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[Abstract]

The emergence of international fragmentation of production as a contemporary phenomenon of international trade is evident from the rapid expansion of global production sharing and the impressive growth of trade in parts and components since the 1990s. Up until now, various studies have illustrated implications of fragmented technology from different perspectives. This paper presents both empirical observations and the latest theoretical findings. It shows in diagram how international fragmentation and global outsourcing of production can act like technological progress on economic growth, and how the decline of service costs contributes to the expansion of the global production sharing network.

[JEL Classification]

F11, F12

[Keywords]

international trade, fragmentation, outsourcing

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1. Introduction

The term "fragmentation" or "outsourcing" has become popular in everyday language as well as professional debates. When the term "outsourcing" is "googled", *Google News* will procure over 367,000 related articles; while a search in *Google Scholar* will yield a result of about 200,000 scholarly works online.[1] According to *Google News Archives*, from 2001 to 2006 more than 400,000 news articles were published online containing phrases with "outsourcing", while the total number between 1994 and 2000 was only 60,000.

Outsourcing occurs when a producer purchases products or semi-products from an outside supplier, rather than performing the corresponding work within its own facilities. These products can be either physically "visible" commodities or "invisible" services. This type of strategy involves a trade-off between the benefits derived from cost savings and efficiency improvements, against the increased difficulties and risks in business administration. Though the term itself is not recent, fragmented technology does lead to a new pattern of international trade via the expansion of global production sharing. This rapid expansion is one of the fundamental characteristics of international fragmentation of production in recent years. To make outsourcing a practicable business strategy, it should be feasible and profitable to divide the originally integrated production into sub-stage production phases. These could be separated geographically or chronologically. Global outsourcing has two-fold implications: it is profitable for outsourcing to occur in a global scope; yet a lion's share of outsourcing may take place in the sub-stage production of parts and components.

A mirror of international fragmentation of production could be international trade in parts and components, which has exhibited a fast growth rate exceeding that in the conventional trade of final goods. This type of trade has grown impressively with enormous improvements in the service sector, in particular the rapid growth in the telecommunications industry and the liberalization of international financial services. Between 1990 and 2005, the world's trade in parts and components grew from about $0.35 trillion to over $1.3 trillion – at a rate of 9.3% per year. This is higher than the average annual growth rate of the world's trade in manufactured goods (excluding chemical products) and that of the world's GDP during the

same period.[2] Unlike intra-industry trade, which seems to favour exchanges among developed economies, outsourcing is good for developing countries as well. In 2005, the total value of trade in parts and components between developing and developed countries and that between developing countries and the newly industrialized economies (NIEs) accounted for over one third of the world total, which is almost as much as the respective trade among developed countries. This is probably so because the international fragmentation of production allows developing countries to capture the production of certain product segments, rather than requiring them to supply a whole product competitively.

This paper examines the emergence of international fragmentation and global outsourcing of production as a new phenomenon in global economy. It introduces trade theories that have recently been developed to illustrate the economic rationales underlying this new phenomenon. Moreover, it evaluates to what extent the widespread incidence of fragmented technology has changed the pattern of the world economy.

The paper is structured in four parts. The next section outlines the growth of international trade in parts and components as a mirror of international fragmentation of production. Section 3 surveys the latest literature related to the theory of international fragmentation of production and global outsourcing. Section 4 summarizes.

2. The growth of international trade in parts and components

International fragmentation and global outsourcing of production since the 1990s has led to large-scale cross border exchanges of parts and components. Figure 1 shows the growth of trade in parts and components[3] between 1990 and 2000. For the world as a whole, this new type of trade grew from $355 billion to $846 billion, at an average growth rate of about 9.1% per year. By comparison, total world trade grew by 6.5% annually on average, while the world GDP expanded by 3.7% annually during the same period. It is evident that international trade in parts and components grew faster than intra-industry trade.

[Figure 1 about here]

The terms “cost savings” and “quality improvements” are closely related to outsourcing. Indeed, quality improvement plays an important role in global outsourcing, especially for those parts that rely on human creativity. Most business administrators will argue that quality improvement is as important as - or even more important - than cost saving. For instance, a typical producer in the American fashion industry may choose to outsource the design of its products to Italy, but outsource the batch processes to China. Though they are part of the

same phenomenon, these two types of outsourcing are somewhat different– the former is driven by considerations of quality improvement whilst the latter seems to be motivated by cost-saving effects. Another typical example is the cooperation between South Korea and China in the mobile phone industry. A South Korean firm reduces costs by outsourcing the processes of assembly and packaging to China; and a Chinese firm in turn can subcontract the design of its products to South Korea for better models. The positive effects of outsourcing are felt by both South Korea and China.

In the case of *North-South* outsourcing, the *North* normally "outsources" production to the *South* in order to gain from the cheaper cost of labour. Production in the *South* may be constrained by the relatively outdated technology it uses. To avoid a loss in quality, the *North* transfers the necessary technology associated with the sub-stage production to the *South*. In this way, global outsourcing can help the *South* gain access to advanced technology transferred from the *North*. The "know-how" process under international fragmentation of production seems to be relatively smooth as it happens "step by step". Since the *South* is capable of producing complex goods of similar quality but at comparatively lower prices, more segments will be outsourced to the *South*. The value of international trade in parts and components will increase not only due to the expansion of production sharing networks and the higher volume of trade, but also as a consequence of the increased average value-added to each unit of intermediate goods that are exchanged.

Figure 2 compares the intra and the extra-regional growth of trade in parts and components for NAFTA, the EU15 and East Asia.[4] It shows that the EU15 as a group is still the most active player in this "new game". This is true for both intra and extra-regional trade. A comparison of the intra- versus the extra-regional rate of growth shows that the EU15 is more "outwardly oriented" when it comes to trade of intermediate goods. From 1991 to 2005, its external trade expanded at an average annual rate of 8.7%, while internal trade grew at 6.3%. East Asia, however, moved from being relatively "outwardly oriented" to relatively "inwardly oriented" within 15 years, as its intra-regional trade grew much faster than its extra-regional trade (14% and 10% respectively). In 2005, the total volume of trade in parts and components for East Asia amounted to over 93% of that for the EU15. In comparison, this share was less than 60% in 1991. It may thus well be that the EU15 will lose its predominant position to East Asia as regards international trade in parts and components.

[Figure 2 about here]

2.1 Trade in parts and components classified by the factor intensities of the corresponding final goods

Based on the commodity aggregation system that was initially developed by Krause (1982)[5] and later updated by Cheng, Leung and Ma (2004), all parts and components will be categorized into three groups – 1) intermediate inputs for human capital intensive goods, 2) intermediate inputs for technology intensive goods, 3) intermediate inputs for unskilled labour intensive goods.

In 2003, about three-quarters of world's total exports of parts and components were for technology intensive products. International trade in parts and components under this category has grown continuously since 1992, at an average rate of 8.2% per year. The growth of trade in parts and components for human capital intensive goods was much slower compared to that for technology intensive goods. Its share of the world's total trade in parts and components changed in a "U"-shape: it declined from 26% in 1992 to 19% in 2000 and then increased to about 22% in 2003. Though the total value of the world's trade in parts and components for unskilled labour intensive goods tripled between 1992 and 2003, its share of the total trade in parts and components is still marginal.

[Table 1 about here]

Table 2 shows the market shares for different groups of countries. Developed countries as a whole still leads in the global market of parts and components, though their market share shrunk significantly in both imports and exports. Exports declined from 84% to 64.3% and imports from over 70% to about 60% between 1992 and 2003. The five newly industrialized economies (NIEs) increased their market share of exports of parts and components. In 2003, over 13% of the world's total parts and components were supplied by NIEs. This represents a significant increase since 1992, when NIEs accounted for only 6.7% of the world's total exports. The increase of developing countries and transitional economies is even more impressive. Developing countries saw a nearly six-fold increase in their exports of parts and components. In 2003, about 16% of all intermediate goods exchanged in the global market originated in developing countries. Meanwhile, their imports accounted for more than one fifth of the world's total imports. Developing countries as a group have been the world's second biggest exporter of parts and components since 1998. Nevertheless, the transitional economies also improved their position in global production sharing. Their share of the world's total exports and imports of parts and components has increased from 0.6% and 0.8% in 1992 to 4.0% and 4.5% in 2003 respectively. The data shows that the only group without significant growth are the least developed countries (LDCs), whose share of the global market was less than 0.01% of exports and less than 0.3% of imports in 2003.

[Table 2 about here]

Table 3 and Table 4 extend Table 2 by classifying parts and components into three categories based on their factor intensities. First of all, developed countries are still the most important exporters in most markets, even though their market shares have declined since the 1990s. Traditional trade theories suggest that developed countries are less competitive and developing countries are more competitive in producing unskilled labour intensive goods. Comparing the different groups of countries shows that developing countries and transitional economies have significantly increased their shares in exporting parts and components for unskilled labour intensive goods. However, this does not signify that developed countries have left this market. Indeed, in 2003, about three fifths of the world's total exports under this category still came from developed countries. As is shown in their trade profiles, around 1.6% to 2.3% of their exports of parts and components were of unskilled labour intensive products, which closely mirrored the world's average level.

Despite their relatively small economic size, NIEs are some of the most active players in the global production network, especially in the market for technology intensive products. From 1992 to 2003, 85% to 90% of exports of parts and components from NIEs fell under the category of technology intensive goods. Human capital intensive goods accounted for the other 9% to 14%. Exports of parts and components for unskilled labour intensive goods from NIEs had almost been "knocked out".

Developing countries are the fastest growing suppliers of intermediate goods to the global production network. In 2003, they contributed more than one-fifth of the world's total exports of parts and components for unskilled labour intensive goods, 20% of that for technology intensive goods, and 9% of that for human capital intensive goods. Their exports of parts and components for technology intensive goods expanded incredibly fast, at an average annual growth rate of over 18%. This might be explained by the sustained economic growth in China and India, both of which are popular destinations for outsourcing.

Finally, besides their expanding share of the world market in parts and components for unskilled labour intensive goods (2.5% in 1992 to 17.3% in 2003), transitional economies also increased their share of human capital intensive goods. In 2003, transitional economies accounted for about 6% of the world's total exports of parts and components for human capital intensive goods - even surpassing the share of NIEs - compared to a share of 0.6% in 1992.

Table 4 presents some additional information from the side of imports. Again, developed countries are the biggest importers of any type of parts and components. As opposed to exports, developed countries' imports of parts and components seem to be rather

stable. In the global markets of parts and components, they absorbed about 85% - 90% of that for unskilled labour intensive goods and around 75% - 80% of that for human capital intensive goods. The only category that shows a clear downward tendency is that of technology intensive goods, where the share declined from about 70% in 1992 to less than 60% in 2003.

Developing countries become more integrated into global production sharing. This is not only due to their increasing exports of parts and components, but also because they import more. Their total imports of parts and components for human capital intensive goods and those for technology intensive goods grew from around 12% and 18%, respectively, in 1992 to 16% and 23% in 2003. Similar to the observation that could be made on the supply side, parts and components for technology intensive goods also became more weighted in import portfolios of NIEs . Relatively speaking, their imports of parts and components for technology intensive goods increased at the cost of imports of unskilled labour intensive and human capital intensive goods. In 2003, about 92% of imports to NIEs of parts and components consisted of technology intensive goods.

[Table 3 about here]

[Table 4 about here]

When looking at the relative positions of trade of intermediate inputs and that in corresponding final goods, parts and components on average account for about 30% of the total world trade in machinery and transport equipment and miscellaneous manufactured articles. The ratio of international trade of intermediate goods to that of trade in final goods can be determined by several factors, such as the complexity of production, the degree of fragmentation, and the specific segments of outsourcing. The data shows that on average the ratio is less than 20% in the category of unskilled labour intensive goods; around one quarter in human capital intensive goods; and one third in technology intensive goods.

Since 2000, over 40% of developing countries' annual total imports of technology intensive goods were of parts and components. Developing countries, as a group, are net importers of parts and components for technology intensive goods. Their surplus primarily comes from trade with developed countries and NIEs. As previously mentioned, such a pattern of outsourcing from the *North* to the *South* may also implicate a gradual knowledge transfer and accelerate the technology progress.

