In the second step, I distinguish vertical trade from horizontal trade in intermediate goods at a commodity level. Finally, in the last step, I aggregate the share of vertical and horizontal trade up to the industry level.

4.1.1 Intermediate Goods

The bilateral trade flows data used in this dissertation cover 1988-1996, and came from OECD's International Trade Commodity Statistics (ITCS). The data are classified by the Harmonized System (HS), Revision 1.[23] There are about 5403 items at the 6-digit

[23] Previously, countries recorded their trade based on SITC (stands for Standard International Trade Classification). Since 1962, there have been 3 revisions of the SITC system: SITC Rev. 1 with data starting in 1962, SITC Rev. 2 with data starting in 1976, and SITC Rev. 3 with data starting in 1986. Most countries currently report their trade based on the Harmonized System (HS) of international trade

level of the HS. Brief descriptions of the HS at the two-digit level are provided in Table 4.1 This database provides detailed bilateral trade data for commodity exports and imports in quantity, value (in thousands of $US at current prices), and unit information (numbers, square meters, and etc) between the United States and its trading partners.[24] The sample consists of 25 OECD countries.[25] In trade data, numbering systems are used to identify commodities. These commodity codes are hierarchal, in that the longer a number is the more specific is the commodity. Here is an example of a hierarchy from HS:

84	nuclear reactors, boilers, machinery and mechanical appliances; parts thereof
8401	nuclear reactors; fuel elements, non-irradiated, for nuclear reactors; machinery and apparatus for isotopic separation; parts of the foregoing
840110	nuclear reactors
840120	isotopic separation machinery, apparatus and parts
840130	fuel elements (cartridges) non-irradiated, and part
840140	parts of nuclear reactors

Two approaches are often used in the literature to select the intermediate goods. First, Yeats (2001), Schuler (1995), Keller (1999), and Kol and Rayment (1989) all propose that trade in goods identified as parts or components should be considered to be

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classification. There have been two revisions of the HS system: the HS Rev.1 with data starting in 1988 and the HS Rev.2 with data starting in 1996. The Harmonized Tariff System is used by the US government to classify the US imports and exports. These codes can be up to 10 digits long. Export codes (called Schedule B) are administrated by the US Census Bureau. Import codes are administrated by the U.S. International Trade Commission (USITC). The first 6 digits conform to an international standard harmonized product code (HS) for imports and the remaining 4 are unique to the U.S. The first 6 digits also match the first 6 digits of the Schedule B codes. This is the main reason that OECD database is only 6-digit long otherwise it is difficult to match product codes across all member countries.

[24] Bilateral trade flows are also available from OECD's ITCS, 1961-1990, Standard Industrial Trade Classification (SITC) Revision 2. This database reports goods up to 5-digit levels and provides information on values, quantities, and unit information. Since most of the quantity and unit information is missing especially in the early periods of data, the trade data based on the Harmonized System is selected in this dissertation to analyze the intermediates trade.

[25] Excluding all of the most unskilled labor abundant countries create a selection bias because the theory of vertical trade is intended to explain the trade in intermediates between the US and undeveloped countries. Trade data for these countries is not an easy process. Hence, I have included only OECD countries which are very diverse in terms of factor endowments. Overall, Australia, Austria, Belgium-Luxembourg, Canada, Denmark, Finland, France, Germany, Iceland, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Sweden, Switzerland, The United Kingdom, The United States, Greece, Portugal, Spain, Turkey, Hungary, Mexico, and Poland are included.

trade in intermediate goods. Yeats (2001) focuses only on individual SITC 7 groups to measure the growing importance of trade in components in international trade because this industry group consists solely of parts and components.[26] Hummels, Ishii, and Yi (1999), on the other hand, employ the United Nations Broad Economic Categories classification scheme to calculate the volume of intermediate goods trade. This method removes the subjectivity of the researchers on the selection of intermediate goods.

The BEC includes nineteen basic categories, which are listed in Table 4.2. Categories (41 and 521) are classified as capital goods, categories (112, 122, 522, and 6) are classified as consumption goods, and categories (111, 121, 2, 3, 42, and 53) are classified as intermediate goods. The BEC scheme has a major disadvantage. Some of the categories such as food products (112, 122), fuel goods (321), and capital goods (41, 51) could be consumed directly by consumers, or used as intermediates in the related industry. In this dissertation, fuel (3), will not be considered as an intermediate good and is omitted from the estimations. In addition to this, categories (111 and 121) are also omitted from the estimations. Exclusion of agriculture products (111 and 121) may create selection bias. However, it is believed that agriculture industry is the least attractive industry for outsourcing because it is relatively resource and raw material intensive industry. The final selection of the intermediate goods includes the categories (2, 42, and 53).

The first version of the BEC in terms of the Standard International Trade Classification, Revision 2, was published in 1976 by the United Nations, which maps the goods according to the end-use classes described in the above scheme. The second

[26] Similarly, Keller, Wolfgang (1999) preferred the 3-digit level of SITC 7 (Revision 2) to analyze the effects of trade in intermediate goods on the technology diffusion across OECD countries.

version of the BEC in terms of the Standard International Trade Classification, Revision 3, was published in 1986 by the United Nations. The trade data used in this dissertation is based on Harmonized System (HS) Revision 1. In order to select the intermediate goods from this trade data, I concord from the BEC to SITC rev.3 using a mapping developed by the United Nations, and then match the SITC rev.3 codes to the HS rev.1 codes using a correspondence table published by the United Nations.[27] In the end, about 2703 items are selected out of 5403 items from the 6-digit level of HS.

4.1.2 Distinguishing Between Horizontal and Vertical Trade in Intermediates

After selecting the intermediate goods, I need to distinguish the share of vertical and horizontal intra-industry trade in intermediate goods at a commodity level. Recall that in Chapter 3, I identify three types of intra-industry trade in goods: the exchange of final goods against final goods, the exchange of final goods against intermediates, and finally the exchange of intermediates against intermediates. This dissertation focuses on the exchange of intermediates against intermediates. The exchange of intermediates against intermediates can be divided into horizontal IIT and vertical IIT.[28] Kol and Rayment (1989) suggest dividing total IIT into horizontal and vertical components by comparing unit values of exports and imports of intermediates. This technique has also been used by

[27] The concordances table from SITC Rev.3 to HS Rev.1 is acquired from the United Nations publication: "Standard International Trade Classification Revision 3" Series M, No.34/Rev.3. The BEC table is obtained from the United Nations publication: "Classification by Broad Economic Categories: defined in terms of SITC Rev.3". Series M, No.53, Rev.3.

[28] Notice the difference between vertical IIT in intermediate goods and vertical IIT in final goods. In the intra-industry trade literature, vertical IIT is defined as the exchange of vertically differentiated finished goods, i.e differentiated by quality, while vertical IIT in intermediates in this dissertation is defined as the exchange of intermediates in the same industry due to vertical disintegration of production process. Similarly, horizontal IIT in final goods is related to horizontally differentiated goods while horizontal IIT in intermediates in this dissertation refers to the exchange of horizontally differentiated intermediates.

Abd-el-Rahman (1991) and Greenaway et al. (1995).[29] Products whose unit values are close are considered as horizontally differentiated goods. More specifically, they argue that if the relative export to import unit values fall within the range of $\pm 15\%$, then simultaneous exports and imports of this good is identified as horizontal IIT. On the other hand, if the relative unit values of a good do not fall within this range, then intra-industry trade in this good is considered as vertical IIT. The reason is that the export prices differ from import prices due to transportation, freight, and insurance costs. Since these costs can not account for unit value differences of more than 15%, it is reasonable to have a 15% range.

I apply the same technique to trade in intermediates. Unit values may differ across traded intermediates because of categorical aggregation, horizontal differentiation, and vertical specialization. The effects of aggregation on unit values will be limited in our empirical analysis because I use commodity statistics at the six-digit level.[30] Quality differences in intermediate goods are not expected to be as serious as in the case of final goods trade, and thereby their effects on imported and exported unit values could be negligible. Turning to the effects of vertical specialization, we expect that vertical specialization definitely generates unit value differences across exported and imported intermediates where both are technologically related. Thus, the unit value differences can

[29] The reason they use unit values is the availability of trade data. Trade statistics do not provide import and export price indices at a very disaggregated level for each sector.

[30] Davis and Weinstein (2002) argue that even at the ten-digit level of trade data based on the Harmonized System, there is an evidence of aggregation bias because the unit values differ considerably within an industry, especially between the developed and developing countries. The differences in unit values could be generated by the fact that very different types of goods are being aggregated together. Nevertheless, for instance, the data reveals that the price of an Italian wool suit jacket is seven times higher than that of a Chinese counterpart. This indicates that the quality differences are the main reason why the unit values diverge among unequal partners. Schott (2000) analyzes whether this dispersion in unit values can be explained by the differences between the exporting and importing country's wealth. His results confirmed the link between the divergence in unit values and the differences in wealth.

be used as an indicator whether IIT in particular intermediates is trade in technologically linked intermediates.

Specifically, I divide the total intra-industry trade at the 6-digit level of HS intermediate product into different categories according to the similarity in unit values:

$$TT_{ihf} = HT_{ihf} + VT_{ihf} \tag{4.1}$$

where TT_{ihf} is the value of total IIT, HT_{ihf} is the value of horizontal IIT, and VT_{ihf} is the value of vertical IIT.[31] The unit value ratios of exports and imports are calculated as follows:

$$UV_i^X = \frac{XV_i}{XQ_i} \quad \text{and} \quad UV_i^M = \frac{MV_i}{MQ_i} \tag{4.2}$$

where XV_i and MV_i stands for export and import values in commodity i between two countries, respectively and XQ_i and MQ_i represent the export quantities and import quantities, respectively. Horizontal IIT is defined as the simultaneous exports and imports of a 6-digit HS commodity where the unit value of exports relative to the unit value of imports is within a range of 0.25:[32]

$$(1-0.25) \le \frac{UV_i^X}{UV_i^M} \le (1+0.25) \tag{4.3}$$

Vertical IIT, VT_{ihf}, occurs when the ratio of unit values falls outside this range:

$$\frac{UV_i^X}{UV_i^M} < (1-0.25) \qquad \text{or} \qquad \frac{UV_i^X}{UV_i^M} > (1+0.25) \tag{4.4}$$

The selection of the range used to separate vertical from horizontal trade is quite arbitrary. If the range is defined too narrowly, we can easily call intermediate goods trade

[31] Total amount of trade at any commodity level is equal to the sum of total intra-industry trade and inter-industry trade.

[32] The selection of 25% is arbitrary. In trade literature, two common values are often employed: 0.15 and 0.25. See Greenaway et al. (1994) and Fontagne and Freudenberg (1997). Their empirical analysis suggest that the results are not very sensitive to the range chosen.

vertical IIT although it is really horizontal IIT. In contrast, if the range is defined too broadly, horizontal IIT will include some of the vertical IIT. This problem will be more severe if the U.S trading partner is relatively undeveloped because the unit values of exports relative to the unit values of imports for final goods between advanced and undeveloped country are recorded to be high due to quality reasons. Taking these considerations into account, this dissertation uses a rather generous measure of horizontal IIT in intermediates, i.e. 25%.

The OECD's database ITCS used in this dissertation provides detailed information on quantities and unit information. Quantity units are described as tons, cubic meters, kilometers, thousand of units, thousand of pairs, millions of kilowatts / hour, and curies. This database reveals that a significant portion of trade at the commodity level is reported as per tonne. In addition, quantity units vary across commodity groups though they are consistent for both exports and imports flows at the 6-digit level of HS through out the period 1988-1996. We are not concerned whether they are reported in the same units across all the US trading partners because we deal with the bilateral trade flows. Thus, this dissertation computes unit values without concerning whether units are the same among different commodity groups or different trading partners or different years. As big as they are consistent within the same commodity group for both exports and imports through out the period, the method would not generate major problems.

I first attempted to use the bilateral trade flows recorded in 1996. However, the results were not satisfactory because most of the quantity and unit information is missing. Hence, I use average bilateral trade flows between 1988 and 1996 to calculate the unit value ratios since the number of products, in which I can calculate unit value ratios is significantly larger than for 1996 alone. The method just described has one major disadvantage. In trade data, it is difficult to track an intermediate good once it is imported. The imported input could be used primarily for the production of a final good that is later consumed by local consumers or it could be used in the production of other intermediate goods or final goods that are later exported back to the original country or to the other countries. However, the trade data provide information only on the export and import values of a given input. By assuming that more than a 25% difference in the export and import unit values of a certain intermediate good indicates vertical trade, then this method clearly overestimates the amount of vertical IIT since some of the trade in this good would not be trade in technologically linked goods if the trade indeed is simply the exchange of differentiated intermediate goods but it has an unit value ratio more than 25%. In this case, we can mistakenly identify horizontal intra-industry in intermediates as vertical intra-industry trade. Unfortunately, we can not track the path of a given product once it has been imported into the country.

Hummels, Rapoport, and Yi (1998) employed the OECD Input-Output Data-Base, which covers 22 manufacturing industries, to measure the amount of vertical trade in each industry. Input-output tables provide interrelationships among industries in terms of gross output, value-added, the amount of output, that is later exported, and the amount of imported intermediate goods, that is used in the production of goods for each OECD country. It looks like these tables overcome the problem just described because they give information on the amount of imported inputs embodied in the exports for each industry. However, these tables have the usual aggregation problem. These tables provide information for only 28 manufacturing industries and each of these industries consists of many goods. With this level of aggregation, these tables clearly will not inform us whether the imported and exported goods are linked.

4.1.3 Measuring Intra-Industry Trade at Industry Level

The IIT index for each industry consists of many intermediate goods. There are two problems often cited regarding the calculation of IIT indices in the literature: the aggregation problem and the choice of method. The most important is the aggregation problem. In theory, IIT is defined as the simultaneous export and import of products, which are close substitutes in production and consumption. Empirical researchers, on the other hand, have defined IIT as the simultaneous export and import of products, which belong to the same statistical product category. If we accept the 3-digit level of aggregation in the calculation of IIT index, an industry is made of many traded goods reported at the 6-digit level. If, instead, we apply the more disaggregated classification, the level of IIT is expected to fall because the chance of exact matching across industries is more difficult. Thus, true amount of IIT will be exaggerated if we use higher level of aggregation.[33]

The other problem involves the choice of method to calculate the IIT at the industry level. The most widely used method for computing the IIT is developed by Grubel and Lloyd (1971). A number of different modifications of the Grubel-Lloyd measure are often employed in the in the empirical literature: unweighted IIT method and weighted IIT method. In the first one, we calculate the IIT at the commodity level and then take the average levels of IIT of goods within a given industry j. Suppose that an economy is made of J industries that are indexed by $j = 1,...,J$ and there are

[33] Such as in Greenaway et al. (1995), Table I indicates that the calculated intra-industry index at the 3-digit

n commodities in each industry that are indexed by $i = 1,...,n$. Total trade in a given commodity i is given by:

$$\left(X_{ihf} + M_{ihf}\right) \tag{4.5}$$

where X_{ihf} and M_{ihf} are the exports and imports of the commodity i between the home country h and the partner country f. Inter-industry trade is defined as the absolute value of the difference between exports and imports value of commodity i and given by:

$$\left|X_{ihf} - M_{ihf}\right| \tag{4.6}$$

IIT is given by subtracting total trade from inter-industry trade:

$$HT_{ihf} = (X_{ihf} + M_{ihf}) - \left|X_{ihf} - M_{ihf}\right| \tag{4.7}$$

Finally, IIT at a commodity level is normalized dividing by total trade:

$$IIT_{ihf} = \frac{\left(X_{ihf} + M_{ihf}\right) - \left|X_{ihf} - M_{ihf}\right|}{\left(X_{ihf} + M_{ihf}\right)} \tag{4.8}$$

This index was originally developed by Grubel and Lloyd (1975). The value of this index is zero if all trade is inter-industry trade, it is equal to one if it is completely IIT. The index in equation (4.8) is known as the unweighted measure of intra-industry trade. Intra-industry trade at the industry level, IIT_{jhf}, can now be calculated by averaging across all commodities that belong to industry j. There is one problem with this method. Suppose that the industry j consists of two intermediate goods, A and B. If the relative size of exports and imports of good A is relatively high compared to B but the trade in good A is inter-industry, then this method may over estimate the significance of IIT of industry j. Due to this problem, Grubel and Lloyd (1975) proposed another method:

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level is significantly higher than that of at the 5-digit level.

using the relative size of exports and imports of a particular good within an industry as weights:

$$IIT_{jhft} = \frac{\sum_{i=1}^{n}\left(X_{jhft} + M_{jhft}\right) - \sum_{i=1}^{n}\left|X_{jhft} - M_{jhft}\right|}{\sum_{i=1}^{n}\left(X_{jhft} + M_{jhft}\right)} \tag{4.9}$$

where $i = 1.......n$ (about 2703 HS items) are products that are included in the j th ISIC industry group, $j = 1.......J$ (ISIC 28 industry groups), $f = 1........F$ (the U.S trading partners: 25 OECD Countries), and IIT_{jhft} stands for either $TIIT_{jhft}$, $VIIT_{jhft}$ or $HIIT_{jhft}$. Hence, IIT_{jhft} computes the export and import flows with country f in industry j, adjusted or weighted according to the relative share of the trade flows in the i products included in j.

This measure has one problem. The index is negatively correlated with a large overall trade imbalance. With national trade balances, the level of IIT will be underestimated. A number of researchers proposed alternative measures to overcome this problem. For example, Aquina (1978) argued that there should be an adjustment equation (4.9) in every industry. The Aquina adjustment is also subject to some level of criticism by empirical researchers. For instance, Stone and Lee (1995) argue that the estimated coefficients in a regression analysis will be biased if the trade imbalance is correlated with any of the explanatory variables. Due to these reasons, I avoid using the Aquina method to calculate the index for each industry.

There are 28 industries at the three-digit level of aggregation of ISIC Rev. 2 (see Table 4.3). Like in the case of IIT at commodity level, I divide the total IIT in intermediate goods into vertical and horizontal trade in each industry as:

$$TT_{jhf} = HT_{jhf} + VT_{jhf} \tag{4.10}$$

To calculate the IIT index for each case, I select the intermediate goods according to the BEC scheme.[34] I then delete the intermediate goods that lacked quantity observations. Excluding these observations could generate a selection bias if a significant portion of intermediate goods trade is eliminated.[35] Table 5.13 shows the percentage of intermediate goods trade used in the estimation for each country after it is subject to the elimination process. Overall, 77 % of the observed intermediate goods trade is selected to use in the estimation though it is smaller for periphery countries, 73%.

Once, I select the intermediate goods, I separately obtained $(X_{ihf} + M_{ihf})$ and $\left|X_{ihf} - M_{ihf}\right|$ at the 6-digit product level of HS products, and thereafter summed over all 6-digit HS products comprising a particular industry using a concordance table from HS to ISIC.[36] Using equation (4.9), I calculated the index for total IIT in intermediate goods for each industry, $TIIT_{jhft}$. To calculate the index for horizontal IIT, $HIIT_{jhft}$, I first selected intermediate goods that satisfy the conditions in equation (4.3) and I calculated the amount of IIT at a 6-digit product level of HS products, and thereafter summed over all 6-digit product level of HS products comprising a particular industry. The weight regarding horizontal IIT is then obtained by dividing horizontal IIT by the total IIT.

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[34] Using the BEC scheme, I end up having 2703 intermediate goods out of 5403 products. The number of horizontally differentiated intermediates goods and vertically differentiated intermediate goods, however, varies across countries due to missing quantity observations and trade flows. For instance, Canada has 719 horizontally differentiated intermediate goods and 1536 vertically differentiated intermediate goods while Spain has 157 and 929, respectively.

[35] In addition to this, Fontagne and Freudenberg (1997) suggest that an empirical researcher should also drop the products from the estimation which do not have a significant share of IIT in total trade of a given product. The selection of intra-industry shares criteria for inter-industry trade is arbitrary. In the literature, it is often argued that if this index is less than 10 percent, then trade in a given product is considered to be inter-industry trade. Due to having limited observations on intermediate goods trade, this dissertation ignores this suggestion.

Finally, the horizontal IIT index is calculated according to its weight in total IIT. In other words, the index of total IIT is multiplied by the weight of horizontal IIT. The process was repeated for the intermediate goods that satisfy the conditions in equation (4.4). This provides the index of vertical IIT in intermediate goods for each industry, $VIIT_{jhft}$. This process provides a consistent relationship between $HIIT_{jhft}$ and $VIIT_{jhft}$ indices because the sum of both always add up to total IIT index:

$$TIIT_{jhf} = HIIT_{jhf} + VIIT_{jhf} \tag{4.11}$$

Notice the difference between equation (4.10) and (4.11). The former is related the amounts of IIT while the later provides the share or indices of each kind in total industry trade in intermediate goods.

4.2 The Explanatory Variables

Since Grubel and Lloyd's (1975) study, numerous empirical studies have examined the determinants of IIT in manufactured goods. These studies can be classified into country-specific studies and industry-specific studies. Although the majority of the empirical studies find stronger support for country-specific variables than industry-specific variables I will consider both. The following explanatory variables stem from Ethier's (1982) model of international division of labor and Feenstra and Hanson's (1997) model of outsourcing.

4.2.1 Industry-Specific Variables

Ethier's (1982) model predicts that the degree of IIT described in equation (3.19) depends on the relative size and factor endowments of two countries but not on parameters that are related to the degree of product differentiation and economies of

[36] The concordances table from HS to ISIC (Rev. 2) is obtained from World Bank "Trade and Production

scale. Despite this prediction, numerous empirical studies have checked whether product differentiation and economies of scale have any explanatory power over the share of IIT in manufactured goods. The results are mixed because there is no consensus among economists how to quantify product differentiation and economies of scale. In spite of this problem, this dissertation will attempt to test whether product differentiation and economies of scale have explanatory power on the shares of IIT by using some widely used proxies.

Differentiation of Products

Variables used as proxies for the degree of product differentiation are the number of 5-digit SITC products in each SITC 3-digit industry group (Greenaway et al. (1995)), unit price variation (Hufbauer (1970)), or research and development expenditure as a fraction of net output or sales (Greenaway and Miller (1993)). Unit price variation is the most widely used indicator for the degree of product differentiation. In Hufbauer (1970), unit price variation is given by the standard deviation of the US export unit values for shipments of product i to different countries, divided by the unweighted mean of these unit values. Fontagne et al. (1997) suggest a slightly different version of Hufbauer's (1970) unit price variation formula:

$$PDI_{jhft} = \sum_{i \in j} \left[\frac{XV_{it}}{\sum_{i \in j} XV_{it}} \times \frac{\max\left(UV^{X}_{ihft}, UV^{X}_{i..t}\right)}{\min\left(UV^{X}_{ihft}, UV^{X}_{i..t}\right)} \right] \tag{4.12}$$

where XV_{it} is the export value for each commodity and UV^{X}_{ihft} is the unit value of the US exports to trading partner f and and $UV^{X}_{i..t}$ is the average unit value of the US exports to all US trading partners. This formula provides an index of the similarity of the unit values

database" CD-ROM.

of the same varieties in any industry j, included in US exports weighted by the export value of that industry. The procedure to calculate this index is quite tedious. First of all, I obtain the export unit value between the US and trading partner f at the product level for each year from 1990 to 1996, i.e UV_{ihft}^{X}. The second step involves calculation of the average export unit value between the US and its all trading partners at the product level for each year, i.e $UV_{i..t}^{X}$.[37] Comparing UV_{ihft}^{X} to $UV_{i..t}^{X}$ yields a proxy for the vertical differentiation of a product. This part of the index is equal or larger than 1. To obtain the average dispersion in industry j for each year, this index is weighted by the ratio of export values of product i to the export values of that industry and then finally the index is aggregated over all products i belonging to industry j. In the end, the production differentiation index has three dimensions: country, industry, and time. We expect a positive relationship between this variable and vertical IIT in intermediates, and a negative relationship between this variable and horizontal IIT in intermediates.

Value-added Per Establishment

Recall, there are two types of economies of scale in Ethier's (1982) model: national returns to scale and international returns to scale.[38] Economies of scale in this hypothesis refer to national returns to scale. If scale economies at the plant level are relatively small, any increase in scale economies would probably increase two-way trade in similar products. On the other hand, large scale economies at the plant level imply a smaller number of firms and consequently a smaller number of component varieties.

[37] The average production differentiation index at the 3-digit ISIC level between the US and its trading partners are tabulated in Table 4.7.

[38] Note that scale at industry level (national returns to scale) is distinct from scale at international level (international returns to scale). National returns to scale is related to the size of the plant while the international returns to scale is related to the size of economy.

Thus, we expect that horizontal IIT is negatively correlated with differences in scale economies. The effect of economies of scale on vertical IIT in intermediates is somewhat ambiguous. In Feenstra and Hanson (1997), unit costs determine the pattern of trade. If scale economies at the plant level are large, then we would expect that the unit cost of producing an intermediate good would be relatively low. This would force a local firm not to outsource some of its activities abroad to remain competitive in the markets. Eventually, the volume of trade in intermediate goods between the home and foreign country drops. We therefore expect negative effect on vertical IIT.

Value added per establishment based on U.S industry data at the 3-digit level of ISIC will be used as a proxy for economies of scale. The World Bank's "The Trade and Production Database" CD-ROM provides data on value added in thousands of $US at the 3-digit ISIC (Rev.2). Monetary data are not deflated, and are expressed in thousands of $US. Therefore, a conversion procedure is necessary to convert the production data into real internationally comparable units. In the literature, PPP exchange rates constructed by Summers and Henston are quite often employed to obtain real data in a common currency ($US) across countries. PPPs are price relatives, which show the ratio of the prices in national currencies of the same good or service in different countries. I will closely follow the procedure developed by Harrigan (1997) to obtain real data to employ in the estimations. The PPP exchange rate in Harrigan's paper is described as:

$$e_{fjt} = E_{ft} P_{fjt} \tag{4.13}$$

where is E_{ft} the nominal exchange rate (foreign currency cost of $1) and e_{fjt} is the cost in $US of purchasing a unit of standardized output which would cost \$ E_{ft} in the US. P_{fjt} is the price level of industry j standardized output in country f in year t. The price level is a unit-less number which expresses the $US cost of output in country f relative to the $US cost of output in the US. If $P_{fjt} > 1$, then the standardized unit of output is more expensive in country f than in the US.

After Harrigan (1997) constructed price levels for each industry, he employed the following formula to calculate real value added y in constant dollars as:

$$y_{fjt} = \frac{Y_{fjt}}{e_{fjt}\pi_{jt}} \tag{4.14}$$

where π_{jt} is the US value added deflator used to make different years comparable.

Notice that the formula describes the method at the industry level. PPPs at the GDP level or economy-wide PPPs are not normally adequate for data comparisons at the level of individual industries. Although researchers, including Harrigan (1997), have developed industry-specific PPPs, they are only available for a limited number of countries, industries, and time periods. Due to the data constraint, this dissertation uses economy-wide PPPs, i.e P_{ft} rather than P_{fjt}. In addition, the above PPPs formula is applied to convert the data into $US. Since the data used in this dissertation is already expressed in $US, the following modified formula is used to obtain real value-added y in units of 1995 dollars for f country as:

$$y_{fjt} = \frac{Y_{fjt}}{(P_{ft}/100)*(\pi_{jt}/100)} \tag{4.15}$$

where P_{ft} is the price level of GDP taken from the Penn World Tables version 6.0, and used for all j. π_{jt} is the implicit price deflator of GDP obtained from Bureau of Economic Analysis' web page is employed to make different years comparable.[39]

To construct real value added for the US, I calculate real value added by simply using the US implicit price deflator of GDP:

$$y_{hjt} = \frac{Y_{fjt}}{(\pi_{jt}/100)} \tag{4.16}$$

Once real value-added data is constructed for each industry for the US and its trading partner f, I calculate absolute differences in real value-added per establishment at the industry level as:

$$DVAEST_{jhft} = \left| \frac{y_{hjt}}{es_{jht}} - \frac{y_{fjt}}{es_{jft}} \right| \tag{4.17}$$

where es_{jht} and es_{jft} is the number of establishments at industry level for the US and foreign country, respectively. The production database reports the number of enterprises in units.

Market Structure

Market structure in Ethier's (1982) model is Chamberlinian monopolistic competition. The industry concentration ratio, or the number of establishments in an industry, is often used as a proxy for market structure. Ethier's (1982) model predicts that an increase in the number of firms will result in an increase in the number of components since each firm produces only one variety in equilibrium. Therefore, horizontal IIT will tend to grow as the number of firms in the economy increases. Considering the model of

[39] Due to unavailability of US value added deflator, this dissertation employs US implicit price deflator for

vertical trade, as the number of establishments in each industry rises, unit costs are expected to increase due to a decline in economies of scale at the plant level. We therefore expect a negative relationship between the number of establishments and vertical IIT.

I use the average number of establishments as a proxy for the market structure:

$$AEST_{jhft} = \frac{es_{jht} + es_{jft}}{2} \tag{4.18}$$

where es_{jht} and es_{jft} is the number of establishments at industry level for the US and foreign country, respectively.

Capital Stocks

Ethier's (1982) model predicts that horizontal IIT in intermediates is more likely to take place between countries with similar factor endowments. In Ethier's model, the differentiated intermediate good is assumed to be a capital-intensive good. In addition, the home country is assumed to be relatively capital-abundant. If capital-endowments increase for the home country, the model predicts that the number of intermediate varieties produced in the home country rises. The home final goods producers begin to rely on locally produced intermediate goods. This will eventually lead to a reduction in horizontal IIT. Thus, differences in physical endowments in each industry between the U.S and its trading partners should reduce horizontal IIT.

Feenstra and Hanson's (1997) model predicts that the growth of the capital stock in the foreign country raises the value of the cutoff intermediate input. The model initially assumed that there are large differences in capital endowments between the two countries. Thus, the growth of capital stock in each industry for the foreign country

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overall GDP obtained from http://www.bea.gov.

would lead to a decline in unit costs. The home firms increasingly engage in outsourcing activities to take advantage of cheaper inputs produced in the foreign country. The share of intermediate goods trade between the two countries thus is expected to increase. Therefore, the model predicts that the relationship between vertical IIT and differences in physical endowments in each industry between the home and foreign country is negative.

The World Bank production data provides gross fixed capital formation (GFCF) in thousands of $US at the 3-digit ISIC industry level. To construct capital stocks at the industry level, I employ a similar method described above to obtain real GFCF for trading partners:

$$i_{jft} = \frac{I_{jft}}{\left(IP_{ft}/100\right)*\left(i\pi_{ht}/100\right)} \qquad (4.19)$$

where i_{jft} is real investment in units of 1995 dollars, IP_{ft} is the price level of investment taken from Penn World Tables version 6.0, and applied for all j, and $i\pi_{ht}$ is the implicit deflator with a base year of 1995 for US fixed non-residential investment obtained from Bureau of Economic Analysis' web page. [40] Note that IP_{ft} is not at the industry-level but rather economy-wide level PPPs.

Nominal GFCF for US are converted to real numbers by use of the US implicit fixed non-residential investment deflator with a base year of 1995 as:

$$i_{jht} = \frac{I_{jht}}{\left(i\pi_{ht}/100\right)} \qquad (4.20)$$

[40] Bureau of Economic Analysis' web page address is http://www.bea.gov.

Once the series on real GFCF is constructed for the US and its trading partner, physical capital endowments at the industry level are calculated according to the perpetual inventory method:

$$K_{jf1988} = 5*\left(i_{jf1987} + i_{jf1988}\right) \qquad (4.21)$$

To construct 1988 capital stocks for industry j, we need only sum the gross fixed capital formation over available years and depreciate them at 10% from 1988 to1996.[41] That is:

$$K_{jft} = (1-0.1)*K_{jft-1} + i_{jft} \qquad (4.22)$$

where i_{jft} is the real GFCF, $(1-0.1)*K_{jft-1}$ is the accumulated gross fixed capital formation until time $t-1$, and K_{jft} is the real capital stocks in industry j for the foreign country f. The method has one important shortcoming: it ignores capital formation made before 1987, which could be still in use in the present time. Similarly, this dissertation assumes that the initial capital stock in each industry in 1988 is 5 times of total GFCF made in year 1987 and 1988. The process will be repeated for the U.S:

$$K_{jht} = (1-0.1)*K_{jht-1} + i_{jht} \qquad (4.23)$$

In the estimation, I use the absolute differences in physical capital endowment in each industry between the U.S and its trading partner:

$$DIFCAP_{jhft} = \left|K_{jht} - K_{jft}\right| \qquad (4.24)$$

where K_{jht} and K_{jft} are the real physical capital stocks in each sector for the US and the foreign country, respectively.

Tariff Rates

Imports are subject to tariff as well as non-tariff barriers. It is expected that the share of IIT is negatively correlated with the level of trade restrictions. Vertical IIT is more sensitive to tariff rates than horizontal IIT in intermediates because intermediate goods that are used in multiple production stages in different countries may cross the borders more than once. At high tariff rates, we see only inter-industry trade in intermediates. As tariff rates decline, we expect that horizontal IIT in intermediates responds quickly since horizontally differentiated intermediate goods cross border only once. When tariff rates are further reduced, the share of vertical IIT in intermediate goods should begin to increase. Thus, vertical IIT trade will be more sensitive to any large reductions in tariff rates but less sensitive to any small change in tariff rates.[42]

The data on non-tariff barriers are not available. Because of this, the average tariff rates at the3-digit ISIC level are used as a proxy for trade restrictions between two countries:

$$TARIFF_{jhf} = \frac{TARIFF_{jh} + TARIFF_{jf}}{2} \tag{5.8}$$

where $TARIFF_{jhf}$ is the simple average tariff rate in each industry between the U.S and its trading partner. The tariff data at the 3-digit level for each country is also acquired from The World Bank "The Trade and Production Database" CD-ROM. The availability of average tariff data varies from country to country and from year to year.

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[41] Schott (2001) and Hummels and Levinsohn (1993) apply the depreciation rate 13.3%.

[42] The 1965 US-Canada auto agreement reduced the tariff rates on the imports of automobiles and its parts considerably. Hummels, Rapoport, Yi (1998)'s findings indicate that the share of vertical trade between the U.S and Canada increased from almost 0 percent in 1965 to 35 percent in 1991.

4.2.2 Country-Specific Variables

Market Size

In Ethier's model, international division of labor is limited by the extent of the market. With free trade, component producers will be able to utilize increasing returns to scale, and thereby increase the number and production of intermediate goods. A country with a small domestic market has limited opportunities to take advantage of economies of scale in the production of differentiated intermediate goods. Thus, the larger the international market the larger the opportunities for production of differentiated intermediate goods and the larger opportunities for trade in intermediate goods. We would expect that market sizes will have a positive effect on horizontal IIT between the two economies.

Hummels et al. (1998) indicates that the share of vertical trade in total trade for large countries is considerably smaller than that of small countries. Large countries such as the US, Germany, and Japan, will likely be able to produce every stages of a good due to economies of scale. Small countries such as Netherlands, Denmark, and Canada, with limited factor resources tend to be more vertically specialized than large countries. In Feenstra and Hanson's model, any reduction in the home country's unit costs due to greater economies of scale will lead to a decline in the usage of imported intermediate goods in the production of final goods.

Two proxies are used for the effects of market size: average market size and differences in market size between two economies. Since the dependent variable is measured on a bilateral basis, it is necessary to use the average GDP as the GDP value (in 1995 constant $US) of the home country h and its partner country f :

$$AGDP_{hft} = \frac{GDP_{ht} + GDP_{ft}}{2} \tag{4.25}$$

The data on GDP for 25 countries in 1995 constant $US is obtained from the OECD Statistical Compendium CD-ROM. It is expected that market size will have a positive impact on horizontal IIT since a greater variety of goods exist in the large markets. On the other hand, we expect large market size to have negative effect on vertical IIT.

Following Balassa and Bauwens (1987), the difference in market sizes is measured as:

$$DGDP_{hft} = 1 + \frac{[w \ln w + (1-w)\ln(1-w)]}{\ln 2} \tag{4.26}$$

where w refers to ratio of home country's GDP to the sum of this country's GDP and its trading partner k 's GDP, i.e, $w = \frac{GDP_{ht}}{GDP_{ht} + GDP_{ft}}$. It has been argued that this indicator is better than the absolute differences in GDP because the latter is sensitive to the absolute size of the trade partners. $DGDP_{hft}$ ranges from 0 to 1, and is independent of the absolute size of the trade partners. Following the discussion made by Hummels et al. (1998), the difference in market sizes is expected to have positive effects on vertical IIT. On the other hand, it is well known fact that the difference in size is traditionally an obstacle to horizontal IIT.

Foreign Direct Investment

Foreign Direct Investment (FDI) is another bilateral variable that has to be considered. During the 1980s, the US was the leading outward FDI investor among OECD countries. In Feenstra and Hanson (1997), it has been shown that the capital movement from the home country to the foreign country increased the volume of intermediate goods trade between two countries. We would therefore presume a positive relationship between vertical IIT and FDI. However, we expect that the FDI should not have any effect on horizontal IIT. Note that the FDI in the world economy is mainly carried out by MNEs. Andersson and Fredricksson (2000) argue that trade in intermediate goods is related to vertical integration of multinationals while trade in final goods is related to horizontal integration. Vertically organized MNEs exploit the differences in factor endowments and technology across countries, while horizontally organized MNEs try to avoid costly trade barriers. In the case of horizontal MNEs, FDI may substitute for exports of the goods that were previously produced in the investor's home country. Thus, we expect that the trade in horizontally differentiated intermediate goods due to FDI are relatively small, while the trade in intermediate goods that are technologically linked due to FDI are relatively high.

It is impossible to collect data on foreign direct investment flows and stocks at the industry level but this data is generally available at a very aggregated level. The data on foreign direct investment flows and stocks at the economy-wide level are taken from the OECD Direct Investment Statistics Yearbook (2000), which provides data on the direct investment flows and stocks in million $US between the U.S and 28 OECD countries from 1988 to 1999. Hence, the foreign direct investment data in this dissertation has only two dimensions: country and time. The FDI flows are defined as the amount of investment made in one year while the FDI stocks are defined as total investment accumulation over years. This dissertation focuses on the FDI stocks rather than on the FDI flows.

I measure real outward FDI stocks $RFDI_{jhft}$ as:

$$RFDI_{jhft} = \frac{FDI_{jhft}}{\left(IP_{jft}/100\right)*\left(i\pi_{jht}/100\right)} \tag{4.27}$$

where IP_{jft} is price level of investment taken from Penn World Tables and applied for all j, and $i\pi_{jht}$ is the implicit deflator with a base year of 1995 for US fixed non-residential investment.