Under the framework of integrated production, producers in the *North* are obliged to set up factories and fully transfer their technology to the *South* in order to gain from the relatively

cheap labour in the *South*. International fragmentation of production makes it possible for firms in the *North* to divide the production into a series of sub-stage blocks. They only have to keep "key processes" at home and relocate the other segments to the *South*. Meanwhile, the *North* would normally transfer the technology needed for those processes to the *South* to ensure the quality of its products. In contrast to the technology transfer in the case of integrated production, international fragmentation of production allows firms in the *North* to transfer technology step by step. Instead of transferring the technology needed for the entire production, firms would alternatively coordinate the transfer of technology to occur at the same pace as outsourcing. In this case, international fragmentation of production could smooth the transfer of knowledge from the *North* to the *South*, which is beneficial for both developed and developing countries. On one hand, developed countries can enjoy cost savings via the outsourcing of sub-stage production(s) to the *South*, while maintaining advances in core technology by keeping the "key processes" *North*-based. On the other hand, the know-how transfer process improves developing countries' capability to produce more complex components with higher quality. Moreover, it appears to be easier for the *South* to develop its own technology to produce differential goods, given the higher starting point attained by absorbing knowledge from the *North*.

2.2 The pattern of the global production sharing network

International trade in parts and components, driven by international fragmentation and production sharing, will provide more space for the growth for non-developed countries, such as NIEs, developing countries, and transitional economies. Figure 3 provides some evidence for this. First of all, in the global scope, the share of trade among developed countries declined significantly from about 60% in 1992 to around 40% in 2003. Second, trade between developed and developing countries accounted for more than 20% of the world's total trade in parts and components. Third, a significant part of the market that previously belonged to trade among developed countries seems to have been taken over by trade between developing countries and NIEs, and by trade between developed countries and transitional economies.[6] Fourth, the total value of parts and components exchanged among developing countries and among NIEs also increased significantly. International trade among NIEs in 2003 was 3.6 times more than in 1992. This rise doubled their share in the global market of parts and components. Trade among developing countries grew by about 27% per year. Their share in the world's market rose from 0.5% in 1992 to 2.2% in 2003.

[Figure 3 about here]

[Figure 4 about here]

Figure 4 distinguishes trade flows into exports and imports between different groups of countries over time. First, developed countries have significantly increased their imports from all the other three groups of non-developed countries between 1992 and 2003. During this period, the share of exports from developed countries to other groups of countries declined, except in the case of exports to transitional economies. In 2002, developed countries as a group began to face trade deficits mainly from trade in parts and components with NIEs. Though they still had a trade surplus with developing countries, the size of the surplus had reduced significantly, even in absolute terms, due to the fact that annual imports of parts and components from developing countries grew almost three times as fast as exports. Second, the share of the total exports from developing countries to the rest of world increased from less than 5% in 1992 to over 13% in 2003. Developed countries and NIEs were the main destinations for these exports. However, developing countries as a group were still net importers of parts and components. Though the gap between imports and exports of their trade with developed countries declined in relative terms, the absolute value of their trade deficit with developed countries was still more than $30 billion in 2003. Third, similar to the rise in trade between developing countries and NIEs, trade between developed countries and transitional economies also increased significantly in both directions since 1992. Fourth, concerning the trade surplus NIEs as a group seem to be the biggest beneficiaries from trade in parts and components. NIEs may here have benefited from their specialization in the production of parts and components for technology intensive goods. This is a consequence of the international fragmentation of production. Their overall surplus of trade in parts and components reached almost $40 billion in 2003, of which about 85% came from international trade with developing countries.

The observations so far seem to be consistent with what traditional trade theories would suggest – in *North-South* trade, the *North* will export relatively capital intensive goods while the *South* will provide relatively labour intensive goods. The data here shows that developed countries are net importers of intermediate inputs for the unskilled labour intensive goods and net exporters of parts and component for technology intensive and human capital intensive products. Developing countries are net exporters of intermediate inputs for unskilled labour intensive goods and net importers of technology intensive and human capital intensive goods.[7] International fragmentation of production opens a new door for international trade. It allows countries to develop via their participation in global production sharing, regardless of whether they are developed countries, NIEs, developing countries, or transitional economies.

2.3 Top exporters and top importers

Figure 5 shows the positions of the top ten exporters and the top ten importers of parts and components in 2003. The top ten exporters consisted of six industrial countries, two NIEs, and two developing countries. They contributed to two thirds of the world's total trade in parts and components in 2003. The degree of concentration was lower than in 1992, when the top ten exporters supplied about 80% of the parts and components exchanged.[8]

[Figure 5 about here]

The U.S. and Germany were still the leading countries in both imports and exports of parts and components. Despite the significant decline of their assembly market shares since 1992, in 2003 they accounted for about one quarter of the global market of parts and components. Indeed, almost all the leading industrial countries lost their market shares in relative terms during the period from 1992 to 2003. However, countries such as Germany, Japan and Italy did increase their trade surplus via the exchange of parts and components.

Within 12 years, the annual exports of parts and components from China increased 16-fold. Mexico's exports and imports accounted for 3.4% of the world's total trade in parts and components, while its GDP was only about 1.8% of the world's GDP. However, in both countries, the trade balance seemed to deteriorate with the expansion of trade in parts and components. Between 1992 and 2003, the share of Mexico's annual trade deficit due to trade in parts and components increased at almost the same pace as the expansion of its exports. China (Chinese mainland plus China Hong Kong SAR) had to shoulder a rather large trade deficit due to parts and components of over $32 billion in 2003. Apart from China Hong Kong SAR, the other NIEs have turned from net importers to net exporters of parts and components. As a whole, their overall global market share in 2003 was about 11.4%, which was even larger than the part of the market controlled by Germany. In comparison, their overall economic size was equivalent to only half of that of Germany.

3. Literature survey

The phenomenon of cross-border production sharing has been associated with concepts such as "vertical fragmentation", "off-shore sourcing", "sub-contracting" or "outsourcing". To some degree, they might just be different labels for the same bottle. Horizontal fragmentation refers to the strategy in which multinationals distribute their production bases around the world in order to supply different markets. Generally, this applies to a situation where the demand (or the potential demand) from the target market is big enough for the company's long-run growth, but trade barriers between the two countries are too high to open bilateral trade. Typically a multinational has to outflow part of its capital abroad to set up a factory in a

third-party country, or in the target nation directly, to more easily deliver their products to target markets.

Vertical fragmentation, as Jones and Kierzkowski (2001b) write, is "*creative destruction in the Schumpeterian tradition*", where the "*break down* [of] *the integrated process into separate stages of production opens up new possibilities for exploiting gains from specialization*." (Jones and Kierzkowski, 2001, p.17) Not only is the original integrated production function divided into separate production blocks, but sub-stage production and the creation of service links are also dispersed. Compared to horizontal fragmentation, vertical fragmentation leads to a worldwide production system in which each block contributes to a part of the final goods, either physically visible or invisible. The exchange of intermediate goods in vertical fragmentation is typically maintained by various service links. Fragmentation can take place either within the same firm or among different firms. A production sharing network driven by fragmentation can therefore range from "nation wide" to worldwide.

In practice, a producer has various options to realize the vertical fragmentation of its production on a global scale. In his online glossary, Deardorff defines outsourcing as the "*performance of a production activity that was previously done inside a firm or plant outside that firm or plant"*.[9] Outsourcing is essentially one special form of business strategy in organizing a global production network. It simply ignores the ownership of blocks and flows within the same production chain. That is to say, one can include any block that could optimize production in the global scope without concern for whether those production units are branched companies or joint ventures abroad, or just independent foreign producers that could supply qualified intermediate inputs. Often, producers (outsourcers) outsource one or several production sub-stage(s) to third-party producers (so called "insourcers" for convenience) using subcontracts, and coordinate outsourced production using various service links. Although the firms pursuing this strategy have to pay additional service costs for coordinating inter-firm production, they could seek intermediate inputs in the global scope and benefit from a higher degree of specialization. On the other side, "insourcers" could at the same time belong to several production value chains and thus benefit from a high degree of production specialization. This could be regarded as the horizontal aspect of vertical fragmentation. Moreover, since inter-firm fragmentation is normally associated with a knowledge transfer from the original producer to a new supplier of intermediate inputs, it may help improve the latter's productivity by accelerating its technological progress.

In short, the application of fragmented technology may allow producers to improve their productivity by improving specialization. Thanks to the rapid growth of the service sector, the

activities of outsourcing are breaking through the boundaries of nations as part of a global phenomenon. In particular, innovation in the information and communication technology industry since the late 1970s has significantly improved the capability of outsourcers to monitor sub-staged production, thereby facilitating production fragmentation in the global scope.

Even though, given that trade is not totally free, welfare change is brought about by the interaction between the distortion caused by trade barriers and the efficiency gains from specialization within a production sharing network , Arndt (1998, 2001) shows that the international fragmentation of production would unambiguously increase welfare in the context of free trade. In that case, the effects of outsourcing may act like technological progress. Furthermore, Arndt (2004a, 2004b) demonstrates that production sharing inside a free trade area could reduce the extent of trade diversion and even convert it into trade creation by generating comparative advantages in sub-stage production.

3.1 Fragmentation and outsourcing in the Ricardian model

In a series of articles, Jones and Kierzkowski (1990, 2001a and 2001b) establish a fundamental framework of production fragmentation, emphasizing the role of "*production blocks*" (stages of production) and "*service links*". One approach to understanding such a fragmented production pattern can be based on the Ricardian view of differing relative productivities of labour. Similar to the logic that the division of labour allows workers to be more specialized in particular tasks, a fragmented production pattern can be more productive than an integrated production pattern by increasing the degree of specialization at sub-stage level. Production blocks generated by vertical fragmentation are found to have different requirements for labour skills, with one economy containing factors more appropriate to one fragment and another economy populated by labour relatively more productive in another fragment. As production is divided into different stages, comparative advantages arise at the level of specific production stage(s), rather than for a finished product. For example, today the market would seek out a country's advantage in producing screens (the components of computers) or engines (the components of automobiles) rather than that in producing computers or automobiles. Even those economies holding limited advantages in technology or factor endowments for producing parts of a complex good could thus participate in global production sharing. In general, a product tends to be "better" (with higher quality and lower price) when its production is composed of more sub-stages.

It is rather straightforward to study the fragmentation of production in the context of the traditional Ricardian model. The basic idea is that fragmentation might lead to greater degrees

of production specialization. Suppose product *A* can be produced by either an integrated production technology, where the marginal labour input coefficient is denoted by α_L, or by a fragmented technology composed of two sub-stage production blocks, of which the marginal labour productivities are denoted by α_{L1} and α_{L2} respectively. Assuming that units of semi-products from the sub-stage of production must be matched one-for-one to obtain a unit of final output; $\alpha_L = \alpha_{L1} + \alpha_{L2}$. The home country shows its comparative advantage in producing and exporting *A* to the foreign country as far as $\frac{\alpha_L}{\alpha_L^*} = \frac{\alpha_{L1} + \alpha_{L2}}{\alpha_{L1}^* + \alpha_{L2}^*} < \frac{w^*}{w}$ [10]. Only a one-way trade exists. Suppose $\frac{\alpha_{L1}}{\alpha_{L1}^*} < \frac{w^*}{w} < \frac{\alpha_{L2}}{\alpha_{L2}^*}$, the home country has comparative advantages at segment *1*, and the foreign country has comparative advantages at segment *2*. From the Ricardian viewpoint, international fragmentation of production has four implications: First, it has productivity effects. The joint productivity of goods *A* will be superior to that under an integrated production pattern. Second, it has a trade creation effect. The overall trade volume between the two countries will increase, even though the total demand of goods *A* is unchanged. Third, it alters the trade pattern. The foreign country gets the chance to participate in the production of goods *A* by specializing in the production of segment *2*. Trade of goods *A* involves a two-way exchange: the home country exports semi-product *1* to the foreign country, and meanwhile imports semi-product *2* of goods *A*. Fourth, it has additional cost-saving effects for the home country.

Deardorff (2001a) studies international fragmentation of production in a small open Ricardian economy with two goods, one of which could be fragmented into sub-stage segments. When the costly fragmentation becomes possible in the export sector, given the assumption that the price of the final good is sticky, the change in the country's trade pattern will be determined by comparative advantages generated from fragmentation, which is reflected in the lower price of intermediate inputs. By employing fragmented technology, the country will be able to enjoy comparative advantages in producing goods where it was not competitive before. In a two-country Ricardian world where the price of final goods is floating, the model shows that the world will unambiguously gain from fragmentation as the total consumption of goods increases. Though countries can unambiguously benefit from employing fragmented technology, some of them might turn out to be net "losers" simply because the possible fall in the terms of trade (as a result of the change in prices) is too big to be compensated.

Long, Riezman, and Soubeyran's (2004) general equilibrium model is also based on the Ricardian model, where labour is the only prime factor considered. The economy has two

sectors: one provides a simple good produced directly by labour; the other provides a complex good that is the assembly of a continuum of components. One unit of each component is assumed to be the combination of one unit of labour and the "aggregate service" that is produced by labour with increasing returns of scale. The production of the aggregate service is positively related to the degree of specialization, and the number of varieties depends on its stage of development and the size of the economy. Initially, the *North* can provide a wider range of services than the *South*. Moreover, it is assumed that the greater range of services in a country may lead to a higher productivity in components (and consequently, the lower price of the complex good). Also, a component that has a high ratio of service to manufacturing labour would be produced in the country that has a greater range of services.

When services are non-traded, free trade will lead to a pattern where the *North* exports components that are more service-intensive, and the *South* exports components that are less service-intensive. Global outsourcing will lower the price of complex goods, of which the production is fragmented across different locations. From the *South*'s point of view, besides the low wage rate, there is a second channel to attract more production blocks from the *North* – to develop the service sector and improve the efficiency in manufacturing components. When services can be traded freely without transportation costs, international trade will be driven by the wage gap between the *North* and the *South,* following from the universal price of the aggregate service. The *North* will outsource all sub-stage productions of the complex good to the *South* in order to maximize gains from the low wage rate there. Furthermore, the range of components to be outsourced is constrained by the transportation costs of the specific services from the *North* to the *South*. In this case, global outsourcing will be encouraged by the savings in the transportation costs of services.

Rodriguez-Clare (2007) analyzes the aggregate effects of fragmentation in both the short term and the long term in the Ricardian context, where a country's labour is located in the production sector and the research sector. Here, final tradable goods are the combination of a continuum of intermediate services. It is assumed that the *North* can outsource a certain share of its intermediate services to the *South* without any additional costs. However, any outsourcing above that share is forbidden. The share of services to be outsourced will be determined by the relative wage gap between the *North* and the *South*, where the wage rate is defined as a function of technology per capita. Generally speaking, countries prefer to outsource intermediate services to another country where the wage rate is lower in comparison to the domestic level. In the short run, the wage in the *North* (both the nominal wage and the real wage) will begin to increase along with fragmentation, but once it reaches

the "optimal degree", the wage rate may decline, while the fragmentation continues to increase. Consequently, the negative effects on terms of trade grow to dominate the efficiency effects. In the long run, the *North* will relocate more labour towards the research sector, which will increase "technology per capita". Inversely, more labour in the *South* will be relocated towards the production sector. As a result, the adjustment in the long run tends to increase the wage rate in the *North* but decrease that in the *South*. Therefore, the *North* will gain more from offshoring in the long run than in the short run because of the improvement in the research sector. On the other hand, the long-run gains of the *South* would be less than those in the short term. The *North* will be the net winner as long as it can adjust its resource relocation quickly enough in response to outsourcing.

3.2 Fragmentation and outsourcing in the Heckscher-Ohlin model

The Heckscher-Olin framework makes it possible to examine cases where there are many factors in the economy and where different production blocks require inputs in different proportions. Taking into account the different factor prices and factor intensities, "*the international market place, with its variety of factor productivities (Ricardo) and factor prices and factor intensities (Heckscher-Olin) provides the richer possibilities associated with trade in production blocks to comparative advantage to add gains to those associated with increasing returns and fragmentation as the scale of output expands.*" (Jones and Kierzkowski, 1990, p.40).

Deardorff (2001b) explores the causes and the consequences of applying fragmentation technology across cones, based on a Heckscher-Ohlin model. Fragmentation of production happens when the cost savings of factor prices are large enough to offset the need for additional resources (typically the cost of additional service links). Where multi-cones exist, it is possible that an industry would be completely eliminated as a result of fragmentation. He further investigates the effect of fragmentation on factor prices and finds that the theorem of factor price equalization (*FPE*) will only be valid conditionally under the framework of production fragmentation. Typically, the production of a good could be fragmented into capital-intensive segment(s), produced in the *North*, and labour-intensive segments, processed in the *South*. Fragmentation seems to contribute to *FPE* when those capital-intensive segments belong to relatively labour-intensive processes in the *North*, and those labour-intensive segments are indeed relatively capital intensive in the *South*. Deardorff (2001a) also examines the effects of fragmentation on factor prices based on the Heckscher-Ohlin model. Again, the result shows that fragmentation can benefit a country by expanding the frontier of

its production possibility, although some factors within the country will unavoidably suffer losses. Moreover, fragmentation could enlarge the area where factor prices can be equalized via international trade. However, *FPE* still requires that factor endowments be more similar than factor intensities. It seems very likely, although not necessarily true, that fragmentation will enhance the possibility of factor price equalization via the increased economic activities resulting from global production sharing.

Baldwin and Roberd-Nicoud (2007) include three features to model international outsourcing: First, one country (the *North*) is technologically superior, in the Hicks-neutral sense, to the other; Second, the production of final goods involves sub-stage tasks; Third, outsourcing can happen in both sectors with iceberg-type coordination costs. Outsourcing could combine the relatively advanced technology in the *North* and the relatively cheap factor prices[11] in the *South*, given the condition that the initial cost gap between the two countries is big enough to assure that cost savings to the *North* can cover the additional coordination cost associated with fragmented technology. When technology spill-over is prohibited, the outsourced sub-stage production(s) can only supply the home country (the *North*) but not the local market. Outsourcing enriches the factor endowments in the *North* via "shadow migration", which can change the world's effective capital-labour ratio due to the exogenous effectiveness difference between the *North* and the *South*. To simplify this idea, ΔK is used to denote the shadow-migration of capital and ΔL is used to denote the shadow-migration of labour. In the *North* (which is relatively capital abundant), if $\Delta K/\Delta L$ is less than the world's initial (without outsourcing) capital-labour ratio, the relative price of the product that is relatively capital intensive trends to increase. The output of the labour-intensive product will rise, as long as $\Delta K/\Delta L$ is less than the capital-labour ratio in the sector that is relatively capital intensive. However, to ensure a fall in the output of capital-intensive products, $\Delta K/\Delta L$ is further required to be less than the capital-labour ratio in the sector that is relatively labour intensive. It appears that the world's total output will vary in the same direction as that of the changes in the *North*, since the exact opposite changes in the *South* would be discounted by the pre-assumed technological disadvantage.

Outsourcing could modify factor prices in the *North* (the outsourcer) via cost-saving effects. Suppose S_X and S_Y denote cost savings that result from the outsourcing of the product that is relatively labour intensive (X) and that is relatively capital intensive (Y), returns to both factors in the *North* will rise as long as the ratio S_X / S_Y is larger than the ratio of the relative capital coefficient and less than the relative labour coefficient between X and Y. The wage rate

in the *North* decreases only when S_X / S_Y is less than the ratio of the relative capital coefficient. On the other hand, the standard Stolper-Samuelson theorem can explain the changes in factor prices in the *South*. The shadow migration of factors to the *North* has similar influence as a decrease in the factor endowments in the *South*. When technology spillover is permitted, the factors owners in the *South* will further benefit from the technology transfer; and the prices of the same factors in both countries will move in the same direction. In the case of two-way intra-industry offshoring, the model shows that the real reward to at least one factor of production will rise and the production of at least one of the two final goods will rise as a consequence of outsourcing. Intra-industry trade exists even though the two nations have exactly the same factor endowments. Changes in factor prices will be ambiguous.

Kohler (2003) alternatively studies international fragmentation of production using a generalized factor price frontier, where international fragmentation and global outsourcing of production provide factor price combinations in addition to the price of the final output. His study is based on a model of two sectors, where sector *2* is a single stage industry and sector *1* produces a complex good using a constant return to scale technology, featuring a continuum of stages ($i \in [0, 1]$) with varying factor intensities. The "downstream" stages in sector *1* are relatively more capital intensive. Outsourcing is subject to iceberg type service cost. The overall cost advantage of outsourcing is independent of the price of the final good, but monotonically increases with *i*.

In Figure 6, ray $(w/r)_0$ represents the wage/rent ratio of the very upstream sub-stage of production, while ray $(w/r)_1$ represents the very downstream sub-stage. Curve $T_{i*}T_{i*}$ shows the equilibrium where the domestic factor price of sub-stage *i* is equal to the factor price when the production of that sub-stage is outsourced. For each sub-stage, there is a curve similar to curve $T_{i*}T_{i*}$ representing the "outsourcing equilibrium" factor price. Slopes of these contours are equal in absolute value to the capital intensity of stage *i*, which tend to be larger as *i* increases (more "downstream" stages). The curve c_0Ec_1, which is defined as the "endogenous fragmentation factor price frontier" (*ef-fpf*), is the assembly of the cross points of curve $T_{i*}T_{i*}$ and ray $(w/r)_{i*}$.[12] The initial equilibrium *E* of international fragmentation is determined by the intersection between the *ef-fpf* of sector *1* and the factor price frontier of sector *2*. In such settings, cost savings in service links can affect the degree of fragmentation in a way that is similar to the expansion of final goods output scale in sector *1*.

[Figure 6 about here]

There are three possibilities as to why the relative price of the final good in sector *1* will increase. First, if the numeraire sector is more capital intensive (the case that curve fpf_2^A

demonstrates) than that of the aggregate domestic value added in sector *1*, w will rise and r will fall. Second, if the numeraire sector is relatively labour intensive in comparison to sector *1* (the case that curve fpf_2^B shows), w will fall and r will rise. In both cases, the points representing the new factor prices (E_A and E_B) are located above the curve $T_{i*}T_{i*}$, meaning that it would be profitable to outsource more sub-stage production (ranged from $i*$ to i_A or from $i*$ to i_B) to the foreign country. Third, in the case where the capital intensity of the numeraire sector is higher than that of the marginal sub-stage $i*$, but lower than the aggregate factor intensity of the domestically located sub-stage(s) for good *1* (curve fpf_2^C), w will fall and r will rise. It becomes more efficient for some stages to be produced at home rather than to be outsourced abroad. In this case, the scale of sector *1* in the home country unambiguously increases because the output of good *1* expands and the number of the stages located domestically increases. Kohler (2003) further proposes that the Jonesian magnification effects underlying the Stolper-Samuelson theorem will be strengthened by the endogenous adjustment of the margin of fragmentation associated with a rise in final goods prices. However, the magnification effect will be mitigated when the relative price of final goods falls.

Venables (1999) builds a model using similar settings, in which the author also orders production blocks from "upstream" to "downstream", and the cost of service links is present. The outsourcing from the *North* to the *South* will start in the most labour intensive segment(s). Therefore, if the upstream activities are relatively labour intensive, outsourcing will increase the trade value; otherwise the total trade value will decrease.

3.3 Fragmentation and outsourcing in the specific factors model

Kohler (2000) provides an alternative view of the international fragmentation of production based on a specific factors model. Capital, as the sector specific factor, can move between segments within the sector (sector *X*) that employs fragmented technology, when only one segment (fragment-*2*) is open for outsourcing. The decision whether or not to outsource this fragment relies on the comparison between the cost-saving effects generated from the wage gap between the home and the foreign country, and the cost of international fragmentation, which is the sum of a fixed cost, and an iceberg type variable cost. These settings allow for the comparison between the case of international capital mobility ("outsourcing with FDI") and that where cross border capital flows are forbidden ("outsourcing without FDI"). When international capital is mobile, fragment-*2* in section X (the sector with the specific factor) will be outsourced because of the increasing marginal productivity of capital of fragment-*2* at the equilibrium level. Meanwhile, capital will move

from the home country to the foreign country. Depending on the relative wage difference, fragment-*2* can be either "outsourced completely" or "partially outsourced". Changes of the domestic wage rate can be unambiguously determined by the foreign wage rate plus trade costs associated with outsourcing. However, net welfare may or may not be improved, regardless of the fact that output will increase, and that the home country will benefit from cost savings and additional capital gains. This is not due to the diminishing marginal return of labour, but rather to the fixed cost of fragmentation. It is more likely that international fragmentation improves welfare when 1) the gap of domestic and foreign wage is large enough, 2) the share of value-added generated by the outsourced segment in the final goods is big enough; and 3) labour demand is elastic enough.

When cross-border capital flows are forbidden, the home country can only choose between "non-outsourcing" and "complete outsourcing" of fragment-*2*. The increasing capital rental at sector *X* resulted from outsourcing of fragment-*2* cannot be balanced via FDI. Since capital is mobile between the two fragments within sector *X*, fragment-*1* will increase its demand for domestic labour. In this case, outsourcing has two-sided effects: 1) a downward pressure on the domestic wage rate due to the lower labour cost in producing fragment-*2* in the foreign country; and 2) an upward pressure resulting from higher labour demand from fragment-*1*. It should be pointed out that outsourcing without FDI of the segment (fragment-*2*) that is relatively labour intensive will decrease the domestic wage rate only when the sector is sufficiently large in terms of its share of overall labour demand; and the differences in factor intensity between fragments within this sector are highly pronounced.