Human Capital

In Ethier 's model, differences in factor endowments reduce the extent of horizontal IIT. Highly skilled laborers, mainly R&D personnel, are necessary ingredients to increase the number of intermediate varieties. If the difference in human capital endowments between countries is large, then we expect a negative sign on horizontal IIT in intermediates. On the other hand, the second comparative static in the model of outsourcing shows that an increase in the ratio of the relative supply of skilled labor in the home country to the foreign country will increase vertical specialization from the home country to the foreign country. Thus, the level of vertical IIT is larger when the differences in human capital endowments between two countries are large. It is difficult to construct a useful measure of skilled labor endowment. It is well recorded that a higher education attainment increases the skill levels of workers. Greenaway and Torstensson (1997) used education data as a proxy for human capital endowment. This dissertation will experiment with a couple of different variables to proxy for the skilled labor endowment. The first proxy I will use in the estimation is obtained from OECD Education at Glance.[43] This data set provides the share of population or labor force aged between 25 and 64 for whom the highest level of education falls into four main categories: below secondary education, upper-secondary education, non-university tertiary education, and university-level education.[44] The sum of the shares of non-university tertiary education and university-level education gives the skilled labor force while the sum of the shares of below secondary education and upper-secondary education provides the share of unskilled labor force for each country. We thus use the absolute differences in the relative ratio of skilled labor/unskilled labor between the home country and the foreign country as a proxy in the estimations:

$$DHUMCAP1_{hft} = \left| \frac{H_{ht}}{L_{ht}} - \frac{H_{ft}}{L_{ft}} \right| \tag{4.28}$$

where H_h and H_f are the shares of skilled labor force proxied by the sum of shares of non-university tertiary education and university-level education in the home and foreign country, respectively and while L_h and L_f are the shares of skilled labor force proxied by the sum of shares of below-upper secondary education upper-secondary education in the home and foreign country, respectively.

The second proxy is acquired from the various publications of OECD Science, Technology, and Industry: Scoreboard of Indicators. This data set provides the number of researchers per ten thousand labor force for each country. Therefore, we employ the absolute differences in the relative ratio of number of researchers between the home country and the foreign country as a proxy in the estimations:

$$DHUMCAP2_{hft} = \left| R_{ht} - R_{ft} \right| \tag{4.29}$$

[43] I first attempted to use Barro and Lee (2000)'s education data set to measure the human capital endowment. However, the educational attainment figures in this data set are constructed at five-year intervals from 1960 to 1990.

where R_h and R_f are the number of researchers in the home and in the foreign country, respectively.

Geographical Distance

In the literature, such as in Balassa (1986), it has been found that the share of intra-industry trade is negatively correlated with geographical distance. Distance will increase the transaction costs including insurance and transportation costs. Considering trade in intermediate goods, vertical trade may pass borders at multiple times. Thus, the effects of transportation costs on the vertical IIT will be expected to be higher than on the horizontal IIT in which goods pass the border only once.[45]

Following Balassa (1986), the geographical distance variable is defined as the weighted distance between h and partner country f:

$$DIST_{hf} = \frac{DIST_f * GDP_f}{\sum_{f=1}^{25} GDP} \qquad (4.30)$$

The weight is the ratio of the GDP of its trading partner f to the sum of the GDPs of the its all trading partners. The distance, denoted as $DIST_f$, is the direct distance in kilometers between the US's capital and its trading partners' capital. The geographical distance data between the U.S and its trading partners is taken from John Haveman's web page.[46]

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[44] Barro and Lee (2000) argue that the population group between 25 and 64 matches closely the labor force in OECD countries. The reason is that restrictions on underage working below age 18 in such developed European countries are well established.
[45] Hummels et al. (1998)'s calculations show that the share of vertical specialized-based trade in total trade for Australia is one of the lowest, 7.4 %. Part of reason may be due to distance to international markets.
[46] The web address is http://www.macalester.edu/research/economics/PAGE/HAVEMAN/Trade.Resources /TradeConcordances.html#gravity.

Table 4.1 The Harmonized System Revision 1 Brief Descriptions (at the 2-digit level)	
Code	Commodity Description
01,…,05	Live animals; animal products
06,…,14	Vegetable products
15	Animal or vegetable fats and oils and their Cleavage Products; Prepared Edible Fats;…..
16,…,24	Prepared Foodstuffs; Beverages, Spirits, and Vinegar; Tobacco and Manufactured Tobacco Substitutes
25,…,27	Mineral products
28,…,38	Products of the chemical or allied industries
39,40	Plastics and articles thereof; rubber and articles thereof
41,…,43	Raw hides and skins, leather, furskins and articles thereof;…..
44,…,46	Wood and articles of wood; wood charcoal; cork and articles of cork;…..
47,…,49	Pulp of wood or of other fibrous cellulosic material; waste and scrap of paper or paperboard;…..
50,…,63	Textile and textile articles
64,…,67	Footwear, headgear, umbrellas, sun umbrellas, walking-sticks, seat-sticks,……
68,…,70	Articles of stone, plaster, cement,asbestos, mica or similar materials; ceramic products; glass,…
71	Natural or cultured pearls, precious or semiprecious stones, precious metals,……
72,…,83	Base metals and articles of base metal
84,85	Machinery and mechanical appliances; electrical equipment; parts thereof;…….
86,…,89	Vehicles, aircraft, vessels and associated transport equipment
90,…,92	Optical, photographic, cinematographic, measuring, checking, precision, …….
93	Arms and ammunition; parts and accessories thereof
94,…,96	Miscellaneous manufactured articles
97	Works of art, collectors' pieces and antiques
98	Commodities and transactions not classified according to kind
99	Special import reporting provisions

Table 4.2 Broad Economic Categories Classification Scheme (BEC,1986)	
Commodity Categories	End-Use Classes
1. Food categories	
11. Primary	
111. Mainly for industry	Intermediate goods
112. Mainly for household consumption	Consumption goods
12. Processed	
121. Mainly for industry	Intermediate goods
122. Mainly for household consumption	Consumption goods
2. Industrial supplies not elsewhere specified	
21. Primary	Intermediate goods
22. Processed	Intermediate goods
3. Fuels and lubricants	
31. Primary	Intermediate goods
32. Processed	Intermediate goods
321. Motor Spirit	Intermediate goods and consumption goods
322. Other	Intermediate goods
4. Capital goods (except transport equipment), and parts and accessories thereof	
41. Capital goods (except transport equipment)	Capital goods
42. Parts and accessories	Intermediate goods
5. Transport equipment and parts and accessories thereof	
51. Passenger motor cars	Intermediate goods and consumption goods
52. Other	
521. Industrial	Capital goods
522. Non-industrial	Consumption goods
53. Parts and accessories	Intermediate goods
6. Consumer goods not elsewhere specified	
61. Durable	Consumption goods
62. Semi-durable	Consumption goods
63 Non-durable	Consumption goods
7. Goods not elsewhere specified	

Table 4.3 International Standard Industrial Classification (ISIC Rev.2)

Code	Industry
311	Manufacture of food products
313	Manufacture of beverages
314	Manufacture of tobacco
321	Manufacture of textiles
322	Manufacture of wearing apparel, except footwear
323	Manufacture of leather products
324	Manufacture of footwear, except rubber or plastic
331	Manufacture of wood products, except furniture
332	Manufacture of furniture, except metal
341	Manufacture of paper and products
342	Manufacture of printing and publishing
351	Manufacture of industrial chemicals
352	Manufacture of other chemicals
353	Manufacture of petroleum refineries
354	Manufacture of miscellaneous petroleum and coal products
355	Manufacture of rubber products
356	Manufacture of plastic products
361	Manufacture of pottery, china, earthenware
362	Manufacture of glass and products
369	Manufacture of other non-metallic mineral products
371	Manufacture of iron and steel
372	Manufacture of non-ferrous metals
381	Manufacture of fabricated metal products
382	Manufacture of machinery, except electrical
383	Manufacture of machinery, electric
384	Manufacture of transport equipment
385	Manufacture of professional and scientific equipment
390	Manufacture of other manufactured products

Table 4.4 Data Sources	
Trade Data	
Bilateral Trade flows of the US with other OECD countries at the 6-digit product level in thousands of $US dollars at current prices	OECD "International Trade Commodity Statistics (ITCS)", 1988-1996, Harmonized System (HS), Revision 1.
Country-Specific Variables	
GDP in values of $US with the base year of 1995	OECD Statistical Compendium CD-ROM, 2000
PPP of GDP (US=100)	Penn World Tables version 6.0
PPP of Investment (US=100)	Penn World Tables version 6.0
FDI in million $US	OECD, Investment Direct Investment Statistics Yearbook, 2000
Education	OECD, Education at Glance, various years
The number of researchers per ten thousand labor force	OECD, Science, Technology, and Industry: Scoreboard of Indicators, various years
US implicit price deflator with a base year of 1995 for overall GDP	Bureau of Economic Analysis' web page: http//www.bea.gov
US implicit price deflator with a base year of 1995 for US fixed non-residential investment	Bureau of Economic Analysis' web page: http//www.bea.gov
Geographical distance in kilometers between the US and other OECD countries	John Haveman's web page: http://www.macalester.edu/research/economics/PAGE/HAVEMAN/
Industry-Specific Variables	
Value added in thousands of $US at the 3-digit ISIC (Rev.2)	The World Bank "The Trade and Production Database" CD-ROM, 1976-1999.
The number of establishments at the 3-digit ISIC (Rev.2)	The World Bank "The Trade and Production Database" CD-ROM, 1976-1999.
Gross Fixed Capital Formation (GFCF) in thousands of $US at the 3-digit ISIC (Rev.2)	The World Bank "The Trade and Production Database" CD-ROM, 1976-1999.
Tariffs in percentage at the 3-digit ISIC (Rev.2)	The World Bank "The Trade and Production Database" CD-ROM, 1976-1999.

Table 4.5 Data Availability of Country-Specific Variables

Country	Education	#Researchers	GDP	Outward FDI*	PPP of Investment	PPP of GDP
Australia	91,92,94,96	90-92,94-95	90-96	90-96	90-96	90-96
Austria	91,92,94,96	90,93,95	90-96	90-96	90-96	90-96
Belgium	91,92,94,96	90,95	90-96	90-96	90-96	90-96
Canada	91,92,94,96	90,95	90-96	90-96	90-96	90-96
Switzerland	91,92,94,96	90,92,95	90-96	90-96	90-96	90-96
Germany	91,92,94,96	90-93,95	91-96	91-96	91-96	91-96
Denmark	91,92,94,96	90-93,95	90-96	90-96	90-96	90-96
Spain	91,92,94,96	90-95	90-96	90-96	90-96	90-96
Finland	91,92,94,96	90,91,93,95	90-96	90-96	90-96	90-96
France	91,92,94,96	90-95	90-96	90-96	90-96	90-96
The UK	91,92,94,96	90-95	90-96	90-96	90-96	90-96
Greece	92,94,96	90,91,93,95	90-96	90-96	90-96	90-96
Hungary			90-96		90-96	90-96
Ireland	91,92,94,96	90,95	90-96	90-93	90-96	90-96
Iceland		90-95	90-96	90-96	90-96	90-96
Italy	91,92,94,96	90,95	90-96	90-96	90-96	90-96
Japan						
Mexico		93-95	90-96	90-96	90-96	90-96
Netherlands	91,92,94,96	93-95	90-96	90-96	90-96	90-96
Norway	91,92,94,96	90,91,93,95	90-96	90-96	90-96	90-96
New Zealand	91,92,94,96	90-93,95	90-96	90-96	90-96	90-96
Poland	96	94,95	90-96		90-96	90-96
Portugal	91,92,94,96	90,92,95	90-96	90-96	90-96	90-96
Sweden	91,92,94,96	90,91,93,96	90-96	90-96	90-96	90-96
Turkey	91,92,94,96	90-95	90-96	90-96	90-96	90-96
USA	91,92,94,96	91,93,95	90-96		90-96	90-96

Note: The symbol '-' divides the first and last year of a time series that the data are available, the symbol ',' divides single years that indicates the data are available in that year.
* indicates that the outward FDI stocks are made by the US into the OECD countries.

Table 4.6 Data Availability of Industry-Specific Variables

Country	Value Added	#Firms	GFCF	Tariffs
Australia	90-92	90-92,96		91-93,96
Austria	90-94	90-94,96	90-94	90-96
Belgium				
Canada	90-94	90-94,96	90	93,95-96
Switzerland				
Germany	91-93	90-94,96		
Denmark	90-92	90-92,96	90-91	
Spain	90-92	90-92,96	90-96	
Finland	90-96	90-96	90-96	
France			90-96	
The UK	90-94,96	90-94,96	90-92	
Greece	90-92	90-92,96	90-92	
Hungary	90-93	90-93,96	90-93	91,93,96
Ireland	90-91	90-91,96	90-91	
Iceland				
Italy	90-94	90-94,96	90-94	
Japan				
Mexico	90-95	90-96	90,91	91,95
Netherlands	90-94	90-94,96	90-93	
Norway	90-96	90-96	90-96	93,95,96
New Zealand	90-96	90-96	90	92,93,96
Poland	90-93	90-93,96	90-93	91,92,95,96
Portugal	90-95	90-96	90-95	
Sweden	90-94	90-94,96	90-96	
Turkey	90-94	90-94,96	90-96	93,95
USA	90-96	90-96	90-96	90,93,95,96

Note: The symbol '-' divides the first and last year of a time series that the data are available, the symbol ',' divides single years that indicates the data are available in that year.

Table 4.7 Average Product Differentiation Index, 1990-1996

Industry	Index
All Industries	3.19
311	4.43
313	-
314	-
321	1.58
322	1.89
323	6.76
324	-
331	1.08
332	1.15
341	1.30
342	1.39
351	7.18
352	3.39
353	2.51
354	2.55
355	2.48
356	17.45
361	1.75
362	2.33
369	2.20
371	4.10
372	3.09
381	1.93
382	0.85
383	3.86
384	0.97
385	1.08
390	1.87

Source: Author own calculations from OECD's Database ITCS, Harmonized System (HS) Rev.1,1988-1996.

Chapter 5

ECONOMETRIC SPECIFICATIONS and RESULTS

In this chapter, my goal is to test some hypotheses generated from Ethier's (1982) model of international division of labor and from Feenstra and Hanson's (1997) model of outsourcing. The hypotheses put forward to explain the share of horizontal IIT and vertical IIT are tested using panel data techniques and data for US intermediate goods trade with 25 OECD countries, 28 industries, over the period of 1990-1996. In the first section of Chapter 5, I provide an overview of the dependent variable used in the econometric model. The second section of this chapter presents the regression models which I have chosen for the econometric analysis, after which I provide results.

5.1 Evidence of Intermediate Goods Trade in the US

This section presents some empirical evidence on intermediate goods trade. The OECD countries are very diverse in terms of per capita incomes. I divide countries into two groups: core countries and periphery countries based on the countries' per capita GDPs. Countries with income per capita above the certain level are core countries and countries with income per capita are less than that are periphery countries.[47] By doing this, I can analyze whether the evidence on intermediate goods trade indicates different behavior for each group. Overall, the data reveal a couple of important empirical facts. First, the degree of fragmentation has not been increased over this period despite the fact that other important studies indicate otherwise. Second, IIT in intermediate goods for all countries is consistently lower than that of in all manufactured goods trade. In addition,

[47] Based on this criteria, core countries are Australia, Austria, Belgium-Luxemburg, Canada, Switzerland, Germany, Denmark, Finland, France, The United Kingdom, Ireland, Iceland, Italy, Japan, Netherlands, Norway, New Zealand, Sweden, and periphery countries are Spain, Greece, Hungary, Mexico, Poland, Portugal, and Turkey.

the share of vertical IIT in total IIT account for a significant portion of total IIT in intermediates. Furthermore, the shares of vertical and horizontal IIT differ across countries and industries. Finally, geographical proximity plays an important role in explaining intermediates trade between the US and Mexico or Canada.

The data presented in Table 5.1 provide the value of individual countries' all manufactures trade, while Table 5.2 illustrates their intermediate goods trade with the US. Overall, Table 5.1 shows that the US total trade with OECD countries increased by 54 per cent while Table 5.2 indicates that intermediates trade increased by 59 per cent. Tables 5.3 and 5.4 illustrate the relative importance of individual countries' total manufacturing goods and intermediate goods trade, respectively. Table 5.4 shows that a significant portion of the US's intermediate goods trade occurred with Canada, about 33 percent, while Mexico accounted for about 14 per cent of the US's intermediate trade. These figures are consistent with our expectation that NAFTA and transportation costs play a significant role in explaining trade.

Table 5.5 provides some evidence on the importance of trade in intermediate goods relative to trade in manufacturing products. The share of intermediates trade slightly increased from 52 per cent to 54 percent over the period 1990 to 1996. Table 5.5 provides additional evidence regarding the periphery countries. In 1990, intermediate goods trade for periphery countries accounted for 60 percent of their total manufactures trade with the US. It drops to 54 per cent in 1996. However, the trend for core countries differed from that of periphery countries- the share of intermediate goods trade increased from 51 per cent in 1990 to 53 per cent in 1996.

Table 5.8 shows the shares of individual industries' intermediate goods trade in total intermediate goods trade for the US with other OECD countries. Intermediate goods trade is significant in industries such as Manufacture of transport equipment (ISIC 384), Manufacture of machinery, electric (ISIC 383), Manufacture of machinery, except electrical (ISIC 382), Manufacture of industrial chemicals (ISIC 351), and Manufacture of non-ferrous materials (ISIC 372). The figures for Manufacture of wearing apparel, except footwear (ISIC 322) are considerably lower. In addition, there is no observed intermediates trade in industries such as Manufacture of beverages (ISIC 313), Manufacture of tobacco (ISIC 314), and Manufacture of footwear, except rubber or plastic (ISIC 324). I expected that the apparel and footwear industries would be a good example of fragmentation of production. There are two possible reasons why the data show no intra-industry trade in these industries. First of all, it could be a result of how I selected the intermediate goods. However, a check on the trade data reveals that none of the bilateral flows at the 6-digit level of HS that belong to the apparel and footwear industries are omitted from the calculations. Second, it could be a result of the sample countries we selected to study. East Asian countries, such as China, Hong Kong, Taiwan, and etc, are the principal supplier of apparel and footwear products to the US. On the other hand, some of OECD countries such as Turkey and Mexico also have cheap labor. However, the trade data reveals that Asia is still the main supplier of these products to the US. Hence, it is not a surprise to see very low trade activity in these industries between the US and other OECD countries.

Table 5.9 shows IIT indices for total manufactured goods trade. At the more aggregated level, we observe that the share of IIT in all manufactured goods for the US is relatively stable during the period analyzed. In 1996, 48 per cent of the US trade with

Canada was IIT. In addition, Mexico also has a high level of IIT, 31 per cent in 1996. The high level of IIT with Canada and Mexico reflects a number of factors including their close proximity and high level of integration due to NAFTA. Apart from these two countries, the periphery countries have relatively low levels of IIT with the US except Mexico. This pattern of IIT is consistent with the new trade models where countries with similar incomes, tastes, and cultures engage in simultaneous exports and imports of similar products. However, some of the core countries such as Australia, New Zealand, and Japan have relatively little IIT. The low level of IIT with Australia and New Zealand can be explained by distance. The low level of IIT between the US and Japan may also be explained by the protectionist trade policies of Japan.

Table 5.10 shows the proportion of IIT in intermediate goods between the US and other OECD countries. The levels of IIT in Table 5.10 are very similar to that in Table 5.9. IIT in intermediate goods is still highest with Canada. Moreover, the core countries show relatively high level of IIT compared to those of the periphery countries. There is only one important difference. IIT in intermediates for all countries is consistently lower than that of in all manufactured goods trade. This result is inconsistent with the recent findings by Jones et al. (2002). They analyzed US trade with Mexico and Canada in televisions, automobile, apparel, aircraft, and semiconductors, over the period of 1992-1999. As in the case of televisions, automobiles, and apparel trade with Mexico, they found that these industries exhibit high level of IIT in parts while they have relatively low level of IIT in final products. Moreover, aircraft trade between the US and Canada also exhibits significant level of IIT in parts and engines while final goods have low level of IIT. The only exception is the semiconductors industry trade between the US and

Canada. The figures indicate that though intra-industry trade in the semiconductor industry as a whole is high, IIT in parts is relatively low.

Table 5.11 provides average Grubel-Lloyd indices of intermediates trade for each country after these are divided into horizontal and vertical trade according to the method described in section 4.1.3. Notice that the level of total IIT reported in Table 5.11 is slightly different from that in Table 5.10. The reason is that some trade flows at the 6-digit level of HS intermediate products are omitted because of the lack of quantity information. At the more aggregated level, vertical IIT in intermediates is consistently higher than horizontal IIT for both types of country groups and all individual countries. Table 5.11 also illustrates the difference between the country groups. Average shares of total, vertical, and horizontal IIT in intermediate goods for the core countries are higher than for the periphery countries although the relative significance of VIIT in the periphery countries' total IIT is slightly higher than that for the core countries. The only exception to this conclusion is Mexico. These results are consistent with the predictions of the two models presented in previous sections: the share of horizontal IIT will be greater when trading partners are similar in terms of economic development, incomes, market sizes, and tastes and cultures while the share of vertical IIT will be higher when trading partners have significant differences in capital/labor stocks, human capital stocks, market sizes, and etc.

In addition, there are substantial differences in IIT with the US across countries within the each country group. Table 5.11 shows total IIT and horizontal IIT indices for the US is the highest with its closest neighbor, Canada, about 40 per cent and 14 per cent, respectively while the UK has the highest vertical IIT with the US. Moreover, other relatively large countries, such as Germany and France, also have large shares of both types of IIT. It is further evident in Table 5.11 that distance also plays a role in explaining the shares of IIT with the US. The shares of vertical and horizontal IIT with Australia and New Zealand are considerably lower than the average shares of the core countries.

Table 5.12 presents the shares of total, vertical, and horizontal IIT in disaggregated manufacturing industries between the US and other OECD countries. The highest level of vertical IIT with all OECD countries is Manufacture of printing and publishing industry (ISIC 342) while the lowest is Manufacture of wearing apparel, except footwear industry (ISIC 322). The low level of vertical IIT in the apparel industry again implies that Asia is the still principal supplier of apparel products to the US. Moreover, Manufacture of machinery, except electrical industry (ISIC 382), Manufacture of machinery, electric industry (ISIC 383), Manufacture of transport equipment industry (ISIC 384), and Manufacture of plastic products industry (ISIC 356) show significant indexes of vertical IIT. The share of horizontal IIT for the US is highest in Manufacture of rubber products (ISIC 355) while it is the lowest in Manufacture of pottery, china and earthenware (ISIC 361).

5.2 Empirical Model

Balassa (1986) argues that the logistic function model is better than a linear or ordinary least squares (OLS) method when the dependent variable takes the value between zero and one. Estimation of a linear or log-linear function may have predicted values of the IIT index that lie outside the theoretically feasible range. On the other hand, Greenaway and Milner (1984) disagree with the appropriateness of this specification because they indicate that the goal should be estimation of determinants of intra-industry trade not prediction. Consequently, they implement OLS. Following Greenaway and

Milner (1984), I test the hypotheses presented in Chapter 4 with the following regression model:

$$y_{nti} = \alpha_n + \mu_t + \gamma_i + \beta_c x_{nt} + \delta_I x^*{}_{nti} + e_{nti} \qquad (5.1)$$

where: y_{nti} is total IIT, vertical IIT, or horizontal IIT indices, x_{nt} is the vector of country-specific explanatory variables with variation in dimensions n, t, $x^*{}_{nti}$ is the vector of industry-specific explanatory variables with variation in all three dimensions n, t, and i, α_n is the country effect, $n = 1.....,N$, μ_t is the time effect, $t = 1.....,T$, γ_i is the industry effect, $i = 1.....,I$; and e_{nti} is the usual white noise disturbance terms which is distributed randomly and independently.

From an econometric point of view, the specific effects, α_n, μ_t, and γ_i, can be treated as random variables (random effects model) or fixed parameters (fixed effects model).

5.2.1 The Fixed Effects Model

If α_n, μ_t, and γ_i are assumed to be fixed parameters to be estimated with $e_{nti} \sim IID\left(0, \sigma_\varepsilon^2\right)$, then (5.1) represents a three-way fixed effects error component model. The x_{nti} are assumed independent of the e_{nti} for all n, t, and i. We can obtain the fixed effects estimates of β_c and δ_I by performing the least squares dummy variable (LSDV) approach, also known as fixed effects least squares. Although the LSDV method described in Greene (1999, ch. 14) is applied to both time and group effects, it can be extended to include an industry effect as well. In order to explain the procedure that this dissertation employs in the estimation, we combine both country x_{nt} and industry specific variables x^*_{nti} into one vector of explanatory variables x_{nti}.[48] Equation (5.1) can be rewritten as

$$y_{nti} = \alpha_n + \mu_t + \gamma_i + \beta x_{nti} + \varepsilon_{nti} \tag{5.2}$$

where full N, T, and I effects are included, but the restrictions

$$\sum_n \alpha_n = \sum_t \mu_t = \sum_i \mu_i = 0 \tag{5.3}$$

are imposed. This restriction is imposed to avoid the dummy variable trap or perfect multicollinearity. Least squares estimates of the slopes are then obtained by regression of

$$\tilde{y}_{nti} = y_{nti} - \bar{y}_{nt.} - \bar{y}_{n.i} - \bar{y}_{.ti} + \hat{y}_{n..} + \hat{y}_{.t.} + \hat{y}_{..i} - \breve{y}_{...} \tag{5.4}$$

on

$$\tilde{x}_{nti} = x_{nti} - \bar{x}_{nt.} - \bar{x}_{n.i} - \bar{x}_{.ti} + \hat{x}_{n..} + \hat{x}_{.t.} + \hat{x}_{..i} - \breve{x}_{...} \tag{5.5}$$

where $\bar{y}_{nt.} = \frac{1}{I}\sum_{i=1}^{I} y_{nti}$, averaging over industries

$\bar{y}_{n.i} = \frac{1}{T}\sum_{t=1}^{T} y_{nti}$, averaging over time

$\bar{y}_{.ti} = \frac{1}{N}\sum_{n=1}^{N} y_{nti}$, averaging over countries

$\hat{y}_{n..} = \frac{1}{TI}\sum_{t=1}^{T}\sum_{i=1}^{I} y_{nti}$, averaging over time and industries

$\hat{y}_{.t.} = \frac{1}{NI}\sum_{n=1}^{N}\sum_{i=1}^{I} y_{nti}$, averaging over country and industries

$\hat{y}_{..i} = \frac{1}{NT}\sum_{n=1}^{N}\sum_{i=1}^{T} y_{nti}$, averaging over country and time

[48] Country-specific variables, such as average GDPs, are repeatedly inserted into all 28 industries. By doing so, all explanatory variables end up having three dimensions in the estimation.

$$\breve{y}_{...} = \frac{1}{NTI}\sum_{n=1}^{N}\sum_{t=1}^{T}\sum_{i=1}^{I} y_{nti}$$, averaging over country, time, and industries

and likewise for the vector of explanatory variables x_{nti}.

As suggested in the LSVD approach, this dissertation includes all necessary dummy variables to account for the three effects in an OLS. Equation (5.2) involves three sets of dummy variables in our case. That is, there are N sets of partner countries dummies, T sets of time dummies, and I sets of industry dummies. For example, the country dummy for $n = 1$ equals 1 whenever country 1 is the US's trading partner and 0 otherwise, the time dummy for $t = 1990$ is 1 only in the first time period and 0 otherwise, and finally the industry dummy for $i = 311$ is 1 whenever the ISIC industry code is 311 and 0 otherwise.

Once all these dummies have been specified, OLS estimates of β can be obtained. However, there has been one problem left in the estimation. At every observation, the country, time and industry-specific dummy variables sum to 1, so there are some redundant coefficients. In order to remove perfect collinearity between all three sets of dummies and a constant term, we could estimate (5.2) directly by OLS, including the constant term, but removing one column from each of the three sets of dummies. Alternatively, we could include all dummies and the constant, but restrict the sum of each the three dummy variables sets to sum to unity. In this dissertation, we implemented the first suggestion: include an overall constant and drop one column of country dummies, one column of time dummies, and one column of industry dummies. Then, the resulting regression model is,

$$y_{nti} = \delta + (\alpha_n - \alpha_1) + (\mu_t - \mu_1) + (\gamma_i - \gamma_1) + \beta x_{nti} + e_{nti} \qquad (5.6)$$

5.2.2 The Random Effects Model

If $\alpha_n \sim IID\left(0,\sigma_\xi^2\right)$, $\mu_t \sim IID\left(0,\sigma_\zeta^2\right)$, $\gamma_i \sim IID\left(0,\sigma_\eta^2\right)$, and $e_{nti} \sim IID\left(0,\sigma_e^2\right)$ are assumed to be independent of each other, then (5.2) represents a three-way random effects model with four independent error components. The x_{nti} are assumed independent of α_n, μ_t, γ_i and e_{nti} for all n, t, and i. In panel econometrics literature, empirical researchers often use the one-way random effects model developed by Balestra and Nerlove (1966) and the two-way random components model formulated by Fuller and Battese (1974). However, few works exist on three-way random components models. The first article that tackled the three error component model is Wallace and Hussain (1969). Their model has error components for cross-sectional units, time, and the interaction between cross-section units and time. They derived the inverse of the variance-covariance matrix, Ω, by 'trial, error, and generalization'. Ghosh (1976) generalizes the two-way error component model to an error structure that consists of four independent error components. He derives the variance-covariance matrix Ω by using the method initially developed by Wallace and Hussain (1969), and obtains best quadratic unbiased (BQU) estimators of the variance components. His procedure provides a Feasible Generalized Least Squares (FGLS) estimator of the regression coefficients.

Wansbeek and Kapteyn (1982) present a two-way error component model with an interaction variable. Likewise, with the interaction term, the model ended up having three error components. They used a spectral decomposition technique (i.e., the eigenvalues and eigenvectors) to derive the variance covariance matrix of the errors. They argue that the spectral decomposition of the error variance-covariance matrix provides more insight into its structure and its application reduces the computation burden drastically. Because of the usefulness of the spectral decomposition technique, Baltagi (1987) uses the results of Wansbeek and Kapteyn (1982) to derive the inverse of the variance-covariance matrix of the three-way error component model with four independent error components originally developed by Ghosh (1976).

In this dissertation, I follow the method described in Baltagi(1987) to obtain the FGLS estimator of (5.2). Following Baltagi (1987), this dissertation utilizes a three-way error component model for the disturbances,

$$e_{nti} = \xi_t + \zeta_n + \eta_i + \varepsilon_{nti} \tag{5.7}$$

where $t = 1.......T$, $N = 1.......N$, and $I = 1.......I$. ξ_t, ζ_n, η_i, and ε_{nti} are random components of the random error e_{nti}. The components are independent of each other, with zero means and variances: $\sigma_\xi^2, \sigma_\zeta^2, \sigma_\eta^2$, and σ_ε^2, respectively. The variance-covariance matrix Ω can be expressed as:

$$\Omega = \sigma_\varepsilon^2 (I_T \otimes I_N \otimes I_I) + \sigma_\xi^2 (I_T \otimes J_N \otimes J_I) + \sigma_\zeta^2 (J_T \otimes I_N \otimes J_I) + \sigma_\eta^2 (J_T \otimes J_N \otimes I_I) \tag{5.8}$$

where $\otimes$ is the kronecker product operator, I is an identity matrix and J is a matrix with unit elements only. In order to find the spectral decomposition, Baltagi (1987) introduces some notation. Let $\bar{J}_N = \frac{1}{N} J_N, \bar{J}_T = \frac{1}{T} J_T, \bar{J}_I = \frac{1}{I} J_I$, $E_N = I_N - \bar{J}_N$,

$E_T = I_T - \bar{J}_T$, and $E_I = I_I - \bar{J}_T$. In the next step, the I 's are replaced by $E_N + \bar{J}_N$, $E_T + \bar{J}_T$, and $E_I + \bar{J}_T$ and J 's replaced by $N\bar{J}_N$, $T\bar{J}_T$, and $I\bar{J}_I$ and collect terms with same matrices. Note that the E 's and $\bar{J}$'s are idempotent, and that multiplication of both equals zero. With the help of these specifications, the following spectral decomposition is obtained:

$$\Omega = \sum_{i=1}^{5} \lambda_i V_i \tag{5.9}$$

where λ 's are eigenvalues (i.e. distinct characteristics roots) of the variance covariance matrix Ω and V 's are the corresponding matrices of eigenprojectors.[49] The eigenvalues and eigenprojectors are provided in Table 5.14. Each V_i is symmetric and idempotent with its rank equal to its trace. In addition, the V_i 's are pairwise orthogonal and sum to the identity matrix. The advantages of this spectral decomposition is that

$$\Omega^r = \sum_{i=1}^{5} \lambda_i^{\,r} V_i \tag{5.10}$$

where r is an arbitrary scalar so that

$$\sigma_\varepsilon \Omega^{-1/2} = \sum_{i=1}^{5} \left(\sigma_\varepsilon \big/ \sqrt{\lambda_i}\right) V_i \tag{5.11}$$

and the typical element of $\hat{y}_{nti} = \sigma_\varepsilon \Omega^{-1/2} y_{nti}$ is given by

$$\hat{y}_{nti} - \theta_1 \bar{y}_{.t.} - \theta_2 \bar{y}_{n..} - \theta_3 \bar{y}_{..i} + \theta_4 \breve{y}_{...} \tag{5.12}$$

where $\theta_i = 1 - \left(\sigma_\varepsilon \big/ \sqrt{\lambda_{i+1}}\right)$ for $i = 1,2,3$ and $\theta_4 = \theta_1 + \theta_2 + \theta_3 - 1 + \left(\sigma_\varepsilon \big/ \sqrt{\lambda_5}\right)$ for $i = 4$. A dot indicates that observations on y have been averaged over that classification. As a result, FGLS or random effects model coefficients can be obtained as OLS of $\hat{y}_{nti}$ on $\hat{x}_{nti}$, where $\hat{x}_{nti} = \sigma_\varepsilon \Omega^{-1/2} x_{nti}$. The best quadratic unbiased (BGQ) estimators of the variance components arise naturally from the fact that $V_i e \sim \left(0, \lambda_i V_i\right)$. Thus,

$$\lambda_i = \frac{e' V_i e}{tr\left(V_i\right)} \tag{5.13}$$

[49] See Wansbeek and Kapteyn (1982) for detail derivation of Ω

is the BQU estimator of λ_i for $i = 1,2,3,4,$ and λ_5 has no unbiased estimator. There are two alternatives for obtaining the BQU estimators of the variance components σ 's. Using one-to-one correspondence provided in Table 5.14, we may obtain feasible estimates of σ 's by replacing the true disturbances by OLS residuals or within residuals obtained by the regression of (5.6). Some argue that substituting OLS or within residuals instead of the true disturbances in (5.12) introduces bias in the corresponding estimates of the variance components. Because of these concerns, one can apply the method initially developed by Swamy and Arora (1972). They suggest running OLS and estimating the variance components from the corresponding mean square errors of these regressions.[50] To summarize the method I apply in this dissertation, I first regressed of y_{nti} on x_{nti} to obtain OLS residuals. Then using these residuals, I transformed the dependent variables and explanatory variables according to equation (5.12). Finally, FGLS is computed by the regression of $\hat{y}_{nti}$ on $\hat{x}_{nti}$, where $\hat{x}_{nti}$ includes the constant term. This provides efficient estimates of the coefficients of the model. Considering the computational warning made by Baltagi (1995), whenever the results indicate negative estimates of σ 's, then I have set corresponding $\theta's$ equal to zero during the transformation process.

5.3 Estimation Results

The data set used in the estimation is a panel data set in three dimensions: the trading partner dimension, the industry dimension, and the time dimension. Thus, the standard panel data analysis technique will be used. As suggested earlier, the methods described above require balanced panel data. However, the data in this dissertation have some missing observations either at the country or at the industry level or at the time

[50] See page 35 in Baltagi(1995)

level. The data availability of country-specific and industry-specific variables is shown in Table 4.5 and Table 4.6, respectively. In order to have a balanced panel, I drop the tariff variable from the estimation since data on tariffs are not available for the majority of countries. Second, I have used differences in the number of researchers, $DHUMCAP2_{hft}$, as a proxy for differences in human capital endowments between the home and foreign country because Mexico does not have education attainment data, proxied by $DHUMCAP1_{hft}$. Furthermore, I have filled in missing values with industry means and then filled in remaining missing values with country means. Finally, I delete countries with missing data from the estimation. In the end, the data set in this dissertation has 15 countries, 25 industries and cover the period of 1990-1996.[51] In addition, there are some zero observations on IIT indices. To avoid selection bias, I have chosen to set zero observations to 0.01 in these regressions.

Before determining the model specification I assess the problems of multicollinearity, heteroskedasticity, and serial correlation. Some explanatory variables are computed from other variables in the regression equation and some explanatory variables such as differences in GDP may reflect differences in other variables such as in physical capital endowments or difference in human capital endowments. There are a number of methods suggested to detect multicollinearity in the data. As suggested in Greene (1997), if we regress each of the explanatory variables against on all the remaining explanatory variables including a constant, we can obtain a measure of the goodness of fit by calculating the value of R^2 in each case. If any of these R^2's is close

[51] Remaining countries are Austria, Canada, Denmark, Finland, The United Kingdom, Ireland, Italy, Netherlands, Norway, New Zealand, Spain, Greece, Mexico, Portugal, and Turkey. Deleted ISIC industries are 311, 313, and 324.

to unity, then we should be concerned about multicollinearity. On the basis of this criterion, multicollinearity in this data exists when pooled OLS is employed. In the case of fixed effects models, I have added dummy variables for the country, time, and industry points before performing the collinearity diagnostics. A multicollinearity problem still exist in this case. The diagnostics of multicolllineraity for the random effects model indicate similar results when we employed the same procedure to the transformed data according to Equation (5.12). The disadvantage of this criterion is that it is too strong considering that some multicollinearity almost always exists in the data. Since there is no clear consensus what degree of multicollinearity will cease to be harmful to the estimates of regression, I have only removed variables that show a perfect collinearity. These are $DGDP_{hft}$, a proxy for the differences in market sizes, and $AEST_{jhft}$, a proxy for market structure. When the explanatory variables are highly correlated, small changes (adding or dropping a variable) in the data can produce wide swings in the parameter estimates. Although the remaining explanatory variables still has high degree of collinearity, to confirm that multicollinearity does not cause wide swings in my econometric results, I have also tested several models and found similar results.