Kohler (2002) extends his study to the efficiency and redistribution effects of international fragmentation. He shows that potential welfare gains to the domestic economy seem to be positively correlated with the initial *North-South* wage difference. The discrete shift from integrated production technology to international fragmentation of production can be demonstrated as a non-cooperative two-stage game. When the market is perfectly free, firms in the *North* choose between domestic integrated production and fragmented technology by investing the segment-specific capital (capital for fragment-*2*) either in the *North* or in the *South*. Since the location of fragment-*2* production in the *South* would increase wages in the *South* and influence the wage rate in the *North*, decisions in previous stages would determine the relative effective wage rate for stages in the downstream. Although complete outsourcing can be a stable equilibrium when the domestic labour demand in the *North* is not sufficiently

elastic, international outsourcing may in this case lead to welfare loss, especially when the outsourced segment is highly labour-intensive compared to the labour demand elasticity.

Feenstra and Hanson (1996)'s model distinguishes skilled labour from unskilled labour. There is only one final good that needs a continuum of intermediate inputs. They find that outsourcing from the *North* to the *South* tends to widen the wage gap between skilled and unskilled labour within a country. However, since the price of final goods will decline as a result of outsourcing, even the real wage of unskilled labour in the *North* may increase. Extending this to a multi-country model, Markusen and Venables (2005) point out that in many cases, a country's production specialization is positively related to the difference between its factor endowments and the world endowment. An increase in specialization may lower a country's trade volume, since the country will only import the components that it does not have comparative advantages in, rather than importing the whole product. As a result, countries with an average world endowment will trade a lot. Fragmentation will lead to a pattern of production that is suitable to those countries whose factor endowments are dissimilar to the world's average level. Lowering trade costs worldwide will draw more countries out of autarky and increase specialization in sub-stage production. Although a worldwide fall in trade costs can boost trade volume and specialization in the world as a whole, international fragmentation may also generate winners and losers.

3.4 Fragmentation and outsourcing at firm levels

Modelling fragmentation and outsourcing at firm levels, Harris (2001) emphasizes that the main driver of international fragmentation could be gains from specialization. Besides increasing returns to component production, he narrows the service costs of international fragmentation to the cost of creating/maintaining an international communication network. Suppliers of intermediate goods are divided into two groups: those who supply the local market and those who supply the global market. While local suppliers are subject to a fixed entrance cost, global suppliers are subject to a network cost which is determined both by the geographic size (the number of markets involved in the network) and the density of users (the number of components traded within the network). The change of the network cost is expressed as a "U"-shape. Initially, it will decrease as the number of network users increases, due to the increasing return to scale. When the market grows to a certain level, however, the overall network cost starts to increase because of the increased cost for resolving network congestions that are a consequence of the "crowdedness" of the network. This brings about multiple equilibriums to the model, among which only the one with the largest market size is stable.

Harris (2001) first finds that the volume of international trade is directly proportional to the total network cost. The lower network cost encourages higher volumes of trade in parts and components. It is more likely to see a higher degree of fragmentation in industries that produce complex products. In general, the number of global components will increase as the size of the global economy expands. Technological progress reduces the average cost of network services in absolute terms and promotes international fragmentation of production. Harris concludes that the substantial reduction in service costs (in particular the cost of communication networks) could lead to a further expansion of international fragmentation.

Grossman and Helpman (2005) consider a general equilibrium model in which outsourcing may take place in both the *North* and the *South*. Producers of final goods can seek partners in the technologically and legally advanced *North*, or they can look in the low-wage *South*. The relative wage in the *North* tends to be higher if the customization of intermediate inputs in the *South* is costly. It would also be more profitable to find a partner in the market containing more suppliers. The relative wage rate in equilibrium is determined by the intersection between the number of intermediate input suppliers in the *North* (curve *NN*) and the *South* (curve *SS*).

[Figure 7 about here]

They find that the expansion of labour in the *South* will cause the relative wage in the *South* to rise, as long as outsourcing continues to take place in both countries. Accordingly, the equilibrium will move from E_0 to E_1, as shown in Figure 7. Because of the presumption that outsourcing is an activity with increasing returns at the industry level and that the number of outsourcing activities is positively related to the number of components producers, the wage of the *North* has to fall relative to that of the *South* in order to maintain the equal profits in both regions. Similarly, a new equilibrium can be found when the technologies for customization improve to a disproportionate extent in the *South*. In such a case, however, the relative wage in the *North* will first increase (shown by the ray $w=w'$), as the technology progress improves the efficiency in the *South*, and afterwards fall to lower than the initial level (for example E_1), as more outsourcing activity shifts from the *North* to the *South*. In both cases, the ratio of trade as part of world income and the share of intra-industry trade will increase. Moreover, the study finds that the improvement of the contracting possibilities in a country tends to raise the relative profitability of outsourcing. The *South* can improve the legal environment in order to attract more outsourcing activities from the *North*.

3.5 The cost of service links and technological progress

Jones and Kierzkowski (1990) argue that service links play a crucial role in the distinction between integrated production and fragmented technology. Under integrated technology, the whole production procedure takes place within a single production block, where the role of services is limited. The implementation of fragmented technology breaks the production into several sub-stage segments that can be located separately in different geographical regions to optimize the production of the final good. Although there are direct cost-saving effects on production, fragmented technology, on the other hand, requires additional service links to chain together the various production blocks. These links can be best thought of as consisting of bundles of activities coordination, transportation, telecommunications, administration, insurance, financial services, and so on. Accordingly, international fragmentation of production involves additional costs of international service links to connect production blocks that are physically located in different countries.

The term "*service links*" in the Jones-Kierzkowski's framework of fragmentation should be distinguished from other "*services*" that are provided elsewhere in international trade. At firm level, the cost of service links will be recorded under the category of "general and administrative costs" or "indirect costs", rather than that of "direct costs". When the cost of overall production is categorized into service costs and direct costs, the former refers to the necessary cost needed to coordinate the fragmented production network, while the latter consists of all the other costs involved in production blocks. Because of increasing returns to scale in service sectors, the cost of service links could be regarded as a fixed cost in the final production function. Generally speaking, a higher degree of fragmentation can lower the direct cost of each unit produced, but require more fixed inputs of service links; whilst a production technology with lower degree of fragmentation or an integrated production pattern would require lower or no service costs, instead leading to higher direct costs. As the total service cost is fixed during the lifetime of a specific technology of fragmented production, the expansion of the market encourages an increase in the degree of international fragmentation.

Originally introduced by Jones and Kierzkowski (1990), Figure 8 illustrates the relationship between the costs and the output of fragmented technology. Part (a) illustrates production functions using different types of technology. Ray *0A* describes how the total production cost rises as output expands, given that the whole production took place in a single production block, which is subject to constant returns to scale. The slope of the curve is equal to the marginal cost of production. Line F_BB introduces a fragmented technology of production that is more advanced than that represented by line *0A*. It breaks up the production into sub-stage segments that can be geographically located in different regions. Fragmentation

could make the production of parts and components more efficient and subsequently render the final product more efficient too. Therefore, line F_BB is flatter than line $0A$. The necessary cost of service links needed to coordinate the distributed production activities would enter the overall production function as a fixed cost ($0F_B$). Thus, it is economically advantageous to shift from integrated production to fragmented technology only when the potential market is big enough. The requisite output level is determined by the cross point of Ray $0A$ and line F_BB. Similarly, line F_CC represents another fragmented technology that is even more advanced. Efficiency can be further improved by using a technology with a higher degree of fragmentation. Nevertheless, the cost of the service links associated with this production pattern is also higher. In the figure, an "optimal" production pattern of the economy can be outlined by $0abC$. To simplify this illustration, the three production technologies will be called "pattern *A*", "pattern *B*" and "pattern *C*".

Part (b) of the figure takes another point of view. On the Y-axis, $0S_A$, $0S_B$, and $0S_C$ are equal to the slope of line $0A$, line F_BB, and line F_CC in part (a), respectively. $0S_A$ denotes the lowest unit cost of integrated production using technology *A*, while $0S_B$ and $0S_C$ indicate the lowest average cost the production in pattern *B* or pattern *C* could achieve.

The corresponding marginal cost of the optimal production pattern $0abC$ in part (a) of the figure is represented by S_Acde. There is no service cost when the market is smaller than O_1. The average cost is always equal to $0S_A$ up until the output reaches point O_1, when the fragmented production pattern *B* replaces pattern *A* as the most advantageous. In range between point O_1 and point O_2[13], the service cost of each unit of production continues declining as the market expands. At point O_2, when the production shifts to the pattern with a higher degree of fragmentation, the direct cost will drop and the unit service cost will increase, similarly to the situation at point O_1. If output is constant overtime, the function of the average cost will also be continuous, despite the discretion towards direct production costs and service costs. Changes in the unit of service costs are represented by the $0O_1$, curve fm and curve gn.

[Figure 8 about here]

3.5.1 The decline of service costs

Lowering service costs significantly promotes international fragmentation of production. As Jones and Kierzkowski (1990) summarize, there are at least three main drivers behind the cost reduction of service links. First, technological innovation makes it easier and cheaper for service links to connect different production blocks. In particular, technological progress in

sectors such as telecommunications and financial services has pronounced effects on reducing the relative costs of service links. Second, deregulation and market liberalization accelerate the pace of cost reductions. The decline of transportation costs and the removal of trade barriers through multilateral trade negotiations not only require producers around the world to compete in the global scope, but also provide them with opportunities to optimize production via international fragmentation and global outsourcing of production. Third, knowledge transfers in the global scope not only enhance the compatibility of products, but also improve the standardization of service links across the world. Both effects allow for the production sharing network to be more profitable and easier to enlarge.

The decline of service costs can be demonstrated as a parallel movement from line F_BB to line $F_{B'}B'$ (as seen in part (a) of Figure 9) – entitled "*a*-type cost reduction". The *a*-type cost reduction does not affect the lowest average cost that production, using fragmented technology B, could eventually achieve. As far as $S_B = S_{B'}$, such a cost reduction does not have long-term fundamental effects.

Another possibility is that line F_BB will turn clockwise to F_BB' as part (b) demonstrates – entitled "*b*-type cost reduction". In this case, the effective cost of service links, which the fragmented production needs to bear, declines as the quality of services improves. Either type of cost reduction lowers the minimum requirement of the market size (level of O_1' or O_1'' instead of O_1) needed to implement a production technology with a higher degree of fragmentation. Even though the *b*-type cost reduction does not change the fixed service cost directly, $S_{B'} < S_B$ implies that it has fundamental effects in the long-term. Essentially, fragmented technology B makes the economy more efficient by increasing the quality of service links.

[Figure 9 about here]

3.5.2 Fragmentation and outsourcing acts like technological progress

The Solow growth model illustrates that technological progress could be a fundamental driver of economic development in the long run. International fragmentation of production may have similar effects on the economy. This idea became widely accepted after Mankiw (2004) announced to the U.S. business community that global outsourcing may act like technological progress. As Baldwin (2006) interpreted, "*Mankiw-offshoring means new trade – trade in intermediate goods and services that were previously packaged together in a black-box production function. … [T]he end result is that more final goods can be produced from*

any given quantity of primary factors." Indeed, the idea that international fragmentation and outsourcing can effectively expand the factor price frontier of the economy is not a new idea in the academic community.

Figure 10 illustrates why international fragmentation of production "acts like" instead of "acts exactly the same way as" technological progress. In brief, by improving production efficiency, technological progress allows the economy to produce the same scale of output, but with lower costs. Suppose the economy remains under an integrated production pattern before and after the technical change; Ray *0A* will turn clockwise to Ray*0A'*. Accordingly, the marginal cost of production will drop from S_A to $S_{A'}$. Line F_BB, which is parallel to Ray *0A'*, represents a fragmented technology that has similar impacts on the economy. Since the cost of service links enters the overall production function as a fixed cost, it tends to disappear as the output approaches infinity. The additional unit payment for service links under fragmented production is measured by the distance between curve *ce* and the horizon indicated by $S_{A'} = S_B$.

[Figure 10 about here]

Arndt (1997, 1999) finds it evident that outsourcing of sub-stage production in labour-intensive industries from the U.S. (a typical capital abundant country) to Mexico (a typical labour abundant country) has similar impacts on the remaining production blocks as that of technological improvement. American workers in the labour-intensive sector gain from this increasing productivity, as long as prices of final goods remain constant or do not decline significantly.

Furthermore, technological progress as an outcome of R&D activities requires a significant amount of physical and human capital as inputs. Generally, it is more competitive to locate R&D activities in the *North* because of its abundance of human capital. From the viewpoint of developing countries, it would be "cheaper" for them to access more advanced technology by participating in the production sharing network, rather than investing in their own R&D activities from zero. On the other side, outsourcing segments that have relatively low value added to the *South* allows the *North* to be more specialized in R&D activities. This can accelerate the progress of technological innovation. If it were true that outsourcing goes hand in hand with technological transfers of the corresponding sub-stage production, the world as a whole would unambiguously benefit by saving the unnecessary duplicated investment in R&D activities, and by distributing the application of advanced technology across borders. Therefore, it is possible that international fragmentation would not only act like technological progress, but also push forward the innovation and the spread of technology.