The fixed effects model and the random effects model given by (5.6) and (5.12) assume that the regression disturbances are homoskedastic with the same variance across countries, industries, and time. If this assumption is violated, then the estimates of the regression coefficients will be consistent but they are no longer efficient. Hetereskadasticity is a problem often encountered in cross-section data. There are several methods of testing for the presence of heteroskedasticity. The most commonly used is White's test, which is computed by finding $(NT)R^2$ from a regression of the squared OLS residual on all of the explanatory variables including a constant. This statistic is asymptotically distributed as chi-squared with $k-1$ degrees of freedom, excluding the constant term. I have rejected the hypothesis of homoskedasticity for the pooled OLS and fixed effects model on the basis of White's test whereas failed to reject for the random effects model. Various solutions are suggested for the hetereskadasticity problem. In this dissertation, the White's robust variance-covariance matrix is used to generate the corrected standard errors and t-statistics.[52]

Furthermore, the fixed effects model and random effects model given by (5.6) and (5.12) assume that there is no correlation across countries, industries, and time. Generally, serially correlation is more suspected in time series than in cross-section data. Hence, we may continue to assume that observations are uncorrelated across countries and industries because it is unlikely that these countries are tied to each other. On the other hand, for instance, an unobserved shock in one period could affect the behavioral relationship for at least the next a couple of years. Thus, ignoring serial correlation will lead to consistent but inefficient estimates of the regression coefficients. The most-often used test for serial correlation is called the Durbin-Watson test. The idea behind the Durbin-Watson test is very simple: if the true disturbances are serially correlated, this will be revealed through the autocorrelations of the OLS residuals. Following Baltagi (1995), I have employed a slightly modified version of the Durbin-Watson statistic for pooled OLS, fixed effects model, and random effects model:

$$d = \sum_{i=1}^{N}\sum_{t=1}^{T}\left(e_{it} - e_{i,t-1}\right)^2 \Big/ \sum_{i=1}^{N}\sum_{t=1}^{T} e_{it}^2 \tag{5.14}$$

[52] SAS can automatically generate the robust variance-covariance matrix by using the ACOV option.

This test is computationally simple and requires only OLS or within residuals or FGLS residuals, e_{it}. Under the null hypothesis of no correlation, the Durbin-Watson statistics for all three cases fall in the inconclusive region though for some cases it is very close to the upper bound of the tabulated values. The data set in this dissertation covers only 7 years so ignoring correlation across time seems reasonable approach in the estimations. Thus, I have decided not to conduct further analysis of serial correlation in my estimations.

Table 5.16 presents results for pooled OLS of equation (5.2) with IIT indices as dependent variables.[53] No country, industry, or time effects are included. As can be seen from this table, we first observe the overall fit of the estimated model is fairly good in regressions of total and vertical IIT indices, 63 per cent and 56 per cent, respectively. However, the R^2 obtained in the regression of horizontal IIT is considerably lower, 26 per cent. In that sense, we are able to explain less of the observed pattern of horizontal IIT with the predictions derived from Ethier's model. The reason probably originates from the fact that there are more zero observations on horizontal IIT than on vertical IIT. Second, the estimated coefficients are almost the same for total and vertical IIT with the significance of $DIST_{hf}$ and the sign of $AGDP_{hft}$ as the only exceptions. This outcome is not surprising since VIIT accounts for most of TIIT. Differences are greater, however, between vertical and horizontal IIT. As evident in Table 5.16, the determinants of vertical and horizontal IITR are not the same, because signs and significance of variables differ.

[53] In the empirical analysis, the explanatory variables are expressed in natural logarithms, with the exception of PDI_{jhft}. Furthermore, the predicted signs of the explanatory variables are provided in Table 5.15. All estimations are performed in SAS 8.2.

Furthermore, the estimated coefficients for HIIT are less precise than those for vertical IIT.

Beginning with industry-specific variables, the production differentiation index does not appear to be significant for either vertical and horizontal IIT though the sign for vertical IIT is consistent with our prediction. Economies of scale turn out to have a negative and statistically significant coefficient for vertical IIT, confirming our predictions. For horizontal IIT, scale economies do not appear to be significant but its sign is consistent with the prediction. Finally, there is a strong evidence that dissimilarities in capital endowments at the industry level have a positive effect on vertical IIT. This is in contrast with Feenstra and Hanson's predictions that any reduction in physical capital differences between two country lead to an increase in vertical trade. A possible interpretation of this result as follows. The outsourcing model already assumed that there are large differences in capital stocks between home and foreign country. Consequently, the model predicts that vertical trade between the two should account for most of trade in intermediates. In that sense, the result is consistent with the outsourcing model. However, when we estimate for horizontal IIT, dissimilarities in capital stocks are statistically insignificant and its sign is inconsistent with the prediction of Ethier's model.

Turning now to the country-specific variables, average market sizes between two economies, $AGDP_{hft}$, does not assert any significant effect on vertical IIT. On the other hand, $AGDP_{hft}$ has a negative influence on the horizontal IIT, contrary to the prediction of Ethier's model. The FDI variable, $RFDI_{hft}$, turns out to have a positive and statistically significant influence on vertical IIT, consistent with the prediction of

Feenstra and Hanson's model. I consider this to be a remarkable result since most international economists suggest that the majority of US multinationals in the OECD countries, especially in Europe, locate their establishments to avoid the costly trade barriers. This result suggests that the use of affiliates in the OECD countries as a base for fragmentation is also becoming an important factor. On the other hand, the FDI variable also has a positive influence on horizontal IIT. Initially, we expect that trade changes in horizontally differentiated intermediate goods due to FDI should be small. This finding clearly deserves further research.

Furthermore, there is some evidence that differences in human capital endowments have a statistically negative effect on horizontal IIT. This finding is clearly in line with the prediction of Ethier's model. Vertical IIT, on the other hand, appears to be simulated by such differences between countries, although never significant. This finding is also consistent with the prediction of Feenstra and Hanson's model. Finally, the results indicate that the geographical distance has a significant, negative effect on horizontal IIT, whereas it has no significant effect on vertical IIT, though its negative sign is consistent the prediction of the hypothesis. The results are, however, inconsistent with the view that the cost of transportation matters most for vertical IIT than for horizontal IIT.

Table 5.17-5.20 present results of the estimation of (5.6) using fixed effects panel data regressions techniques. All variables in the estimation equations can vary across partner countries, across industries, and across years. The question is then whether we should pool the data across partner countries, or across industries, or across years. To answer this question, I have estimated four alternative specifications regarding inclusion of fixed effects: one-way FEM (country effects), two-way FEM (country and time effects), two-way FEM (country-industry), and three-way FEM (country-industry-time). One can test the joint significance of these dummy variables by employing Chow's test to determine whether we should pool the data or not:

$$H_0 : \alpha_1 = ... = \alpha_{n-1} = 0,\ \mu_1 = ... = \mu_{t-1} = 0, \text{ and } \gamma_1 = ... = \gamma_{i-1} = 0$$

Under the null hypothesis, the efficient estimator is pooled OLS. The restricted residual sums of squares (RRSS) is that of pooled OLS with only a single overall constant term and the unrestricted residual sums of squares is that from the within regression in (5.7). Then, the F ratio used for the test is:

$$F = \frac{(RRSS - URSS)/N + T + I - 3}{URSS/(NTI - N - T - I - K + 3)} \xrightarrow{H_0} F_{(N+T+I-3),(NTI-N-T-I-K+3)} \quad (5.15)$$

where K is the number of explanatory variables (excluding the dummies, but including the constant term).[54] Based on the OLS residuals, the calculated test-statistics in all three cases, reported in Table 5.20, strongly reject the null hypotheses that there are no specific effects, and hence the specifications including all three effects should be preferred, i.e three-way FEM, over the simple pooled OLS.

There are, however, doubts about the three-way FEM in that most of the country and industry dummies and all the time dummies are insignificant in all estimations. The doubts regarding the three-way FEM further increased because most of the explanatory variables became insignificant in this specification, except $DVAEST_{jhft}$ and $DIST_{hf}$ for vertical IIT. In addition, R^2 values barely change when I put the dummies into estimations compared to the results of OLS. Consequently, I estimate three alternative

[54] Harris and Matyas (1998)

specifications of (5.6). Table 5.17 presents results of the estimation with only countries dummies, i.e one-way FEM. Chow tests fail to reject the hypothesis of identical country-specific effects in all cases. When we estimate (5.6) with country and time dummies reported in Table 5.18, the test clearly rejects pooling across countries and years in all estimations. Finally, Table 5.19 presents results including country and industry effects. The tests results indicate that we should pool the data across countries and industries for the vertical IIT. However, the hypothesis of identical country-specific and industry-specific effects can be rejected in the case of the horizontal IIT. [55]

Furthermore, the results in Table 5.20 show that some industry dummies are statistically significant while others are not. These results may suggest that some industries, such as the textile industry (ISIC 321), are more likely subject to fragmentation of production than others such as the rubber industry (ISIC 355). In addition, the significance of these dummies varies across each type of IIT. For example, the furniture industry (ISIC 332) has significant dummies for horizontal IIT while it does not have for vertical IIT. The insignificance of the furniture industry dummy for vertical IIT may suggest that vertical type fragmentation is less likely to be observed in furniture goods because of the fact that it is quite costly to transport the processed intermediates across borders due to bulkiness of these goods. Turning to the estimates of the explanatory variables, $DVAEST_{jhft}$ for vertical IIT seems to be one of the most robust and consistent variables in all of the four specifications.

[55] The degrees of freedom for the Chow tests are $((N-1),(NT-N-K+1))$ for one-way FEM, $((N+T-2),(NT-N-T-K+2))$ for two-way FEM (country-time), and $((N+I-2),(NI-N-I-K+2))$ for two-way FEM (country-industry). See Baltagi (1995).

The alternative to FEM is a random effects model (REM). Consequently, the question of model selection naturally arises. In the REM, the x_{nti} are assumed independent of α_n, μ_t, γ_i and ε_{nti} for all n, t, and i, i.e., $E(e_{nti} / x_{nti}) = 0$. This is important given that the disturbances contain country, or industry, or time effects which are unobserved and may be correlated with x_{nti}. In this case, $E(e_{nti} / x_{nti}) \neq 0$ and the GLS estimator of the REM, $\hat{\beta}_{REM}$, becomes biased and inconsistent for β. However, the within transformation in (5.6) wipes out these specific effects and leaves the within estimator $\hat{\beta}_{FEM}$ unbiased and consistent for β. The FEM is costly in terms of degrees of freedom lost. In that sense, the random effects model has some advantages in a wide longitudinal data set. On the other hand, we are not sure whether all three specific effects are uncorrelated with the other regressors, as is assumed in the random effects model.

To decide whether the fixed effects model or random effects model are appropriate, Hausman (1978) developed a test to compare $\hat{\beta}_{REM}$ and $\hat{\beta}_{FEM}$. Under the null hypothesis of no correlation $H_0 : E(e_{nti} / x_{nti}) = 0$, both OLS estimates of LSDV (FEM) and FGLS of REM are consistent but OLS is inefficient, whereas under the alternative, OLS is consistent but FGLS is not. Therefore, we can base a test around the difference: $\hat{q}_1 = \hat{\beta}_{REM} - \hat{\beta}_{FEM}$. Under the null hypothesis, $H_0 : p \lim \hat{q}_1 = 0$ and $\operatorname{cov}(\hat{q}_1, \hat{\beta}_{REM})$, the variance of $\hat{q}_1$ will be equal to $\operatorname{var}(\hat{q}_1) = \operatorname{var}(\hat{\beta}_{FEM}) - \operatorname{var}(\hat{\beta}_{REM})$. The Hausman test statistic is then given by

$$m_1 = \hat{q}_1 [\operatorname{var}(\hat{q}_1)]^{-1} \hat{q}_1 \tag{5.16}$$

Under the null hypothesis, m_1 is asymptotically distributed as chi-squared with K degrees of freedom.

The test statistic m_1 is described for the one-way error component model. The question is whether we can extend to the two-way or three-way error component model or not. For the two-way model, Baltagi (1995) suggests that m_1 can still be based on the difference between the fixed effects estimator and the random effects estimator. Similarly, we can compare two estimators for the three-way model, one which assumes that α_n, μ_t, and γ_i are fixed and another that assumes α_n, μ_t, and γ_i are random such that $E(\alpha_n / x_{nti}) = E(\mu_t / x_{nti}) = E(\gamma_i / x_{nti}) = 0$. This test is based upon $\hat{\beta}_{REM} - \hat{\beta}_{FEM}$. In the calculations of the Hausman statistic, the constant term was excluded from both the three-way FEM and the three-way REM estimations since the test is based on the slope coefficients only. Large values of the test statistic argue in favor of the FEM specification. The resulting Hausman χ^2_7 test statistics is $m_1 = 7.12$ for vertical IIT and 2.60 for horizontal IIT. The 5 per cent and 1 per cent critical values from chi-squared distribution with 7 degrees of freedom are 14.07 and 18.48. Hence, the REM is preferred over the FEM. [56]

Table 5.21 presents the results from the random effects model of equation (5.12). The overall fit drops drastically compare to the FEM, a phenomenon often encountered in the case of REM. Comparing the three-way FEM estimates and three-way REM estimates, utilizing the REM does appear to significantly improve the significance of parameter estimates. The efficiency of REM estimates further confirms the fact that the REM is the right specification to analyze the determinants of intra-industry trade in

[56] We may also employ a Lagrange multiplier (LM) test, developed by Breusch and Pagan (1980) to test whether there are country, industry, and time effects for the random two-way error component model. Based on this test, we may decide whether the random effects model is appropriate to our problem. The data in this dissertation, however, involve three dimensions. Since this LM test is limited to two dimensions, I have decided not to conduct the LM test.

intermediates. On the other hand, the REM estimates are quite similar to the simple pooled OLS model's estimates, with several exceptions. First of all, the sign of economies of scale for horizontal IIT is no longer inconsistent with the prediction of Ethier's model though it is still not significant. In addition, dissimilarities in capital endowments at industry level no longer have a significant impact on vertical IIT. Finally, average market size between two countries, $AGDP_{hft}$, does now assert a significant effect on vertical IIT. This result is inconsistent with the expectation of the Feenstra and Hanson's model. It also contradicts the recent findings of Hummels et al. (1998) where they found that large countries have considerably smaller share of vertical specialized based trade in total trade. On the other hand, $AGDP_{hft}$, has a significant positive effect on the horizontal IIT, which is now in line with the prediction of Ethier's model. Overall, the REM results confirm the fact that the determinants of vertical and horizontal IIT indeed differ. Economies of scale and foreign direct investment are the main determinants of vertical IIT, while the country-specific factors contribute most of the explanatory power behind the horizontal IIT.

Comparing these results to those in Harrigan (1995) reveals several interesting differences. Harrigan (1995) used the Helpman and Krugman's (1985) model to derive a gravity-type equation to study the volume of trade in differentiated intermediates. This equation implies that the bilateral volume of trade in manufactured goods depends on the importing country's production structure. Harrigan (1995) estimated the equation for 9 different industries using 2-digit trade data for 21 OECD countries in 1995. He argued that monopolistic competition model could explain the bilateral trade in manufactured intermediates among OECD countries because they are similar in terms of production technologies and factor endowments. The empirical results indicate that the country's production structure does not affect its intermediates imports. Consequently, Harrigan (1995) regressed the dependent variable on the importing country factor endowments, capital, land, and two types of labor. The estimation revealed that the volume of bilateral intermediates trade is explained by factor endowments, which is in contrast with his expectations. Although Harrigan (1995) does not use the intra-industry trade index as a dependent variable in his regressions, we can still compare his findings with the estimates of the three-way REM found in this dissertation. The results show that the production structure indeed matters for total IIT in intermediates while differences in factor endowments proxied by $DPCAP_{jhft}$ and $DHUMCAP2_{hft}$ do not have an impact. In that sense, the results in this dissertation are inconsistent with his findings and they are in line with his predictions. However when we disentangle the trade in intermediates into vertical and horizontal, differences in factor endowments matter for horizontal IIT.

Gorg (2000) studies the determinants of inward processing trade (IPT) in the European Union at the sector level, which is used as a proxy for fragmentation in trade. His results indicate that US IPT in the EU is positively affected by comparative advantage. Furthermore, his results suggest that US FDI has a significant positive effect on the level of US IPT in the EU. In addition, the index of relative labor costs variable has a positive effect on US IPT in the EU. Comparing his findings with the results reported in Table 5.21, it appears that the signs and significance of $RFDI_{hft}$ for vertical

IIT are consistent with his findings while differences in factor endowments proxied by $DPCAP_{jhft}$ and $DHUMCAP2_{hft}$ are not.[57]

[57] I have compared his results to my results for only VIIT because IPT could be a good proxy for vertical trade in intermediates.

Table 5.1 The Value of Total Manufacturing Goods Trade between the US and OECD Countries				
	1990	1992	1994	1996
All Countries	482,978,428	524,845,474	639,667,023	744,146,936
Core	433,694,438	459,856,548	551,564,490	629,820,234
Periphery	49,283,990	64,988,926	88,102,533	114,326,702
Core				
Australia	8,019,033	7,462,147	7,985,674	10,171,240
Austria	1,326,287	1,672,069	2,390,563	3,334,601
Belgium	10,989,417	10,840,062	13,830,768	14,999,143
Canada	145,930,754	156,721,203	204,074,576	237,304,085
Switzerland	7,204,596	7,416,555	9,517,677	13,193,520
Germany	40,252,217	44,649,318	46,043,524	55,882,585
Denmark	1,675,578	1,942,249	2,169,902	2,575,388
Finland	1,297,116	1,087,881	1,779,315	2,748,894
France	22,290,709	25,157,793	25,867,313	27,748,124
United Kingdom	35,672,846	35,566,422	40,446,407	49,315,872
Ireland	3,049,175	3,461,490	4,626,809	6,678,490
Iceland	12,371	21,782	23,784	33,800
Italy	16,590,137	17,217,247	17,568,102	22,558,351
Japan	118,284,838	124,661,052	152,003,039	154,935,781
Netherlands	12,599,019	13,703,082	14,274,064	16,314,500
Norway	1,031,939	1,068,377	1,272,423	1,537,684
New Zealand	1,173,756	1,230,923	1,401,412	1,539,571
Sweden	6,294,652	5,976,899	6,289,139	8,948,607
Periphery				
Spain	4,863,568	4,718,404	4,871,213	6,136,603
Greece	460,008	310,505	362,680	364,910
Hungary	158,746	197,552	415,061	572,814
Mexico	42,132,890	57,589,688	79,896,527	104,370,793
Poland	125,717	371,065	438,765	563,160
Portugal	683,608	663,384	844,454	978,416
Turkey	859,451	1,138,326	1,273,830	1,340,003

Note: Using equation (4.5), we obtained the total trade at the 6-digit level of HS product level for all products, and thereafter summed over all products compromising a particular industry. The economy-wide measure of total trade for each country is then obtained by aggregation of all ISIC (Rev.2) industries. Values are in thousands of $US.
Source: Author own calculations from OECD's Database ITCS, Harmonized System (HS) Rev.1,1988-1996.

Table 5.2 The Value of Intermediates Trade between the US and OECD Countries				
	1990	1992	1994	1996
All Countries	250,602,727	270,884,129	334,423,749	398,614,871
Core	221,005,096	232,328,626	283,911,953	336,692,336
Periphery	29,597,631	38,555,504	50,511,796	61,922,535
Core				
Australia	3,927,448	3,797,000	4,438,922	5,638,018
Austria	745,378	1,031,123	1,445,973	2,316,426
Belgium	6,384,117	6,842,342	7,921,856	9,407,220
Canada	85,125,294	88,758,204	112,372,821	132,835,953
Switzerland	4,165,735	4,005,332	5,595,670	7,830,881
Germany	19,865,689	20,617,976	23,407,492	28,846,400
Denmark	642,678	752,029	915,470	1,150,629
Finland	772,331	700,882	1,102,616	1,642,430
France	12,848,737	14,077,909	15,061,024	16,141,460
United Kingdom	18,553,294	19,626,182	22,765,709	27,370,572
Ireland	1,942,168	2,120,706	2,786,473	4,457,484
Iceland	7,225	15,912	10,231	16,980
Italy	7,198,925	7,346,367	8,121,621	10,155,354
Japan	49,356,320	52,431,264	66,993,976	74,856,031
Netherlands	6,184,900	6,928,651	7,057,783	8,727,363
Norway	536,511	555,685	709,868	855,327
New Zealand	329,833	336,337	553,266	678,236
Sweden	2,418,514	2,384,726	2,651,182	3,765,574
Periphery				
Spain	2,061,611	2,128,112	2,258,247	3,139,031
Greece	126,571	112,536	113,780	146,372
Hungary	113,989	102,854	232,787	269,882
Mexico	26,408,931	35,254,899	46,689,799	57,026,904
Poland	46,581	127,116	176,878	262,760
Portugal	2,061,611	2,128,112	2,258,247	3,139,031
Turkey	126,571	112,536	113,780	146,372

Note: Using equation (4.5), we obtained the total trade at the 6-digit level of HS product level for intermediate products, and thereafter summed over all products compromising a particular industry. The economy-wide measure of total trade for each country is then obtained by aggregation of all ISIC (Rev.2) industries. Values are in thousands of $US.
Source: Author own calculations from OECD's Database ITCS, Harmonized System (HS) Rev.1,1988-1996.

Table 5.3 The Relative Importance of Individual Countries' All Manufactures Trade in the US All Manufactures Trade with OECD Countries				
	1990	1992	1994	1996
All Countries	1	1	1	1
Core	0.89796	0.87618	0.86227	0.84637
Periphery	0.10204	0.12382	0.13773	0.15363
Core				
Australia	0.01660	0.01422	0.01248	0.01367
Austria	0.00275	0.00319	0.00374	0.00448
Belgium	0.02275	0.02065	0.02162	0.02016
Canada	0.30215	0.29860	0.31903	0.31889
Switzerland	0.01492	0.01413	0.01488	0.01773
Germany	0.08334	0.08507	0.07198	0.07510
Denmark	0.00347	0.00370	0.00339	0.00346
Finland	0.00269	0.00207	0.00278	0.00369
France	0.04615	0.04793	0.04044	0.03729
United Kingdom	0.07386	0.06777	0.06323	0.06627
Ireland	0.00631	0.00660	0.00723	0.00897
Iceland	0.00003	0.00004	0.00004	0.00005
Italy	0.03435	0.03280	0.02746	0.03031
Japan	0.24491	0.23752	0.23763	0.20821
Netherlands	0.02609	0.02611	0.02231	0.02192
Norway	0.00214	0.00204	0.00199	0.00207
New Zealand	0.00243	0.00235	0.00219	0.00207
Sweden	0.01303	0.01139	0.00983	0.01203
Periphery				
Spain	0.01007	0.00899	0.00762	0.00825
Greece	0.00095	0.00059	0.00057	0.00049
Hungary	0.00033	0.00038	0.00065	0.00077
Mexico	0.08724	0.10973	0.12490	0.14026
Poland	0.00026	0.00071	0.00069	0.00076
Portugal	0.00142	0.00126	0.00132	0.00131
Turkey	0.00178	0.00217	0.00199	0.00180

Note: Individual countries' all manufactures trade reported in Table 5.1 is divided by the US total trade with all OECD countries reported in Table 5.1.
Source: Author own calculations from OECD's Database ITCS, Harmonized System (HS) Rev.1,1988-1996.

Table 5.4 The Relative Importance of Individual Countries' Intermediates Trade in the US Intermediates Trade with OECD Countries				
	1990	1992	1994	1996
All Countries	1	1	1	1
Core	0.88189	0.85767	0.84896	0.84466
Periphery	0.11811	0.14233	0.15104	0.15534
Core				
Australia	0.01567	0.01402	0.01327	0.01414
Austria	0.00297	0.00381	0.00432	0.00581
Belgium	0.02548	0.02526	0.02369	0.02360
Canada	0.33968	0.32766	0.33602	0.33324
Switzerland	0.01662	0.01479	0.01673	0.01965
Germany	0.07927	0.07611	0.06999	0.07237
Denmark	0.00256	0.00278	0.00274	0.00289
Finland	0.00308	0.00259	0.00330	0.00412
France	0.05127	0.05197	0.04504	0.04049
United Kingdom	0.07403	0.07245	0.06807	0.06866
Ireland	0.00775	0.00783	0.00833	0.01118
Iceland	0.00003	0.00006	0.00003	0.00004
Italy	0.02873	0.02712	0.02429	0.02548
Japan	0.19695	0.19356	0.20033	0.18779
Netherlands	0.02468	0.02558	0.02110	0.02189
Norway	0.00214	0.00205	0.00212	0.00215
New Zealand	0.00132	0.00124	0.00165	0.00170
Sweden	0.00965	0.00880	0.00793	0.00945
Periphery				
Spain	0.00823	0.00786	0.00675	0.00787
Greece	0.00051	0.00042	0.00034	0.00037
Hungary	0.00045	0.00038	0.00070	0.00068
Mexico	0.10538	0.13015	0.13961	0.14306
Poland	0.00019	0.00047	0.00053	0.00066
Portugal	0.00121	0.00111	0.00083	0.00113
Turkey	0.00214	0.00195	0.00228	0.00158

Note: Individual countries' intermediates trade reported in Table 5.2 is divided by the US intermediates trade with all OECD countries reported in Table 5.2.
Source: Author own calculations from OECD's Database ITCS, Harmonized System (HS) Rev.1,1988-1996.

Table 5.5 The Share of Intermediates Trade in all Manufactures Trade by Country				
	1990	1992	1994	1996
All Countries	0.52	0.52	0.52	0.54
Core	0.51	0.51	0.51	0.53
Periphery	0.60	0.59	0.57	0.54
Core				
Australia	0.49	0.51	0.56	0.55
Austria	0.56	0.62	0.60	0.69
Belgium	0.58	0.63	0.57	0.63
Canada	0.58	0.57	0.55	0.56
Switzerland	0.58	0.54	0.59	0.59
Germany	0.49	0.46	0.51	0.52
Denmark	0.38	0.39	0.42	0.45
Finland	0.60	0.64	0.62	0.60
France	0.58	0.56	0.58	0.58
United Kingdom	0.52	0.55	0.56	0.56
Ireland	0.64	0.61	0.60	0.67
Iceland	0.58	0.73	0.43	0.50
Italy	0.43	0.43	0.46	0.45
Japan	0.42	0.42	0.44	0.48
Netherlands	0.49	0.51	0.49	0.53
Norway	0.52	0.52	0.56	0.56
New Zealand	0.28	0.27	0.39	0.44
Sweden	0.38	0.40	0.42	0.42
Periphery				
Spain	0.42	0.45	0.46	0.51
Greece	0.28	0.36	0.31	0.40
Hungary	0.72	0.52	0.56	0.47
Mexico	0.63	0.61	0.58	0.55
Poland	0.37	0.34	0.40	0.47
Portugal	0.45	0.45	0.33	0.46
Turkey	0.62	0.47	0.60	0.47

Note: The value of individual countries' intermediates trade reported in Table 5.2 is divided by the value of each country's all manufactures trade reported in Table 5.1.
Source: Author own calculations from OECD's Database ITCS, Harmonized System (HS) Rev.1,1988-1996.

Table 5.6 The Value of the US Manufactures Trade with all OECD Countries by Industry (ISIC, Revision 2)				
Industry (ISIC)	1990	1992	1994	1996
311	9,952,428	12,125,646	13,620,192	16,826,347
313	4,198,781	4,633,815	5,031,812	6,074,626
314	3,176,075	2,945,547	3,393,420	3,079,870
321	5,695,907	6,406,900	7,987,560	9,831,684
322	4,257,629	5,430,924	7,194,515	10,963,006
323	1,473,917	1,540,595	1,804,684	2,176,320
324	1,875,200	1,723,247	2,065,413	2,475,483
331	5,901,044	8,005,969	10,799,309	12,242,801
332	4,093,995	4,781,344	6,305,554	7,680,722
341	14,896,366	14,026,208	16,074,652	20,251,888
342	4,228,150	4,862,599	5,228,425	5,980,753
351	28,588,188	32,894,661	39,301,857	48,533,503
352	12,862,545	16,468,935	19,509,841	24,217,099
353	9,297,443	7,127,927	6,739,179	9,078,987
354	700,296	983,528	1,168,383	1,369,113
355	4,836,407	5,199,940	6,612,110	7,546,537
356	4,520,635	5,414,706	6,826,817	8,479,066
361	950,352	1,017,839	1,091,793	1,090,630
362	2,743,863	3,216,934	4,161,215	5,064,779
369	2,442,776	2,305,472	2,807,124	3,374,517
371	8,372,853	7,946,368	10,617,776	11,347,514
372	13,973,139	13,828,674	17,119,286	22,202,638
381	11,331,930	12,551,949	16,142,115	20,097,681
382	95,751,220	101,073,591	126,667,172	140,682,035
383	61,628,403	69,119,515	89,198,789	104,965,063
384	129,757,488	139,271,791	165,671,355	184,669,371
385	19,865,250	23,371,185	27,918,784	33,675,679
390	15,606,151	16,569,668	18,607,891	20,169,227

Note: The value of exports and imports of all 6-digit product level of HS manufacturing products comprising a particular industry is summed using a concordance table from HS to ISIC. Values are in thousands of $US.
Source: Author own calculations from OECD's Database ITCS, Harmonized System (HS) Rev.1,1988-1996.

Table 5.7 The Value of the US Intermediates Trade with all OECD Countries by Industry (ISIC Rev.2)

Industry (ISIC)	1990	1992	1994	1996
311	1,107,458	1,779,988	1,368,978	2,646,056
313	-	-	-	-
314	-	-	-	-
321	4,527,616	5,119,063	6,416,135	7,886,694
322	4,898	4,604	7,260	4,953
323	752,399	709,020	788,830	831,913
324	-	-	-	-
331	5,816,131	7,905,784	10,673,264	12,087,307
332	1,593,765	2,149,775	2,902,655	3,471,483
341	14,449,625	13,430,865	15,251,025	19,138,653
342	972,014	1,204,858	1,242,854	1,661,625
351	27,751,890	32,049,019	38,374,806	47,351,668
352	9,621,661	11,674,999	13,384,741	15,711,857
353	738,822	647,378	666,700	827,048
354	504,743	763,555	887,027	1,099,118
355	4,121,071	4,203,741	5,219,648	5,887,864
356	2,158,666	2,695,479	3,309,115	4,299,282
361	235,758	280,409	379,383	493,200
362	2,309,426	2,748,839	3,607,178	4,446,886
369	2,437,832	2,300,863	2,801,986	3,367,990
371	8,356,795	7,936,252	10,581,510	11,316,248
372	13,973,139	13,828,674	17,119,286	22,202,638
381	8,297,573	8,836,515	11,699,352	14,725,911
382	40,818,501	41,845,153	52,968,596	63,935,771
383	37,592,657	42,372,441	57,477,687	70,201,003
384	54,496,361	57,933,848	67,502,041	74,121,472
385	4,457,709	5,215,323	5,910,003	6,696,998
390	3,506,219	3,247,685	3,883,688	4,201,236

Note: The value of exports and imports of all 6-digit product level of HS intermediate products comprising a particular industry is summed using a concordance table from HS to ISIC. Values are in thousands of $US.
Source: Author own calculations from OECD's Database ITCS, Harmonized System (HS) Rev.1,1988-1996.

Table 5.8 The Relative Importance of Individual Industry's Intermediates Trade in Total Intermediates Trade by Industry (ISIC Rev.2)				
Industry (ISIC)	1990	1992	1994	1996
311	0.00442	0.00657	0.00409	0.00664
313	-	-	-	-
314	-	-	-	-
321	0.01807	0.01890	0.01919	0.01979
322	0.00002	0.00002	0.00002	0.00001
323	0.00300	0.00262	0.00236	0.00209
324	-	-	-	-
331	0.02321	0.02919	0.03192	0.03032
332	0.00636	0.00794	0.00868	0.00871
341	0.05766	0.04958	0.04560	0.04801
342	0.00388	0.00445	0.00372	0.00417
351	0.11074	0.11831	0.11475	0.11879
352	0.03839	0.04310	0.04002	0.03942
353	0.00295	0.00239	0.00199	0.00207
354	0.00201	0.00282	0.00265	0.00276
355	0.01644	0.01552	0.01561	0.01477
356	0.00861	0.00995	0.00989	0.01079
361	0.00094	0.00104	0.00113	0.00124
362	0.00922	0.01015	0.01079	0.01116
369	0.00973	0.00849	0.00838	0.00845
371	0.03335	0.02930	0.03164	0.02839
372	0.05576	0.05105	0.05119	0.05570
381	0.03311	0.03262	0.03498	0.03694
382	0.16288	0.15448	0.15839	0.16039
383	0.15001	0.15642	0.17187	0.17611
384	0.21746	0.21387	0.20185	0.18595
385	0.01779	0.01925	0.01767	0.01680
390	0.01399	0.01199	0.01161	0.01054

Note: The value of individual industries' intermediates trade reported in Table 5.7 is divided by the value of the US total intermediates trade with all OECD countries reported in Table 5.2.
Source: Author own calculations from OECD's Database ITCS, Harmonized System (HS) Rev.1,1988-1996.

Table 5.9 Grubel-Lloyd Indices of All Manufactures Trade between the US and OECD Countries				
	1990	1992	1994	1996
All Countries	0.25	0.25	0.24	0.25
Core	0.26	0.27	0.26	0.26
Periphery	0.23	0.21	0.20	0.21
Core				
Australia	0.15	0.18	0.17	0.17
Austria	0.19	0.23	0.26	0.22
Belgium	0.24	0.26	0.26	0.25
Canada	0.43	0.42	0.45	0.48
Switzerland	0.28	0.30	0.27	0.27
Germany	0.34	0.33	0.33	0.34
Denmark	0.25	0.24	0.22	0.23
Finland	0.25	0.24	0.21	0.24
France	0.30	0.32	0.30	0.31
United Kingdom	0.36	0.36	0.36	0.37
Ireland	0.26	0.28	0.32	0.25
Iceland	0.28	0.23	0.16	0.22
Italy	0.18	0.23	0.19	0.22
Japan	0.24	0.22	0.24	0.26
Netherlands	0.27	0.30	0.26	0.28
Norway	0.23	0.21	0.19	0.21
New Zealand	0.21	0.19	0.17	0.20
Sweden	0.27	0.28	0.24	0.23
Periphery				
Spain	0.19	0.22	0.17	0.18
Greece	0.21	0.18	0.21	0.21
Hungary	0.17	0.20	0.14	0.21
Mexico	0.33	0.33	0.32	0.31
Poland	0.22	0.15	0.22	0.19
Portugal	0.20	0.22	0.15	0.20
Turkey	0.27	0.17	0.16	0.18
Source: Author own calculations from OECD's Database ITCS, Harmonized System (HS) Rev.1,1988-1996.				

Table 5.10 Grubel-Lloyd Indices of Intermediates Trade between the US and OECD Countries				
	1990	1992	1994	1996
All Countries	0.24	0.23	0.22	0.23
Core	0.24	0.25	0.24	0.25
Periphery	0.23	0.19	0.18	0.18
Core				
Australia	0.13	0.18	0.17	0.15
Austria	0.17	0.19	0.24	0.19
Belgium	0.24	0.22	0.23	0.23
Canada	0.41	0.41	0.41	0.44
Switzerland	0.27	0.25	0.24	0.26
Germany	0.34	0.32	0.32	0.33
Denmark	0.18	0.25	0.20	0.26
Finland	0.20	0.28	0.15	0.21
France	0.26	0.28	0.29	0.31
United Kingdom	0.34	0.34	0.36	0.35
Ireland	0.20	0.22	0.22	0.23
Iceland	0.18	0.14	0.12	0.19
Italy	0.24	0.27	0.22	0.25
Japan	0.25	0.23	0.26	0.30
Netherlands	0.26	0.27	0.26	0.24
Norway	0.17	0.20	0.17	0.18
New Zealand	0.19	0.17	0.17	0.15
Sweden	0.27	0.26	0.22	0.20
Periphery				
Spain	0.25	0.20	0.18	0.17
Greece	0.16	0.16	0.19	0.19
Hungary	0.13	0.18	0.11	0.17
Mexico	0.29	0.29	0.27	0.30
Poland	0.26	0.14	0.20	0.17
Portugal	0.22	0.16	0.17	0.18
Turkey	0.28	0.16	0.14	0.12
Source: Author own calculations from OECD's Database ITCS, Harmonized System (HS) Rev.1,1988-1996.				

Table 5.11 Grubel-Lloyd Indices of Total, Vertical, and Horizontal IIT in Intermediate Goods in the US by Country, 1990-1996

Country	TIIT	VIIT	HIIT
All Countries	0.2246	0.1770	0.0476
Core	0.2392	0.1859	0.0533
Periphery	0.1872	0.1542	0.0329
Core			
Australia	0.1475	0.1215	0.0260
Austria	0.2139	0.1893	0.0246
Belgium	0.2318	0.1672	0.0646
Canada	0.4095	0.2633	0.1462
Switzerland	0.2600	0.2116	0.0485
Germany	0.3150	0.2248	0.0902
Denmark	0.2403	0.1720	0.0683
Finland	0.2063	0.1736	0.0327
France	0.2718	0.2066	0.0651
United Kingdom	0.3555	0.2737	0.0817
Ireland	0.2433	0.2153	0.0280
Iceland	0.0900	0.0717	0.0183
Italy	0.2562	0.2217	0.0345
Japan	0.2467	0.1890	0.0577
Netherlands	0.2341	0.1870	0.0471
Norway	0.1845	0.1431	0.0414
New Zealand	0.1631	0.1261	0.0370
Sweden	0.2357	0.1887	0.0470
Periphery			
Spain	0.2132	0.1580	0.0552
Greece	0.1529	0.1288	0.0241
Hungary	0.1555	0.1349	0.0206
Mexico	0.2696	0.2089	0.0607
Poland	0.1487	0.1242	0.0244
Portugal	0.1843	0.1668	0.0176
Turkey	0.1859	0.1580	0.0279

Source: Author own calculations from OECD's Database ITCS, Harmonized System (HS) Rev.1,1988-1996.