3.6 Selected empirical studies on fragmentation and outsourcing

Evidence of international fragmentation and outsourcing has also been found in a series of empirical studies. Yeats (1997) provides an overview of the global production sharing network based on a survey of trade in parts and components for OECD countries, and of trade in tariff-induced offshore assembly processing activities. He shows that the share of components in the OECD's total exports of machines and transportation equipment has steadily increased between 1978 and 1995. While the U.S. and Germany were still the two biggest importers in 1995, their combined share of imports of parts and components were approximately 40% lower than in 1978. The data also indicates a trend of deeper involvement of developing countries in international production sharing, especially for of Mexico and China. Although the investigation into the tariff induced "*offshore assembly processing*" (*OAP*) activities of the U.S. is initially designed to illustrate the development of *North-South* production sharing, the data shows that both developing countries and developed countries could be important players in *OAP* activity. OECD trade barriers, labour cost differences, transportation costs, and governmental policies all significantly influence production sharing between developing and developed countries. The scale of the global production network is indeed "very big"; and international trade in parts and components is growing at a faster pace than that of aggregate trade flows.

Ng and Yeats (1999) provide a comprehensive survey of production sharing in East Asia. The direct evidence of the expansion of East Asian production sharing network comes from the rapid growth of intra-regional trade in parts and components, which accounts for about half of the total intra-regional trade in commodities. Within the network, assembly operations tend to migrate to low-waged countries, and high-waged countries prefer to increase their specialization in producing intermediate goods. In Singapore, Taiwan and Japan most assembly operations are typically in a "sunset" stage, while other countries in the region, such as Indonesia, Thailand and Malaysia, seem to have "*the broadest and most mature assembly capacity for components*". Ng and Yeats (2003) furthermore show that international trade in parts and components has become responsible for a significant part (over 20%) of all intra-industry trade in manufactured goods. About two-thirds of these are intermediate goods of office machinery and telecommunications equipment. This high level of concentration in production reflects the comparative advantages of most East Asian countries. Within the region, Japan is the most important supplier of parts and components, while China (including Chinese Hong Kong SAR) is the biggest importer of components. Assuming that production of components is relatively capital and technical intensive, and that assembly operations are

relatively low-cost labour intensive, Ng and Yeats (2003) point out that "*trade in parts and components … often serves as a means of penetrating markets for high technology or high skill products*". They expect that the Heckscher-Ohlin theory might be more suitable to explain the pattern of production sharing in East Asia, where countries' roles in the production network are mainly based on their factor endowments.

Based on detailed analyses of the East Asian production network, Kimura and Ando (2005a, 2005b) find evidence that the formation of international production networks has changed the pattern of production in various sectors in East Asia, especially in those sectors where the value chain is reconstructed by vertical fragmentation. Basically, international fragmentation of production tends to increase the concentration of arm-length transactions due to two factors: First, service links are indeed non-homogeneous activities and are subject to strong economies of scale; second, in reality trade costs are not yet totally "dead", though they have been significantly reduced. The changing behaviour of Japanese firms reflects the trend of "two-dimensional" fragmentation, which will enhance the vertical production chain and allow local firms to penetrate production sharing, initially dominated by multinationals.

Athukorala and Yamashita (2005) also observe the changing production pattern in East Asia, using trade data of parts and components based on the classification SITC rev.3. They find that international trade in parts and components has grown faster than the conventional trade in final goods. The degree of dependence of East Asian economies on the production sharing network is "*proportionately larger*" compared to countries in North America or Europe. International fragmentation of production can promote intra-regional economic interdependence among East Asian countries, without lessening the region's dependence on the global economy.

Kaminski and Ng (2001) focus on the ten central European economies (CEEC-10)[14]. They show that trade in parts and components of these countries has been growing rapidly. Though all of these countries run deficits in trade of intermediate goods, the gap is on the decline. As for the composition of trade items, both their exports and imports are highly concentrated in parts and components of motor vehicles, telecommunications equipment, and furniture. The EU-15 countries, especially Germany, are the major market for parts and components originating from the CEEC-10. Most of the trade between the CEEC-10 and the EU-15 countries can be attributed to their participation in the common production network, which consists of both vertical and horizontal fragmentation. International fragmentation will

help the CEEC-10 members catch up with the EU-15 countries in a process marked by the convergence of the composition of their trade in parts and components.

Other empirical contributions come from case analyses of specific industries. For instance, in a study of production fragmentation in the Italian textile and clothing industry, Graziani (2001) regards the whole industry as a value-added chain that is composed of four sub-staged segments, each characterized by different factor intensities. Most of the outsourced segments in the Italian textile and clothing industries are relatively labour intensive. Within the production chain, developing countries could grow via upgrading from low-value added sub-stage production towards more capital intensive and higher value-added segment(s). Although textiles and clothing might generally seem to be too expensive to be produced domestically in most developed countries, international fragmentation of production does allow them to keep some of their advantages, by focusing on more sophisticated and skill intensive stage(s) of production. For instance, Italian textile producers have improved the quality of their products by enhancing services, while Italian clothing producers have managed to identify the uniqueness of their products by stressing the fashion content. These strategies allow Italian producers to classify "made in Italy" as high quality products and to distinguish these from products from developing countries, which are cheaper but normally characterized by lower quality.

Petrucci and Quintieri (2001) come to similar conclusions while examining the evolution of the Italian apparel industry based on a general equilibrium model with vertical product differentiation and sector specific factors. Normally, exploiting comparative advantages at high value-added, high quality end of the spectrum can compensate for losses in low value-added mass-producing branches of apparel. The successful experience seen in both the apparel industry and the textile and clothing industry in Italy suggests that developed countries could also gain from international fragmentation and outsourcing by developing competitive advantages in producing higher quality goods.

Ruane and Görg (2001) examine the fragmentation of the electronics industry in Ireland, by examining the level of outward/inward processing trade (*OPT/IPT*)[15]. They find that the electronics industry is the most important sector in Ireland when it comes to participating in international production sharing, as its *IPT* grew three times faster than that of the EU between 1988 and 1997. Despite the trend for shifting towards high-skilled intensive

segments of fragmented production, the Irish electronics industry still maintains its competitiveness mainly because of its relatively low-cost high-skilled labour force.

4. Concluding remarks

International fragmentation and global outsourcing of production lead to a new production pattern in the global economy. As a symbol of globalization, global production sharing eliminates border constraints, and makes it possible for firms to fragment and therefore optimize production in a global scope. It provides opportunities for all countries, regardless of their distinct starting points, to integrate their growth in global development.

Emphasizing the framework of international fragmentation of production introduced by Jones and Kierzkowski (1990) and the literature enriched by economists from different schools since the 1990s, this study examined the phenomenon of international fragmentation and global outsourcing of production from the perspective of international trade. It showed through empirical evidence that the international fragmentation of production has become a symbol of globalization. Theoretically, the economic rationales behind this new phenomenon of international trade can be illustrated and explained by various studies based on classic trade models.

International trade in parts and components will make it easier for countries, especially developing countries, to be more competitive in cross-border production sharing. To some extent, international fragmentation and global outsourcing of production could drive economic growth in a manner similar to growth driven by technological progress.

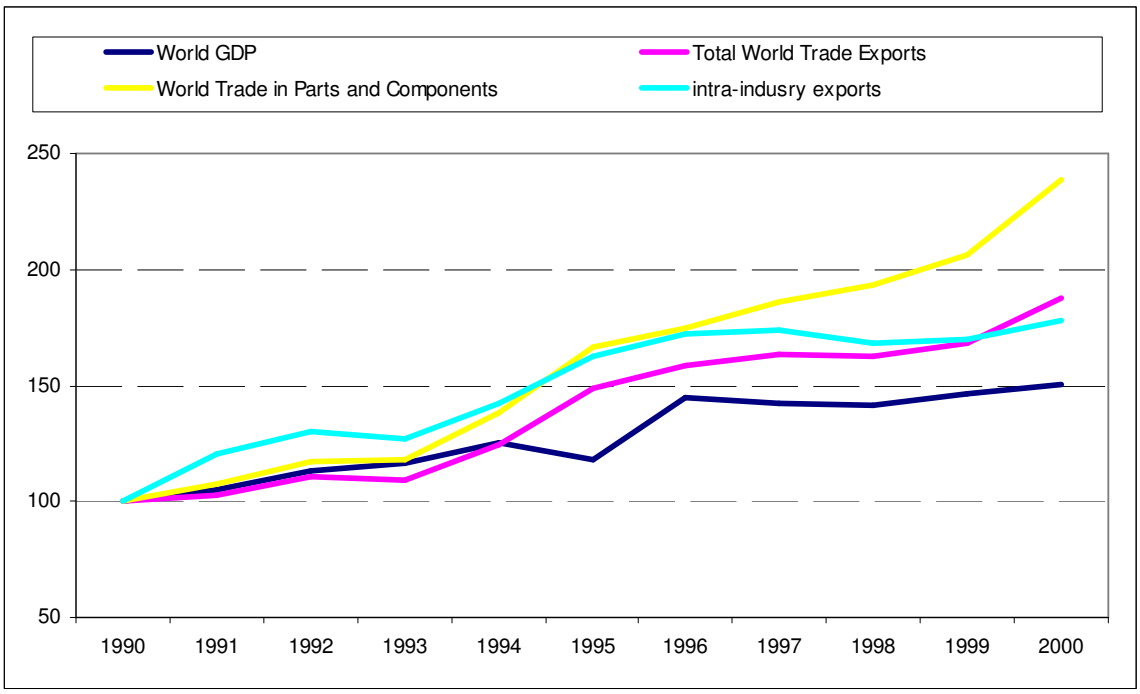
Notes

[1] This is based on a search performed at Nov.2, 2007.
[2] During this period the world's trade in manufactures (excluding chemical products) grew at about 8.1% annually while the world's GDP expanded by 4.8% annually.
[3] Following Ng and Yeats (2003), the trade flow in parts and components is defined as the sum of those items under the groups SITC7 ("Machinery and transport equipment") and SITC8 ("Miscellaneous manufactured articles") in the UN COMTRADE database, with their description in SITC rev.2 classification containing "Parts, nes of...". "Parts, nes of " is used as the keyword to identify parts and components, as Ng and Yeats (2003) have done.
[4] All data is for imports plus exports. East Asia is defined as ASEAN 10 plus Japan, South Korea, and China (including Hong Kong and Macao).
[5] According to Kraus' classification, tradable goods are split into four categories: natural resource intensive, unskilled labour intensive, human capital intensive, and technology intensive.
[6] Between 1992 and 2003, the share of trade between developing countries and NIEs grew from 4.3% to 10.3%, and that between developed countries and transitional economies grew from 1.6% to 7.1%.
[7] Net exporter(s) and net importer(s) of parts and components

	Net exporter(s)	Net importer(s)
Parts and components for unskilled labour intensive products	Developing countries (1994 - 2003), Transitional economies	Developed countries, NIEs Developing countries (1992, 1993)
Parts and components for technology intensive products	Developed countries, NIEs (1993 - 2003, except 1997)	Developing countries, Transitional economies, NIEs (1992, 1997)
Parts and components for human capital intensive products	Developed countries, NIEs (1998 – 2003, except 2000),	Developed countries, Transitional economies, NIEs (1992-1997, 2000)

[8] In 1992, 8 of the 10 top exporters of parts and components were developed countries. The remaining two were NIEs (Singapore and Taiwan, China).
[9] See http://www-personal.umich.edu/~alandear/glossary/
[10] w represents wage rate. When labelled with the superscript *, it denotes the corresponding variables for the foreign country.
[11] Due to the absolute difference between the *North* and the *South*, outsourcers from the *North* can pay for factors in the *South* based on the local factor prices rather than their marginal productivities.
[12] For instance, there is a curve T_0T_0 cross ray $(w/r)_0$ at point c_0 and a curve T_1T_1 cross ray $(w/r)_1$ at point c_1. The slope of each cross point indicates the marginal capital intensity of that sub-stage production.
[13] The range includes point O_1 but excludes point O_2.
[14] The ten countries are Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia.
[15] *OPT* are intermediate goods that are temporarily exported outside EU for processing and then re-imported as final goods for sale in the EU. Inversely, *IPT* are intermediate goods that are temporarily imported from outside EU. They are re-exported to the market(s) outside the EU when processed into final goods.