Table 5.12 Grubel-Lloyd Indices of Total, Vertical, and Horizontal IIT in the US by Industry (ISIC Rev.2), 1990-1996

Industry	OECD			Core			Periphery		
	TIIT	VIIT	HIIT	TIIT	VIIT	HIIT	TIIT	VIIT	HIIT
311	0.2265	0.1870	0.0395	0.2048	0.1666	0.0382	0.2824	0.2396	0.0428
313	-	-	-	-	-	-	-	-	-
314	-	-	-	-	-	-	-	-	-
321	0.2403	0.1931	0.0472	0.2588	0.2084	0.0504	0.1926	0.1538	0.0389
322	0.0986	0.0938	0.0047	0.0941	0.0933	0.0008	0.1100	0.0951	0.0148
323	0.2229	0.2048	0.0181	0.2382	0.2193	0.0188	0.1837	0.1674	0.0163
324	-	-	-	-	-	-	-	-	-
331	0.1777	0.1569	0.0207	0.2004	0.1814	0.0190	0.1192	0.0940	0.0252
332	0.2628	0.2296	0.0332	0.3229	0.2858	0.0371	0.1084	0.0850	0.0233
341	0.1835	0.1415	0.0420	0.1531	0.1108	0.0423	0.2619	0.2207	0.0412
342	0.4027	0.3137	0.0890	0.4378	0.3311	0.1067	0.3125	0.2692	0.0433
351	0.2275	0.1669	0.0606	0.2426	0.1791	0.0635	0.1888	0.1356	0.0532
352	0.2794	0.2363	0.0432	0.2963	0.2464	0.0499	0.2361	0.2104	0.0258
353	0.1687	0.0946	0.0742	0.2095	0.1128	0.0967	0.0638	0.0477	0.0161
354	0.2566	0.2178	0.0388	0.3373	0.2871	0.0503	0.0490	0.0398	0.0092
355	0.3249	0.1755	0.1494	0.3434	0.1537	0.1898	0.2771	0.2315	0.0455
356	0.3166	0.2606	0.0560	0.3446	0.2733	0.0713	0.2445	0.2277	0.0168
361	0.2283	0.2238	0.0044	0.2971	0.2910	0.0062	0.0512	0.0512	0.0000
362	0.2170	0.1727	0.0443	0.2067	0.1665	0.0402	0.2434	0.1885	0.0549
369	0.2415	0.1891	0.0524	0.2669	0.1974	0.0695	0.1763	0.1679	0.0084
371	0.1637	0.1403	0.0234	0.1564	0.1293	0.0271	0.1823	0.1686	0.0138
372	0.2172	0.1438	0.0734	0.2075	0.1178	0.0897	0.2421	0.2106	0.0315
381	0.3138	0.2371	0.0767	0.3405	0.2471	0.0934	0.2453	0.2113	0.0340
382	0.3476	0.3089	0.0387	0.3824	0.3339	0.0484	0.2581	0.2444	0.0136
383	0.3579	0.2806	0.0773	0.3894	0.3009	0.0885	0.2769	0.2285	0.0484
384	0.3044	0.2309	0.0734	0.3120	0.2401	0.0719	0.2847	0.2073	0.0774
385	0.2242	0.1824	0.0418	0.2324	0.1952	0.0372	0.2032	0.1495	0.0537
390	0.2847	0.1751	0.1097	0.2217	0.1370	0.0847	0.4468	0.2729	0.1739

Source: Author own calculations from OECD's Database ITCS, Harmonized System (HS) Rev.1,1988-1996.

Table 5.13 The Percentage of Intermediates Trade used in the Estimations over Actual Total Intermediates Trade by Country

	1990	1992	1994	1996
All Countries	0.77	0.77	0.78	0.77
Core	0.78	0.78	0.79	0.78
Periphery	0.70	0.69	0.71	0.73
Core				
Australia	0.77	0.75	0.74	0.74
Austria	0.67	0.66	0.72	0.74
Belgium	0.73	0.72	0.74	0.73
Canada	0.87	0.87	0.87	0.86
Switzerland	0.71	0.69	0.75	0.78
Germany	0.73	0.73	0.74	0.73
Denmark	0.64	0.67	0.71	0.66
Finland	0.76	0.73	0.76	0.74
France	0.65	0.67	0.72	0.67
United Kingdom	0.72	0.73	0.74	0.73
Ireland	0.57	0.59	0.62	0.72
Iceland	0.13	0.36	0.35	0.34
Italy	0.78	0.78	0.77	0.76
Japan	0.76	0.75	0.76	0.74
Netherlands	0.69	0.71	0.69	0.69
Norway	0.52	0.40	0.53	0.56
New Zealand	0.70	0.64	0.58	0.64
Sweden	0.59	0.54	0.66	0.65
Periphery				
Spain	0.78	0.73	0.75	0.75
Greece	0.66	0.63	0.67	0.74
Hungary	0.88	0.79	0.78	0.71
Mexico	0.69	0.69	0.71	0.73
Poland	0.67	0.54	0.50	0.46
Portugal	0.68	0.79	0.75	0.73
Turkey	0.74	0.70	0.66	0.54

Note: The share is obtained by dividing the amount of intermediate goods trade between the US and trading partner used in the estimation over the actual amount of intermediate goods trade tabulated in Table 5.2. Discrepancy is due to lack of quantity data.

Table 5.14 Eigenvalues and Eigenprojectors of Ω			
i	λ_i	V_i	rank V_i
1	σ_ε^2	$\dot{Q}$	$INT - T - N - I + 2$
2	$NI\sigma_\xi^2 + \sigma_\varepsilon^2$	$E_T \otimes \bar{J}_N \otimes \bar{J}_I$	$(T-1)$
3	$TI\sigma_\zeta^2 + \sigma_\varepsilon^2$	$\bar{J}_T \otimes E_N \otimes \bar{J}_I$	$(N-1)$
4	$NT\sigma_\eta^2 + \sigma_\varepsilon^2$	$\bar{J}_T \otimes \bar{J}_N \otimes E_I$	$(I-1)$
5	$NI\sigma_\xi^2 + TI\sigma_\zeta^2 + NT\sigma_\eta^2 + \sigma_\varepsilon^2$	$\bar{J}_T \otimes \bar{J}_N \otimes \bar{J}_I$	1

Note: $\dot{Q} = I_T \otimes I_N \otimes I_I - I_T \otimes \bar{J}_N \otimes \bar{J}_I - \bar{J}_T \otimes I_N \otimes \bar{J}_I - \bar{J}_T \otimes \bar{J}_N \otimes I_I + 2\bar{J}_T \otimes \bar{J}_N \otimes \bar{J}_I$

Source: Baltagi (1987)

Table 5.15 Variable Definition and Expected Signs

Variable Definition	Expected Signs		
	TIIT	VIIT	HIIT
PDI_{jhft} =product differentiation index for each partner country at industry level	+/-	+	-
$DVAEST_{jhft}$ = absolute differences in value added per establishment at industry level between the US and its trading partner.	-	-	-
$DPCAP_{jhft}$: absolute differences in physical capital endowment in each industry between the U.S and its trading partner.	+/-	+/-	-
$AGDP_{hft}$ =average GDP between the US and its trading partner	+/-	-	+
$RFDI_{hft}$: outward FDI stocks from the US into OECD countries	+/-	+	+/-
$DHUMCAP2_{hft}$:absolute differences in the relative ratio of number of researchers between the US and its trading partner	+/-	+	-
$DIST_{hf}$ =the geographical distance variable is defined as the weighted distance between the US and its trading partner	-	-	-

Note: Variables with four subscripts indicates that this variable has three dimensions: industry, country, and time. Variables with three subscripts indicates that this variable has two dimensions: country and time.

Table 5.16: Simple OLS Results for Total, Vertical, and Horizontal IIT

Independent Variables	Dependent Variables		
	Total IIT	Vertical IIT	Horizontal IIT
Constant	-0.02528 (-0.01)	-1.88247 (-0.91)	1.84596*** (1.75)
PDI_{jhft}	0.000511 (1.45)	0.00043 (1.61)	5.31E-05 (0.22)
$DVAEST_{jhft}$	-0.02387* (-8.50)	-0.02369* (-9.35)	-0.00013 (-0.07)
$DPCAP_{jhft}$	0.0183* (5.47)	0.01579* (4.83)	0.00126 (0.91)
$AGDP_{hft}$	-0.0032 (-0.04)	0.06334 (0.88)	-0.06497*** (-1.77)
$RFDI_{hft}$	0.03723* (13.1)	0.02013* (7.52)	0.0161* (10.05)
$DHUMCAP2_{hft}$	0.000587 (0.09)	0.00761 (1.34)	-0.00671** (-2.05)
$DIST_{hft}$	-0.01146** (-2.15)	-0.00383 (-0.75)	-0.00806* (-2.77)
R^2	0.63	0.56	0.26
F	575.9	416.37	115.41
No. of observations[a]	2351	2317	1711

Note: t-values (given within parentheses) are based on White's method. Asterisks indicate statistical significance at different levels: *(1%), **(5 %), ***(10%).
[a] Panel data have 2625 observation points (15 countries, 25 industries, and 7 years).

Table 5.17: Fixed Effects Results for Total, Vertical, and Horizontal IIT with Country Dummies			
Independent Variables	Dependent Variables		
	Total IIT	Vertical IIT	Horizontal IIT
Constant	-1.29787 (-0.33)	-2.60478 (-0.70)	-2.60478 (-0.70)
PDI_{jhft}	0.000454 (1.53)	0.000418*** (1.70)	0.000418*** (1.70)
$DVAEST_{jhft}$	-0.02267* (-7.55)	-0.0237* (-8.69)	-0.0237* (-8.69)
$DPCAP_{jhft}$	0.02165* (6.43)	0.01822* (5.49)	0.01822* (5.49)
$AGDP_{hft}$	0.10889 (0.73)	0.14719 (1.05)	0.14719 (1.05)
$RFDI_{hft}$	-0.02578 (-0.76)	-0.02637 (-0.82)	-0.02637 (-0.82)
$DHUMCAP2_{hft}$	-0.00811 (-0.45)	-0.01669 (-0.99)	-0.01669 (-0.99)
$DIST_{hft}$	-0.28249*** (-1.91)	-0.23348*** (-1.67)	-0.23348*** (-1.67)
α Austria	0.04261 (1.33)	0.03389 (1.12)	0.03389 (1.12)
α Canada	-0.04235 (-0.20)	-0.12542 (-0.63)	-0.12542 (-0.63)
α Denmark	-0.01977 (-0.43)	-0.06124 (-1.43)	-0.06124 (-1.43)
α Spain	0.31428** (2.00)	0.23467 (1.59)	0.23467 (1.59)
α Finland	-0.16823*** (-1.88)	-0.16519*** (-1.94)	-0.16519*** (-1.94)
α United Kingdom	0.69327** (2.45)	0.54614** (2.04)	0.54614** (2.04)
α Greece	-0.19716** (-2.48)	-0.17618** (-2.31)	-0.17618** (-2.31)
α Ireland	-0.33119 (-1.53)	-0.26365 (-1.30)	-0.26365 (-1.30)
α Italy	0.56814** (2.09)	0.46849*** (1.82)	0.46849*** (1.82)
α Mexico	0.03827 (0.36)	0.02719 (0.27)	0.02719 (0.27)
α Netherlands	0.25051*** (1.78)	0.19437 (1.46)	0.19437 (1.46)
α Norway	-0.15861*** (-1.69)	-0.16924*** (-1.94)	-0.16924** (-1.94)
α New Zealand	-0.18229** (-.198)	-0.16422*** (-1.89)	-0.16422** (-1.89)
α Portugal	-0.24982*** (-1.92)	-0.19734 (-1.60)	-0.19734 (-1.60)
R^2	0.65	0.57	0.29
F	222.8	157.6	49.69
Chow test	0.22	0.122	0.26

No. of observations[a]	2351	2317	1711

Note: t-values (given within parentheses) are based on White's method. Asterisks indicate statistical significance at different levels: *(1%), **(5 %), ***(10%). Omitted Country is Turkey.
[a] Panel data have 2625 observation points (15 countries, 25 industries, and 7 years).

Table 5.18: Fixed Effects Results for Total, Vertical, and Horizontal IIT with Country and Time Dummies			
Independent Variables	Dependent Variables		
	Total IIT	Vertical IIT	Horizontal IIT
Constant	-97.2549 (-0.99)	-98.7608 (-1.09)	1.46779 (0.02)
PDI_{jhft}	0.000511*** (1.73)	0.000473*** (1.86)	1.31E-05 (0.06)
$DVAEST_{jhft}$	-0.02305* (-7.67)	-0.0241* (-8.86)	0.00101 (0.57)
$DPCAP_{jhft}$	0.02181* (6.48)	0.01838* (5.54)	0.00217 (1.54)
$AGDP_{hft}$	3.43707 (1.01)	3.48275 (1.10)	-0.04279 (-0.02)
$RFDI_{hft}$	-0.02224 (-0.63)	-0.0233 (-0.70)	0.00101 (0.06)
$DHUMCAP2_{hft}$	-0.00772 (-0.38)	-0.0174 (-0.93)	0.00959 (1.04)
$DIST_{hft}$	-0.37884** (-2.02)	-0.33098*** (-1.90)	-0.05101 (-0.57)
α Austria	0.02391 (0.65)	0.01482 (0.43)	0.00692 (0.40)
α Canada	-0.35509 (-0.95)	-0.43927 (-1.27)	0.0738 (0.38)
α Denmark	-0.04775 (-0.85)	-0.09037*** (-1.72)	0.03832 (1.41)
α Spain	0.20939 (1.17)	0.13092 (0.78)	0.07752 (0.87)
α Finland	-0.19533*** (-1.94)	-0.19487** (-2.05)	-0.00374 (-0.08)
α United Kingdom	0.41855 (1.14)	0.27323 (0.79)	0.14389 (0.78)
α Greece	-0.20925** (-2.48)	-0.18937** (-2.35)	-0.02139 (-0.58)
α Ireland	-0.43024*** (-1.77)	-0.3641 (-1.60)	-0.07337 (-0.64)
α Italy	0.32348 (0.94)	0.22548 (-.69)	0.09802 (0.57)
α Mexico	-0.07576 (-0.50)	-0.08618 (-0.62)	0.00451 (0.06)
α Netherlands	0.18537 (1.24)	0.13 (0.92)	0.05268 (0.72)
α Norway	-0.19933*** (-1.86)	-0.21264** (-2.15)	0.00973 (0.18)
α New Zealand	-0.19163** (-2.06)	-0.17411** (-1.98)	-0.02064 (-0.50)
α Portugal	-0.30723** (-2.07)	-0.25582*** (-1.83)	-0.05406 (-0.79)
μ 1990	0.49859 (0.99)	0.49948 (1.07)	-0.00035 (-0.00)
μ 1991	0.52076	0.52136	2E-05

	(0.99)	(1.07)	(0.00)
μ 1992	0.40967 (0.96)	0.40891 (1.04)	0.00129 (0.00)
μ 1993	0.31673 (0.93)	0.31729 (1.01)	-0.0001 (0.00)
μ 1994	0.18332 (0.90)	0.18381 (0.97)	-0.00012 (0.00)
μ 1995	0.11956 (1.02)	0.11786 (1.08)	0.00208 (0.03)
R^2	0.65	0.57	0.29
F	175.2	124.1	38.96
Chow test	0.14	0.08	0.16
No. of observations[a]	2351	2317	1711

Note: *Note*: t-values (given within parentheses) are based on White's method. Asterisks indicate statistical significance at different levels: *(1%), **(5%), ***(10%). Omitted Country is Turkey and omitted year is 1996.

[a] Panel data have 2625 observation points (15 countries, 25 industries, and 7 years).

Table 5.19: Fixed Effects Results for Total, Vertical, and Horizontal IIT with Country and Industry Dummies			
Independent Variables	Dependent Variables		
	Total IIT	Vertical IIT	Horizontal IIT
Constant	-1.04303 (-0.28)	-2.52705 (-0.70)	1.52821 (0.88)
PDI_{jhft}	0.000186 (0.54)	0.000131 (0.52)	3.95E-05 (0.16)
$DVAEST_{jhft}$	-0.01777* (-4.09)	-0.01476* (-3.52)	-0.00333 (-1.53)
$DPCAP_{jhft}$	0.00641 (0.87)	0.00898 (1.26)	-0.00212 (-1.05)
$AGDP_{hft}$	0.11096 (0.78)	0.14759 (1.08)	-0.0375 (-0.58)
$RFDI_{hft}$	-0.02503 (-0.78)	-0.02611 (-0.84)	0.00103 (0.07)
$DHUMCAP2_{hft}$	-0.00833 (-0.48)	-0.01654 (-1.00)	0.00804 (1.14)
$DIST_{hft}$	-0.28328** (-2.00)	-0.2337*** (-1.71)	-0.05264 (-0.81)
α Austria	0.04907 (1.58)	0.04457 (1.49)	0.00188 (0.13)
α Canada	-0.04003 (-0.20)	-0.11276 (-0.59)	0.06228 (0.67)
α Denmark	-0.01629 (-0.37)	-0.05575 (-1.33)	0.03481*** (1.79)
α Spain	0.31629* (2.10)	0.23958*** (1.64)	0.07568 (1.09)
α Finland	-0.16131*** (-1.90)	-0.15462*** (-1.87)	-0.01062 (-0.28)
α United Kingdom	0.68979** (2.54)	0.55048** (2.08)	0.13849 (1.14)
α Greece	-0.19124** (-2.52)	-0.1673** (-2.23)	-0.02587 (-0.82)
α Ireland	-0.32707 (-1.60)	-0.25471 (-1.29)	-0.08005 (-0.86)
α Italy	0.57545** (2.20)	0.48212*** (1.90)	0.0931 (0.79)
α Mexico	0.03659 (0.36)	0.02315 (0.24)	0.00744 (0.16)
α Netherlands	0.25822*** (1.92)	0.20439 (1.56)	0.05026 (0.83)
α Norway	-0.15413*** (-1.76)	-0.16034*** (-1.90)	0.00198 (0.04)
α New Zealand	-0.17096** (-1.97)	-0.1561*** (-1.86)	-0.0194 (-0.50)
α Portugal	-0.24699** (-2.00)	-0.19385 (-1.60)	-0.05607 (-1.03)
γ ISIC=311	-0.12195* (-3.02)	-0.01483 (-0.39)	-0.10602* (-5.05)
γ ISIC=321	-0.14048*	-0.04958***	-0.09332*

	(-4.70)	(-1.80)	(4.96)
γ ISIC=322	-0.28935* (-9.00)	-0.14566* (-4.87)	-0.13706* (-6.91)
γ ISIC=323	-0.13131* (-3.83)	-0.00136 (-0.04)	-0.12666* (-6.44)
γ ISIC=331	-0.18094* (-5.46)	-0.06188** (-2.04)	-0.11785* (-5.80)
γ ISIC=332	-0.11298* (-3.04)	-0.01631 (-0.44)	-0.09013* (-3.86)
γ ISIC=341	-0.18672* (-5.16)	-0.08554* (-2.57)	-0.103* (-5.26)
γ ISIC=342	0.01973 (0.55)	0.11215* (3.28)	-0.09381* (-4.57)
γ ISIC=351	-0.11881* (-3.54)	-0.04546 (-1.46)	-0.0756* (-3.80)
γ ISIC=352	-0.05991*** (-1.82)	0.03742 (1.22)	-0.09906* (-5.28)
γ ISIC=353	-0.14064* (-3.53)	-0.08321** (-2.47)	-0.05242*** (-1.90)
γ ISIC=354	-0.12927* (-3.66)	-0.00394 (-0.11)	-0.11966* (-6.10)
γ ISIC=355	-0.00493 (-0.14)	-0.01171 (-0.39)	0.00599 (0.22)
γ ISIC=356	-0.04856 (-1.47)	0.05149*** (1.69)	-0.09944* (-5.23)
γ ISIC=361	-0.121* (-3.08)	0.0249 (0.65)	-0.13812* (-7.30)
γ ISIC=362	-0.12092* (-3.66)	-0.03323 (-1.09)	-0.08533* (-3.82)
γ ISIC=369	-0.13543* (-4.27)	-0.0218 (-0.73)	-0.11279* (-6.09)
γ ISIC=371	-0.15541* (-4.89)	-0.04685 (-1.59)	-0.10949* (-5.83)
γ ISIC=372	-0.12551* (-3.83)	-0.04544 (-1.46)	-0.08105* (-4.24)
γ ISIC=381	-0.07834** (-2.44)	0.000773 (0.02)	-0.08236* (-4.25)
γ ISIC=382	-0.00205 (-0.05)	0.09551* (2.92)	-0.10004* (-5.13)
γ ISIC=383	0.00266 (0.07)	0.05633*** (1.70)	-0.05658* (-2.66)
γ ISIC=384	-0.06276 (-1.64)	-0.02479 (-0.70)	-0.04042*** (-1.83)
γ ISIC=385	-0.1257* (-3.47)	-0.0043 (-0.12)	-0.1189* (-6.28)
R^2	0.69	0.60	0.60
F	125.75	86.6	86.6
Chow test	1.36***	0.85	1.43***
No. of observations[a]	2351	2317	1711

Note: t-values (given within parentheses) are based on White's method. Asterisks indicate statistical significance at different levels: *(1%), **(5 %), ***(10%). Omitted Country is Turkey and omitted industry is 390.