Figure 1: Global income and trade, 1990-2000



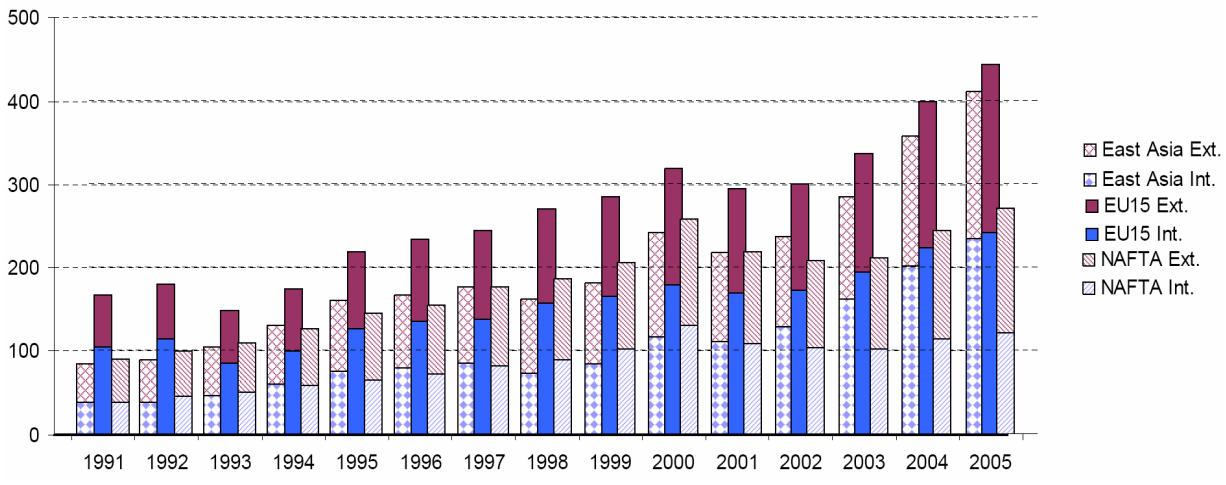
Data source:

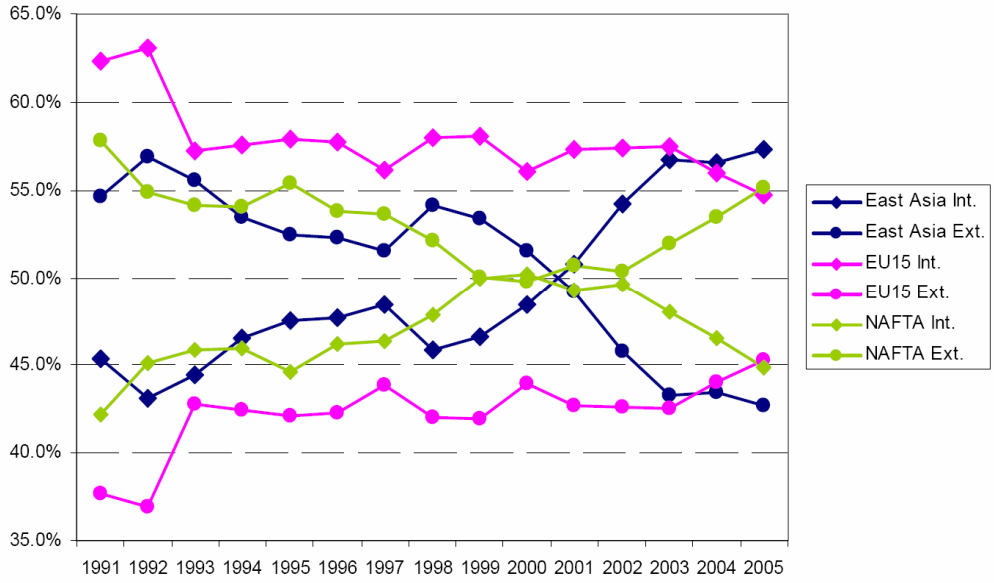
1. GDP form World Develop Indicator, 2002, World Bank
2. Trade data comes from Ng and Yeats (2001)

3. Intra-industry exports data is calculated from Industrial Demand-Supply Balance Database, 2004, UNIDO

Notes: Year 1990 is the base year.

Figure 2: Trade in parts and components by Regions (billion US dollars)





Data source: The author's calculation based on UN COMTRADE online database.

Table 1: Share of the three groups of parts and components

Year	parts and components for unskilled labor intensive goods	parts and components for human capital intensive goods	parts and components for technology intensive goods
1992	1.7%	26.0%	72.4%
1993	1.7%	23.8%	74.5%
1994	1.7%	23.5%	74.8%
1995	1.8%	22.6%	75.6%
1996	1.9%	22.3%	75.8%
1997	1.9%	21.4%	76.7%
1998	1.9%	21.3%	76.7%
1999	2.0%	20.8%	77.2%
2000	1.9%	19.0%	79.1%
2001	2.0%	19.4%	78.6%
2002	2.1%	20.8%	77.1%
2003	2.2%	21.9%	75.9%

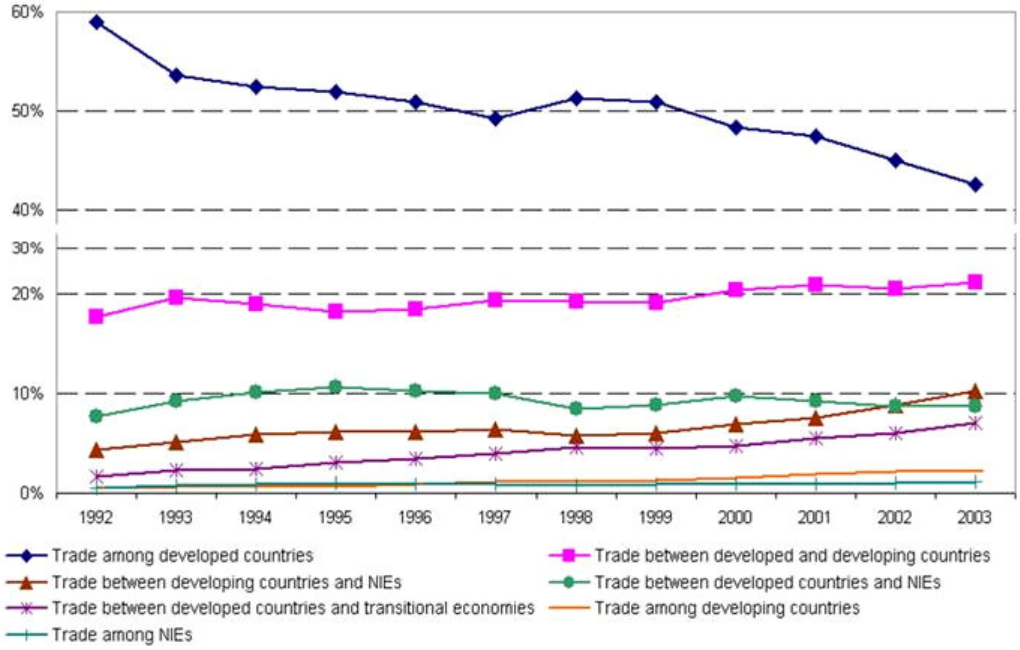
Data source: The author's calculation based on UN COMTRADE online database.

Table 2: Share of trade in parts and components

	PART I: Share of the world's total exports of parts and components					PART II: Share of the world's total imports of parts and components				
	Developed Countries	Developing countries	LDCs	NIEs	Transitional economies	Developed countries	Developing countries	LDCs	NIEs	Transitional economies
1992	85.5%	5.6%	0.0%	8.3%	0.5%	72.3%	16.5%	0.1%	10.3%	0.7%
1993	82.2%	6.8%	0.0%	10.2%	0.7%	68.0%	18.4%	0.1%	12.4%	1.1%
1994	80.4%	7.6%	0.0%	11.2%	0.8%	67.9%	17.6%	0.1%	13.1%	1.3%
1995	79.6%	8.0%	0.0%	11.2%	1.2%	66.5%	17.6%	0.2%	13.9%	1.7%
1996	78.9%	8.8%	0.0%	10.6%	1.7%	65.0%	18.7%	0.2%	13.4%	2.7%
1997	78.1%	9.8%	0.0%	10.3%	1.8%	63.7%	19.2%	0.2%	13.7%	3.3%
1998	77.7%	10.8%	0.0%	9.3%	2.3%	66.3%	18.4%	0.2%	11.3%	3.8%
1999	75.8%	12.2%	0.0%	9.8%	2.2%	67.9%	17.6%	0.1%	11.1%	3.2%
2000	72.6%	13.9%	0.0%	11.2%	2.4%	65.5%	18.7%	0.2%	12.5%	3.2%
2001	71.9%	14.6%	0.0%	10.6%	2.9%	64.7%	19.6%	0.2%	11.9%	3.6%
2002	69.9%	15.7%	0.0%	11.0%	3.4%	63.3%	20.8%	0.2%	11.9%	3.8%
2003	67.4%	16.3%	0.0%	12.1%	4.2%	62.2%	21.0%	0.3%	12.1%	4.4%

Data source: The author's calculation based on UN COMTRADE online database.

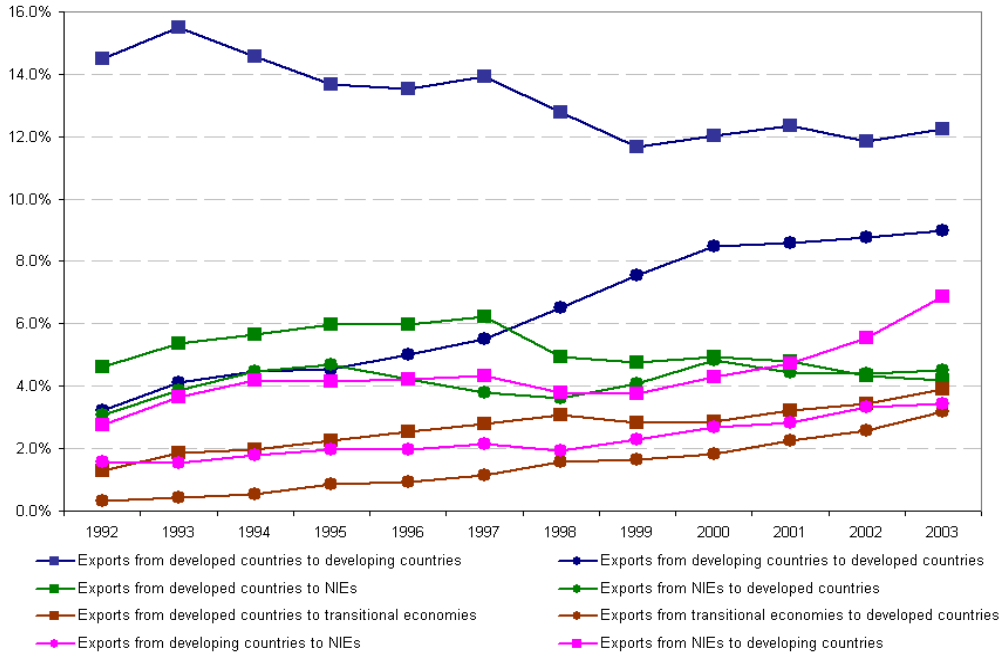
Figure 3: Comparison of the shares of trade in parts and components between groups



Data source: The author's calculation based on UN COMTRADE online database.

Notes: It doest not print out those lines representing trade between developing countries and transitional economies, trade among transitional economies, and trade between NIEs and transitional economies into the figure because their shares were always less than 1% of the world's total trade value.

Figure 4: Comparison of the shares of trade in parts and components between groups with different trade directions



Data source: The author's calculation based on UN COMTRADE online database.

Table 3: Share of the world's total exports of parts and components for different categories of products

Year	Share of the world's overall exports of parts and components for unskilled labor intensive products				Share of the world's overall exports of parts and components for technology intensive products				Share of the world's overall exports of parts and components for human capital intensive products			
	Developed Countries	Developing countries	NIEs	Transitional economies	Developed Countries	Developing countries	NIEs	Transitional economies	Developed Countries	Developing countries	NIEs	Transitional economies
1992	80.1%	9.7%	7.8%	2.5%	83.5%	6.3%	9.7%	0.5%	91.4%	3.4%	4.6%	0.6%
1993	77.5%	11.7%	7.5%	3.4%	80.3%	7.4%	11.8%	0.6%	88.5%	4.9%	5.8%	0.9%
1994	75.0%	14.7%	6.4%	4.0%	78.0%	8.2%	13.1%	0.7%	88.2%	5.2%	5.5%	1.1%
1995	76.2%	12.8%	5.0%	6.0%	77.2%	8.7%	13.1%	1.0%	87.9%	5.1%	5.5%	1.5%
1996	73.3%	14.7%	4.6%	7.4%	76.7%	9.7%	12.2%	1.4%	86.8%	5.3%	5.8%	2.1%
1997	71.6%	15.7%	4.2%	8.5%	76.1%	10.7%	11.6%	1.5%	85.7%	5.8%	6.1%	2.4%
1998	71.4%	13.3%	3.6%	11.7%	75.6%	12.0%	10.6%	1.8%	85.3%	6.3%	5.3%	3.1%
1999	69.3%	15.9%	3.2%	11.6%	73.4%	13.6%	11.3%	1.7%	85.0%	6.9%	5.1%	3.1%
2000	64.2%	21.3%	3.3%	11.2%	70.0%	15.2%	12.9%	1.9%	83.7%	7.9%	5.2%	3.3%
2001	61.9%	21.8%	2.8%	13.5%	69.3%	16.1%	12.3%	2.3%	82.8%	8.2%	5.0%	4.0%
2002	60.0%	22.0%	2.6%	15.3%	66.7%	17.5%	13.1%	2.7%	81.7%	8.9%	4.9%	4.5%
2003	58.9%	21.3%	2.5%	17.3%	63.7%	18.5%	14.4%	3.3%	79.8%	8.9%	5.6%	5.7%

Data source: The author's calculation based on UN COMTRADE online database.

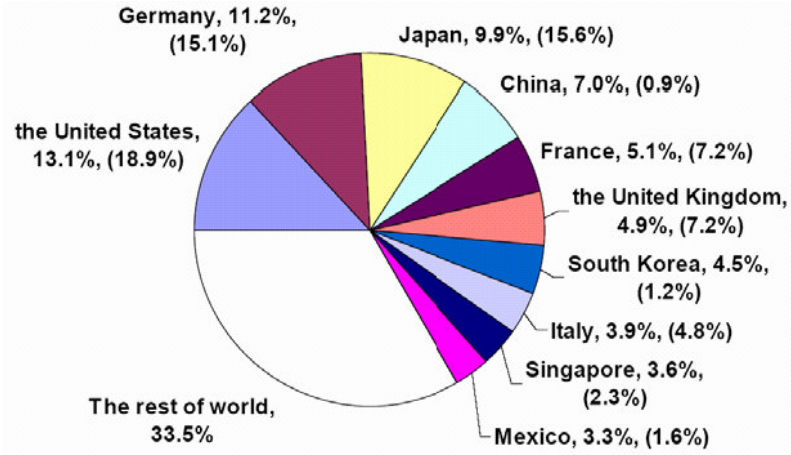
Table 4: Share of the world's total imports of parts and components for different categories of products

Year	Share of the world's overall imports of parts and components for unskilled labor intensive products				Share of the world's overall imports of parts and components for technology intensive products				Share of the world's overall imports of parts and components for human capital intensive products			
	Developed Countries	Developing countries	NIEs	Transitional economies	Developed Countries	Developing countries	NIEs	Transitional economies	Developed Countries	Developing countries	NIEs	Transitional economies
1992	89.0%	5.1%	4.7%	1.2%	69.0%	18.3%	11.9%	0.7%	81.1%	11.9%	6.1%	0.8%
1993	87.2%	6.2%	4.9%	1.7%	64.5%	20.1%	14.2%	1.1%	77.2%	14.0%	7.5%	1.2%
1994	86.2%	6.3%	5.7%	1.9%	64.4%	19.3%	14.9%	1.3%	77.8%	13.1%	7.7%	1.4%
1995	86.7%	5.8%	4.7%	2.7%	63.4%	18.8%	16.0%	1.6%	75.3%	14.7%	7.8%	2.1%
1996	85.5%	6.4%	4.2%	3.8%	61.8%	19.9%	15.6%	2.6%	74.0%	15.7%	7.0%	3.1%
1997	84.8%	6.8%	4.4%	3.9%	60.5%	20.3%	15.8%	3.1%	73.2%	15.9%	6.6%	4.1%
1998	85.9%	6.1%	3.4%	4.5%	63.2%	19.9%	13.2%	3.4%	75.7%	14.0%	5.2%	4.9%
1999	87.8%	5.4%	3.1%	3.7%	64.5%	19.2%	13.2%	3.0%	78.3%	12.9%	4.4%	4.2%
2000	85.3%	7.5%	3.2%	3.9%	62.6%	19.6%	14.6%	3.0%	75.0%	16.1%	4.7%	4.0%
2001	85.1%	8.0%	2.7%	4.1%	61.5%	20.8%	14.1%	3.4%	75.2%	16.1%	4.4%	4.1%
2002	86.5%	6.7%	2.3%	4.4%	59.1%	22.5%	14.4%	3.7%	75.4%	16.1%	4.2%	4.1%
2003	85.9%	6.5%	2.0%	5.5%	57.7%	23.0%	14.8%	4.2%	74.7%	16.0%	4.1%	5.0%

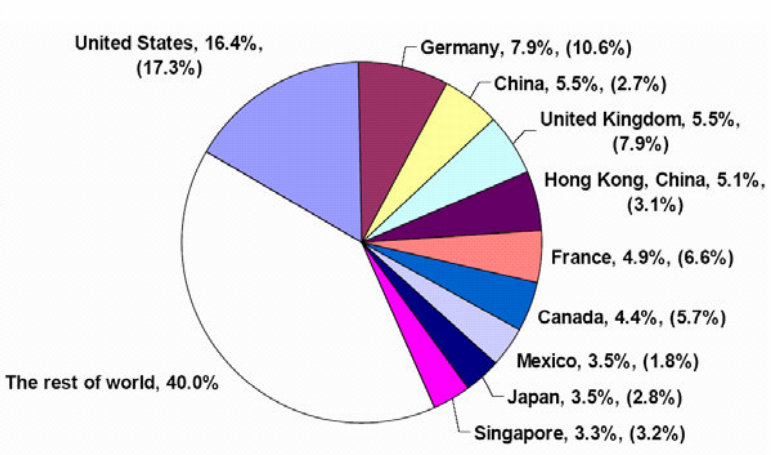
Data source: The author's calculation based on UN COMTRADE online database.

Figure 5: Top countries/regions in international trade in parts and components

Part a. The top ten exporters



Part b. The top ten importers



Data source: The author's calculation based on UN COMTRADE online database.
Notes: The percentages in the blankets represent the shares in 1992.

Figure 6: The factor price frontier for a multistage industry with international outsourcing, Kohler (2003)

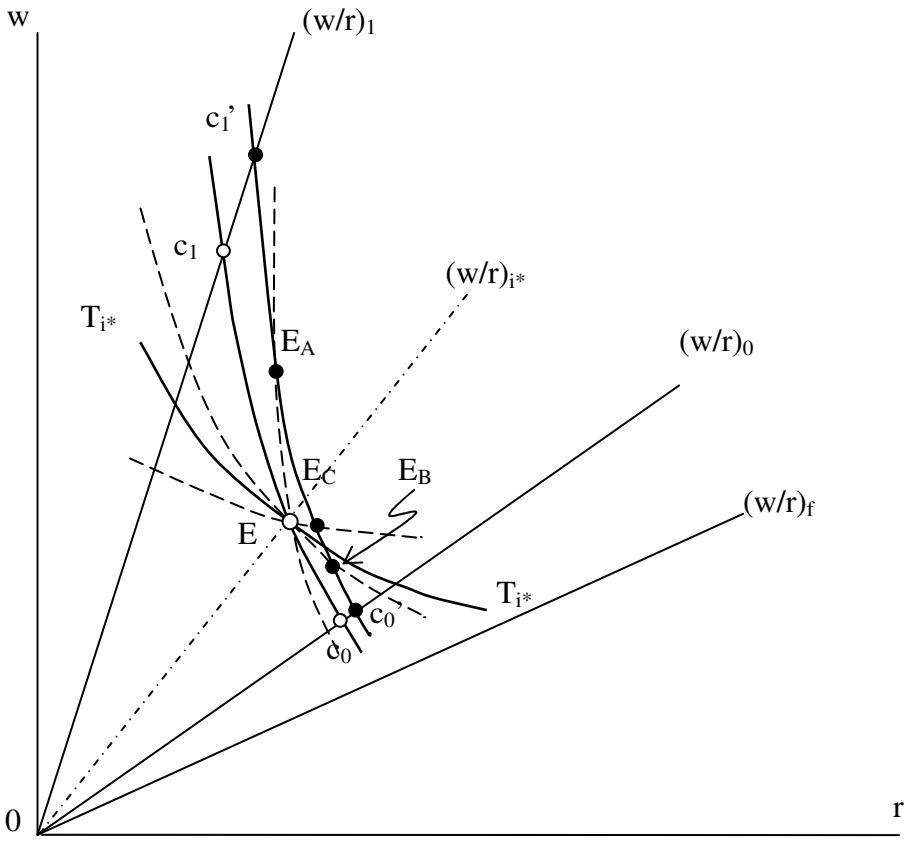


Figure 7: Outsourcing and labor supply growth in the south,
Grossman and Helpman (2005)

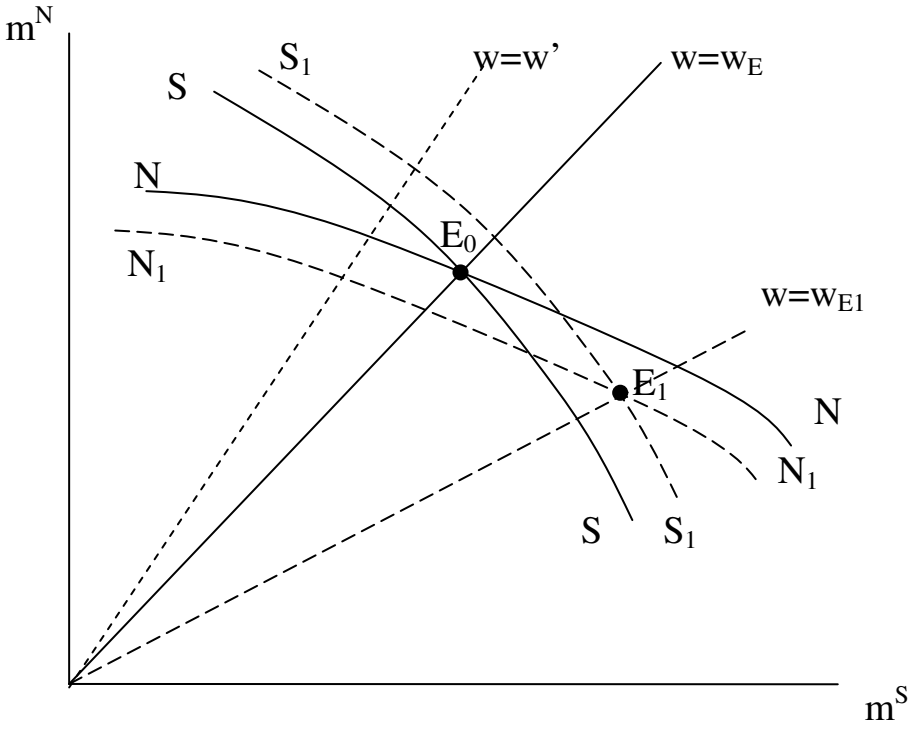


Figure 8: Average costs and output under fragmentation, Jones and Kierzkowski (1990)