[a] Panel data have 2625 observation points (15 countries, 25 industries, and 7 years).

Table 5.20: Fixed Effects Results for Total, Vertical, and Horizontal IIT with Country, Industry, and Time Dummies			
Independent Variables	Dependent Variables		
	Total IIT	Vertical IIT	Horizontal IIT
Constant	-92.99 (-0.99)	-92.2974 (-1.05)	-1.00669 (-0.02)
PDI_{jhft}	0.000241 (0.71)	0.000183 (0.72)	4.34E-05 (0.18)
$DVAEST_{jhft}$	-0.01851* (-4.25)	-0.01548* (-3.70)	-0.00335 (-1.55)
$DPCAP_{jhft}$	0.00673 (0.92)	0.00929 (1.30)	-0.00211 (-1.05)
$AGDP_{hft}$	3.30035 (1.02)	3.2616 (1.07)	0.04995 (0.03)
$RFDI_{hft}$	-0.0217 (-0.65)	-0.0233 (-0.73)	0.00151 (0.20)
$DHUMCAP2_{hft}$	-0.00785 (-0.41)	-0.01696 (-0.92)	0.00907 (1.14)
$DIST_{hft}$	-0.37546** (-2.13)	-0.32468*** (-1.92)	-0.0541 (-0.64)
α Austria	0.03076 (0.86)	0.02648 (0.78)	0.00164 (0.09)
α Canada	-0.33971 (-0.92)	-0.4057 (-1.22)	0.0549 (0.30)
α Denmark	-0.04315 (-0.81)	-0.0829 (-1.63)	0.03514 (1.38)
α Spain	0.21558 (1.25)	0.14271 (0.87)	0.07156 (0.84)
α Finland	-0.18747** (-1.98)	-0.18238** (-1.99)	-0.00893 (-0.20)
α United Kingdom	0.42635 (1.20)	0.29587 (0.87)	0.12892 (0.73)
α Greece	-0.20315** (-2.50)	-0.17995** (-2.28)	-0.02517 (-0.73)
α Ireland	-0.42194*** (-1.84)	-0.34853 (-1.59)	-0.08117 (-0.75)
α Italy	0.34035 (1.02)	0.25492 (0.80)	0.08437 (0.51)
α Mexico	-0.07224 (-0.51)	-0.08229 (-0.62)	0.00384 (0.05)
α Netherlands	0.19562 (1.36)	0.14434 (1.05)	0.04772 (0.69)
α Norway	-0.19309*** (-1.93)	-0.20055** (-2.11)	0.00347 (0.072)
α New Zealand	-0.17986** (-2.05)	-0.16527** (-1.95)	-0.01898 (-0.49)
α Portugal	-0.30195** (-2.16)	-0.24846*** (-1.83)	-0.05653 (-0.88)
γ ISIC=311	-0.12165** (3.00)	-0.01454 (-0.38	-0.10602* (-5.04)
γ ISIC=321	-0.14039*	-0.04949***	-0.09332*

	(-4.69)	(-1.80)	(-4.95)
γ ISIC=322	-0.28942* (-9.00)	-0.14574* (-4.87)	-0.13706* (-6.90)
γ ISIC=323	-0.13099* (-3.82)	-0.00104 (-0.03)	-0.12666* (-6.43)
γ ISIC=331	-0.18112* (-5.46)	-0.06206** (-2.04)	-0.11786* (-5.80)
γ ISIC=332	-0.11304* (-3.03)	-0.01637 (-0.45)	-0.09013* (-3.80)
γ ISIC=341	-0.18635* (-5.15)	-0.08518** (-2.56)	-0.10299* (-5.25)
γ ISIC=342	0.0193 (0.54)	0.11175* (3.27)	-0.09383* (-4.57)
γ ISIC=351	-0.11781* (-3.50)	-0.04448 (-1.43)	-0.07559* (-3.79)
γ ISIC=352	-0.05907*** (-1.79)	0.03825 (1.25)	-0.09905* (-5.26)
γ ISIC=353	-0.13778* (-3.44)	-0.08041** (-2.39)	-0.05235*** (-1.89)
γ ISIC=354	-0.12852* (-3.64)	-0.00321 (-0.09)	-0.11964* (-6.08)
γ ISIC=355	-0.00389 (-0.11)	-0.01069 (-0.36)	0.00601 (0.22)
γ ISIC=356	-0.04928 (-1.49)	0.05081*** (1.66)	-0.09949* (-5.24)
γ ISIC=361	-0.11976* (-3.05)	0.02611 (0.68)	-0.13808* (-7.27)
γ ISIC=362	-0.11993* (-3.62)	-0.03226 (-1.06)	-0.08531* (-3.81)
γ ISIC=369	-0.13537* (-4.26)	-0.02174 (-0.73)	-0.11279* (-6.08)
γ ISIC=371	-0.15438* (-4.85)	-0.04584 (-1.55)	-0.10947* (-5.81)
γ ISIC=372	-0.12462* (-3.80)	-0.04456 (-1.43)	-0.08103* (-4.23)
γ ISIC=381	-0.07858** (-2.44)	0.000544 (0.01)	-0.08237* (-4.25)
γ ISIC=382	-0.00221 (-0.06)	0.09536* (2.92)	-0.10005* (-5.13)
γ ISIC=383	0.00271 (0.07)	0.0564*** (1.70)	-0.05659* (-2.65)
γ ISIC=384	-0.06198 (-1.62)	-0.02403 (-0.68)	-0.04041*** (-1.83)
γ ISIC=385	-0.12437* (-3.44)	-0.00352 (-0.10)	-0.11888* (-6.26)
μ 1990	0.47747 (0.99)	0.46572 (1.03)	0.0136 (0.05)
μ 1991	0.49921 (1.00)	0.48694 (1.04)	0.01421 (0.05)
μ 1992	0.39336 (0.97)	0.38292 (1.01)	0.01196 (0.05)
μ 1993	0.30346 (0.94)	0.29622 (0.97)	0.0085 (0.05)
μ 1994	0.17628 (0.90)	0.17227 (0.94)	0.00484 (0.04)

μ 1995	0.11477 (1.03)	0.11033 (1.05)	0.00511 (0.09)
R^2	0.69	0.60	0.37
F	111.36	76.24	29.77
Chow test	9.21*	5.79*	9.55*
No. of observations[a]	2351	2317	1711

Note: t-values (given within parentheses) are based on White's method. Asterisks indicate statistical significance at different levels: *(1%), **(5 %), ***(10%). Omitted Country is Turkey, Omitted Year is 1996, Omitted Industry is 390.

[a] Panel data have 2625 observation points (15 countries, 25 industries, and 7 years).

Table 5.21: Random Effects Results for Total, Vertical, and Horizontal IIT			
Independent Variables	Dependent Variables		
	Total IIT	Vertical IIT	Horizontal IIT
Constant	8.35043* (3.88)	-1.83364*** (-1.74)	2.59215** (2.13)
PDI_{jhft}	0.000333 (0.85)	0.000211 (0.57)	9.54E-05 (0.47)
$DVAEST_{jhft}$	-0.01893* (-5.24)	-0.01739* (-5.09)	-0.00279 (-1.47)
$DPCAP_{jhft}$	0.000669 (0.12)	0.00681 (1.34)	-0.00367 (-1.26)
$AGDP_{hft}$	0.6888* (3.92)	0.23643*** (1.76)	0.20463** (2.17)
$RFDI_{hft}$	0.02802* (8.26)	0.0178* (5.39)	0.01239* (6.94)
$DHUMCAP2_{hft}$	0.000274 (0.05)	0.00519 (0.79)	-0.00555*** (-1.78)
$DIST_{hft}$	-0.03436* (-4.86)	-0.00932 (-1.42)	-0.01734* (-4.64)
R^2	0.31	0.12	0.12
F	150.04	44.62	44.67
Hausman Test[h]	7.02	7.12	2.60
No. of observations[a]	2351	2317	1711

Note: t-values are given within parentheses. Asterisks indicate statistical significance at different levels: *(1%), **(5 %), ***(10%).

[a] Panel data have 2625 observation points (15 countries, 25 industries, and 7 years).

[h] Based on the results from three-way FEM and three-way REM.

Chapter 6

SUMMARY AND CONCLUSIONS

The increased importance of fragmentation in world trade has created an interest among trade economists in explaining the determinants of trade in intermediate goods. This dissertation has shown that a substantial part of trade in intermediates between the US and OECD countries takes the form of intra-industry. Moreover, this dissertation is the first attempt to conduct an empirical study of intra-industry trade in intermediates between the US and selected OECD countries.

In the newly developed fragmentation literature, various factors have been suggested to explain the recent growth of trade in intermediate goods. Much of the recent literature attempts to explain the trade in intermediates using Ricardian and/or H-O models where differences in production technologies and factor endowments are critical determinants. These issues are explicitly incorporated in the model of outsourcing in Feenstra and Hanson (1997). Some studies, however, stress the importance of product differentiation and economies of scale. Ethier (1982) developed a model where increasing returns and product differentiation are emphasized to explain trade in intermediates. Consequently, I have briefly summarized Ethier's model to explain horizontal IIT and Feenstra and Hanson's model for vertical IIT.

The hypotheses drawn from these models are then put forward empirically investigate IIT in intermediates between the US and other selected OECD countries for the period of 1990-1996. I begin by constructing Grubel-Lloyd (GL) indices of trade for the analysis. To construct the GL indices, I have first selected intermediate goods from trade data at the 6-digit product level using the BEC tables. After I selected the intermediate goods, I constructed IIT indexes at the industry level that take into account the two different types of exchange in intermediates: vertical IIT and horizontal IIT. I define vertical IIT as the exchange of intermediates which belong to the same industry but which are located at different stages on the production spectrum. Horizontal IIT is defined as the exchange of intermediate goods belonging to the same industry but differing in terms of characteristics or technological specifications, and technologically unrelated. To divide trade in intermediates into vertical and horizontal IIT, I have used the relative unit values of exports and imports, calculated at the product level. IIT is considered horizontal when this ratio falls within the range of 1 ± 25 per cent. Where relative unit values are outside this range, ITT is then considered to be vertical. To construct IIT indexes at the industry level, the amounts of each are summed over all 6-digit categories comprising a particular industry, and then subsequently the total IIT index is divided into each type of IIT according to its weight in total intra-industry trade.

A quick look at the data reveals several empirical facts regarding the shares of vertical IIT and horizontal IIT in total trade in intermediate goods. First, the degree of fragmentation has not been increased over this period despite the fact that other important studies indicate otherwise. Second, IIT in intermediate goods for all countries is consistently lower than that of in all manufactured goods trade. In addition, the share of vertical IIT in total IIT account for a significant portion of total IIT in intermediates. Furthermore, the shares of vertical and horizontal IIT differ across countries and industries. Finally, geographical proximity plays an important role in explaining intermediates trade between the US and Mexico or Canada.

The data set used in this dissertation involves three dimensions which allow me to utilize panel data techniques, which can be performed using both fixed effects models (FEM) and random effects models (REM). Although one-way and/or two-way FEM and REM of IIT have been estimated previously, this dissertation is the first to conduct three-way FEM and REM models in the IIT literature. A simple test is carried out whether REM or FEM is the right specification. The test results support REM which also yields more efficient estimates than the FEM estimates. The only striking result from the three-way FEM estimations is the significance of the industry dummies.

Based on results from the REM, I found that vertical IIT is determined by economies of scale, the size of market, and FDI. Particularly, differences in value added per establishment, a proxy for economies of scale, are found to have a negative impact on vertical IIT. Differences in value added per establishment may proxy for technological differences, which is main source of comparative advantage in the Ricardian model. The importance of dissimilarity in value added per establishments confirms the findings by Harrigan (1997) that industry-level technological differences are a main driving force behind the pattern of specialization in goods. Furthermore, the results show that outward FDI into other OECD countries increases the degree of vertical IIT. The average GDPs, a proxy for the size of markets, is expected to have a negative impact on the degree of vertical IIT. Instead we found that vertical IIT is positively linked with the size of market. Firms buy their inputs, wherever the best conditions are offered. Large countries will likely produce every stage of a good due to economies of scale. A large market, however, does not quarantee that available inputs in the US market are cheaper. Some of the large OECD countries are most likely to offer better prices than the US. Recent developments in transportation and technological progress has enabled US firms to take better advantage of international differences in input prices. That has lead to an increase in the use of foreign inputs relative to domestic inputs. Thus, I argue that the size of markets between the US and other OECD countries is most likely to capture this side of the story of globalization. However, the effects of product differentiation, dissimilarities in physical capital and human capital endowments, and distance variables on vertical IIT are not statistically significant though their signs are consistent with predictions.

Turning now to the results for the horizontal IIT, I found that horizontal IIT is positively affected by the size of the two markets and FDI, while it is negatively affected by dissimilarity of human capital endowments and distance variables. These findings are consistent with our expected signs, with the exception of FDI. Initially, I expected that horizontal FDI will not lead to trade in intermediates, while vertical FDI will increase the use of foreign inputs in the production. Given the lack of information on the activities carried out by horizontal FDI, I leave this for future research. However, the coefficients of variables measuring product differentiation, economies of scale, and dissimilarities in physical capital endowments do not generate any significant statistical results. The insignificance of product differentiation and national economies of scale on horizontal IIT confirms the hypothesis made by Ethier (1982) that the product differentiation and economies of scale are necessary for the appearance of IIT but they do not affect the degree of IIT. International increasing returns to scale, proxied by the size of two markets, on the other hand, do matter for horizontal IIT. Dissimilarity in physical capital at industry level, however, has the opposite effect to that predicted by Ethier's model.

In sum, the regression results support the hypothesis that the determinants of vertical and horizontal IIT differ. Empirical results suggest that various factors have played a role behind the pattern of specialization in intermediate goods for both types of ITT. A combination of technological differences and FDI are the main factors for vertical IIT, while international returns to scale, FDI, similarity of human capital endowments, and geographical proximity are for horizontal IIT. Based on these results, I conclude that the data partially support the hypotheses drawn from Feenstra and Hanson's outsourcing model and Ethier's model of international division of labor.

The results in this dissertation leave several issues for further research. First of all, I have employed the unit values technique to separate vertical trade from horizontal trade at the commodity level. This method has one drawback: it is difficult to track an intermediate good once it is imported with the currently available trade data. Trade data used in this dissertation provide information only on the export and import values and quantities of a given input. The imported input could be used primarily for the production of a final good that is later consumed by local consumers or it could be used in the production of other intermediate goods or final goods that are later exported back to the original country or to the other countries. It may be worthwhile to investigate this link in more detail in a future study to confirm whether 25% differences between unit values of exports and imports truly reflects value-added activities. Furthermore, it may be beneficial to separate countries under study into two groups based on their GDPs because selected OECD countries have enormous differences in factor endowments, production technologies, and incomes.

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APPENDIX A

To get the expression for intermediate goods prices, assuming that component producers will equate marginal revenue and marginal cost, we take the first derivative of a representative firm's total cost function and total revenue function with respect to z_{hh} and set these equal to each other, this yield,

$$q + z_{hh}\frac{dq}{dz_{hh}} = -t^{'}(Y)a \,. \tag{A.1}$$

The variable $\frac{dz_{hh}}{dq}$ can be derived from the equation (3.6). The derivative of the equation (3.6) is found as:

$$\frac{dz_{hh}}{dq} = z_{fh}\left[\frac{\frac{1}{1-\theta}q^{\frac{-\theta}{1-\theta}}q^{*\frac{1}{1-\theta}}}{\left(q^{\frac{1}{1-\theta}}\right)^{2}}\right] \tag{A.2}$$

$$= z_{fh}q^{*\frac{1}{1-\theta}}\left(\frac{1}{1-\theta}\right)q^{-\frac{\theta}{1-\theta}-\frac{2}{1-\theta}} \tag{A.3}$$

$$= z_{fh}q^{*\frac{1}{1-\theta}}\left(\frac{1}{1-\theta}\right)q^{-\left(\frac{2-\theta}{1-\theta}\right)} \tag{A.4}$$

Equation (A.4) can be rearranged as,

$$= \left(\frac{1}{1-\theta}\right)z_{fh}\left(\frac{q^{*}}{q}\right)^{\frac{1}{1-\theta}}\frac{1}{q} \tag{A.5}$$

The middle term is equivalent to equation (3.6), z_{hh}. Thus, it is simplified:

$$\frac{dz_{hh}}{dq} = \frac{1}{1-\theta}\frac{z_{hh}}{q} \tag{A.6}$$

Thus, I can substitute equation (A.6) into equation (A.1). Note that I reversed the above equation when I inserted it into equation (A.1) assuming that they are symmetric.

$$q + z_{hh}(1-\theta)\frac{q}{z_{hh}} = -t^{'}(Y)a \tag{A.7}$$

After some manipulations,I can get the expression for q as:

$$q = \frac{-t^{'}(Y)a}{\theta} \tag{A.8}$$

The same method is also applied to foreign component's price, q^*.

APPENDIX B

To derive equation (3.11), we set $\pi = 0$, and substitute equation (3.9) into this, and after some manipulations, I can simplify the formula for the components output level for both home and foreign varieties, z and z^*, respectively.

$$\pi = \frac{-t^{'}(Y)a}{\theta} z + t^{'}(Y)[az + b] \tag{B.1}$$

$$0 = \frac{-t^{'}(Y)a}{\theta} z + t^{'}(Y)[az + b] \tag{B.2}$$

$$0 = \frac{-t^{'}(Y)a}{\theta} z + t^{'}(Y)az + t^{'}(Y)b \tag{B.3}$$

$$z = \frac{-t^{'}(Y)b}{\frac{t^{'}(Y)a\theta - t^{'}(Y)a}{\theta}} \tag{B.4}$$

$$z = \frac{-b}{\frac{(a - a\theta)}{\theta}} \tag{B.5}$$

Finally, express the output of each variety in home country as,

$$z = \frac{b\theta}{a(1-\theta)} \tag{B.6}$$

Similarly, the same method is also applied to foreign variety of component output, z^*.

APPENDIX C

To derive the equation (3.12), substitute equation (3.11) into the equation (3.5), and solve for the number of varieties or the number of components producing firms since the model assumes that each firm produces only one variety:

$$Y = n\left[a\frac{b\theta}{a(1-\theta)} + b\right] \quad \text{(C.1)}$$

$$Y = n\left[\frac{b\theta}{(1-\theta)} + b\right] \quad \text{(C.2)}$$

$$n = \frac{Y}{\left(\dfrac{b\theta + b(1-\theta)}{(1-\theta)}\right)} \quad \text{(C.3)}$$

This can be simplified to get the expression for the number of components in home country:

$$n = \frac{(1-\theta)Y}{b} \quad \text{(C.4)}$$

Likewise, the same method is also applied to the number of components in foreign country, n^*.