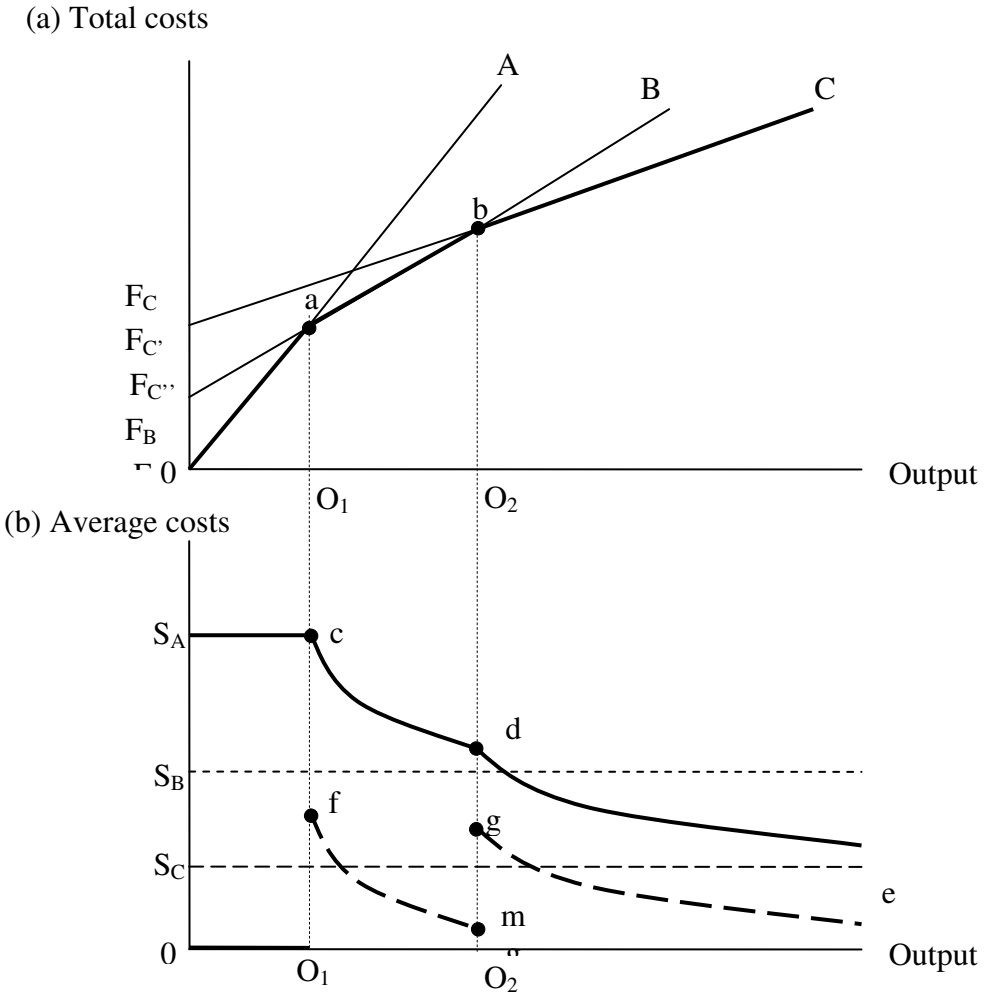


Figure 9: The cost reduction of service links

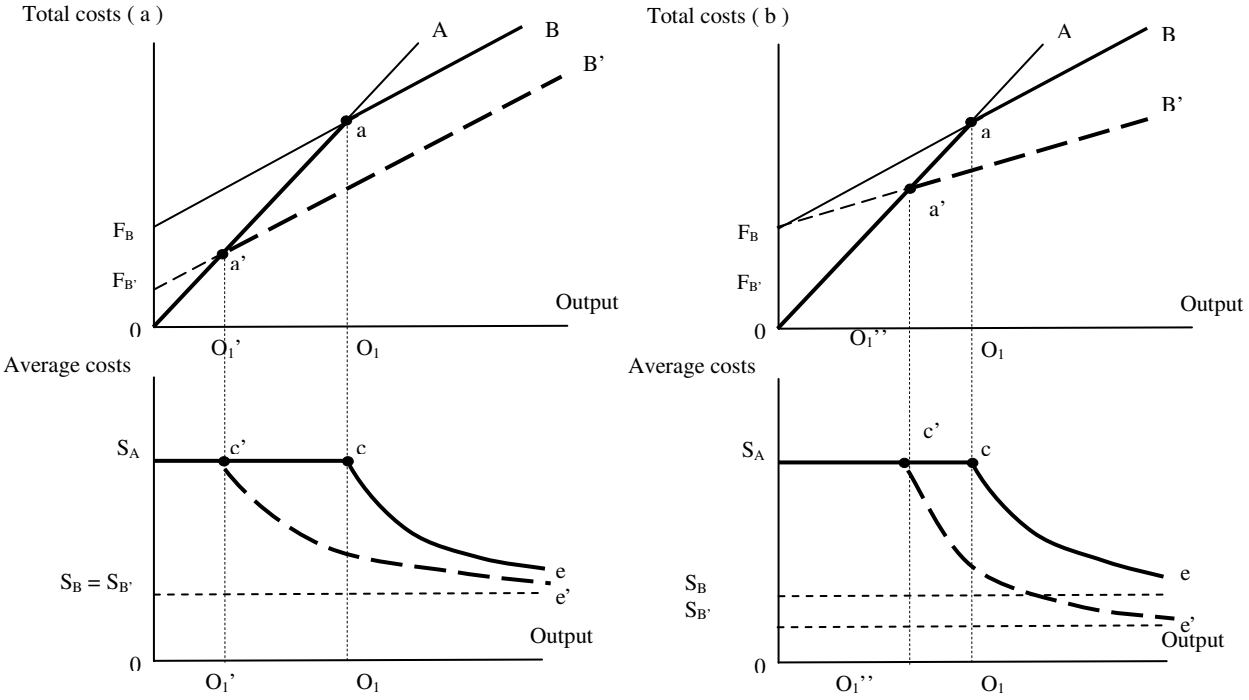
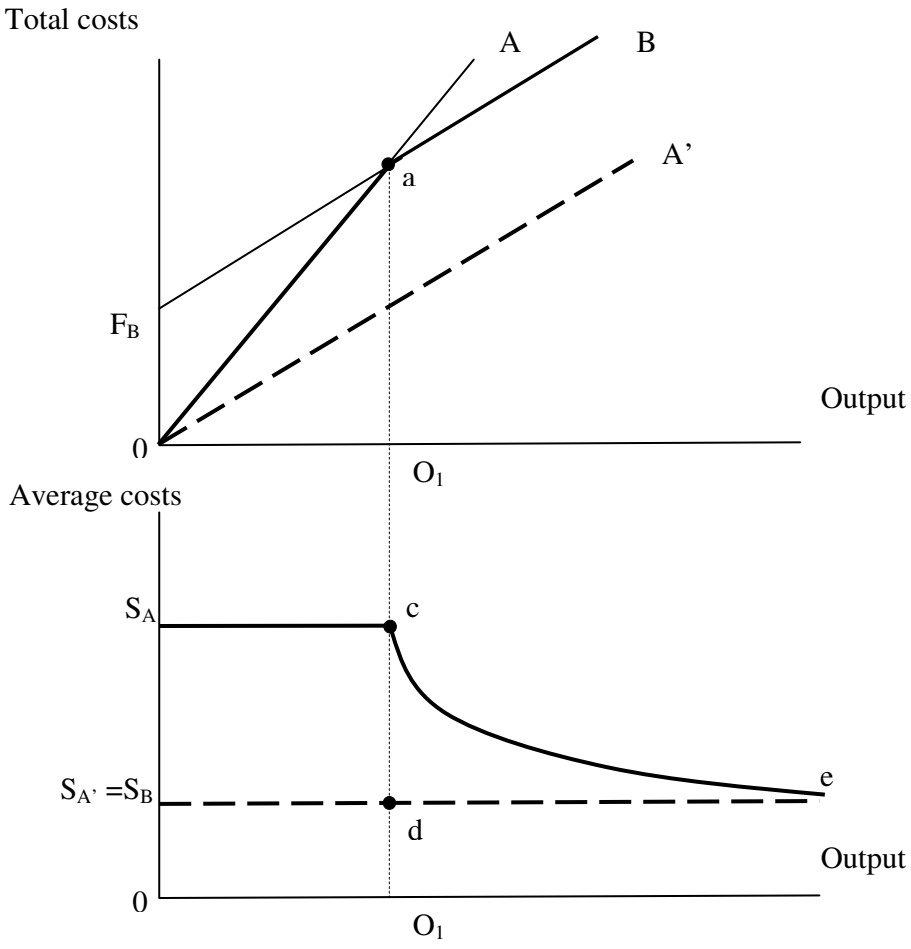


Figure 10: The cost reduction of service links and technological progress



References

Arndt, S.W. (1997) Globalization and the open economy. *North American Journal of Economics and Finance*, p.71-79.

_____ (1998) Globalization and the gains from trade. In K. J. Koch and K. Jaeger (eds.) *Trade Growth and Economic Policy in Open Economies*. New York: Springer-Verlag.

_____ (1999) Globalization and economic development. *The Journal of International Trade and Economic Development*, p.309-318.

_____ (2001) Offshore Sourcing and Production Sharing. In S. W. Arndt and H. Kierzkowski (eds.) *Fragmentation: New Production Patterns in the World Economy*. Oxford: Oxford University Press.

_____ (2004a) Trade Diversion and Production Sharing. *Journal of Economic Assymetries*, Vol.1, No.1.

_____ (2004b) Global Production Networks and Regional Integration. In Plummer, M. (eds.) *Empirical Methods in International Trade*, Edward Elgar.

Athukorala, P. and Yamashita, N. (2005) Production fragmentation and trade integration: East Asia in a global context. *The North American Journal of Economics and Finance*, Vol 17(3), p. 233-256.

Baldwin, R.E. (2006) Globalisation: the great unbundling(s) Finnish Prime Minister's Office. http://hei.unige.ch/~baldwin/PapersBooks/

_____ and Roberd-Nicoud, F. (2007) Offshoring: General Equilibrium Effects on Wages, Production and Trade. *CEP Discussion Paper*, No 794.

Cheng, L.K. and Fung, W.K. (2001) The globalization of trade and production: a case study of Hong Kong's textile and clothing industries. In L.K. Cheng and H. Kierzkowski (eds.) *Global Production and Trade in East Asia*, London: Kluwer Academic Publishers.

Cheng, L.K., Leung, S.F., and Ma, Z. (2004) Revealed comparative advantages and intra-regional trade of the world's three major regions: 1980-1995. In Kwan, Y.K. and Yu, E.H. (eds.) *Critical Issues in China's Growth and Development*, Williston: Edward Edgar

Davidson, R. and MacKinnon, J.G. (1993) *Estimation and Inference in Economics*. New York: Oxford University Press.

Deardorff, A.V. (2001a) Fragmentation in simple trade models. *North American Journal of Economics and Finance*, Vol. 12, No. 2, p.221-237.

_____(2001b) Fragmentation across cones. In S. W. Arndt and H. Kierzkowski (eds.) *Fragmentation: New Production Patterns in the World Economy*. Oxford: Oxford University Press.

Eithier, W.J. (2005) Globalization, globalisation: trade, technology and wages. *International Review of Economics & Finance*, Vol. 14, No. 3, p. 237-258.

Feenstra, R.C. and Hanson, G.H. (1996) Foreign investment, outsourcing, and relative wages. In R.C. Feenstra, G.M. Grossman, D.A. Irwin (eds.) *The political economy of trade policy: papers in honor of Jagdish Bhagwati*. Cambridge, MA: MIT Press.

Graziani, G. (2001) International subcontracting in the textile and clothing industry. In S. W. Arndt and H. Kierzkowski (eds.) *Fragmentation: New Production Patterns in the World Economy*. Oxford: Oxford University Press.

Grossman, G.M. and Helpman, E. (2002) Integration vs. outsourcing in industry equilibrium. *Quarterly Journal of Economics*, 117:1, p. 85-120.

_____ and _____ (2005) Outsourcing in a Global Economy. *Review of Economic Studies* 72, p. 135–159.

Harris, R.G. (2001) A Communication-Based Model of Global Production Fragmentation. In S. W. Arndt and H. Kierzkowski (eds.) *Fragmentation: New Production Patterns in the World Economy*. Oxford: Oxford University Press.

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

Jones, R. and Kierzkowski, H. (1990) The role of services in production and international trade: A theoretical framework. In R. Jones and A. Krueger (eds.) *The Political Economy of International Trade: Essays in Honor of Robert E. Baldwin*, Cambridge, MA: Blackwell.

_____ and _____ (2001a) Globalization and consequences of international fragmentation. In R. Dornbusch, G. Galvo and M. Obsfeld, (eds.) *Money, capital mobility and trade: Festschrift in honor of Robert A. Mundell*, Cambridge: MIT Press.

_____ and _____ (2001b) A framework for fragmentation. In S. W. Arndt and H. Kierzkowski (eds.) *Fragmentation: New Production Patterns in the World Economy*. Oxford: Oxford University Press.

Kaminski, B. and Ng, F. (2001) Trade and production fragmentation: Central European economies in European Union networks of production and marketing. *World Bank Working Paper* 2611, Washington, D.C.

Kimura, F. and Ando, M. (2005a) Two-dimensional fragmentation in East Asia: conceptual framework and empirics. *International Review of Economics and Finance*, Vol.14, Issue.3, p. 317-348.

_____ and _____ (2005b) Global Supply Chains in Machinery Trade and the Sophisticated Nature of Production/Distribution Networks in East Asia. *KUMQRP Discussion Paper* No. 2005-15.

Kohler, W. (2000) A specific-factors view on outsourcing. Johannes Kepler University Linz, *Economics working papers* No. 2000-20.

_____ (2002) Aspects of international fragmentation. Johannes Kepler University Linz, *Economics working papers* No. 2002-08.

_____ (2003) Factor Price Frontiers with International Fragmentation of Multistage Production. Johannes Kepler University Linz, *Economics working papers* No. 2003-05.

Krause, L.B. (1982) *U.S. Economic Policy toward the Association of Southeast Asian Nation*. Brookings Institution, Washington, D.C.

Long, N.V., Riezman, R. and Soubeyran, A. (2004) Fragmentation and Services. *The North American Journal of Economics and Finance*, Vol. 16, 2005, p.137-152

Markusen, J.R. and Venables, A.J. (2005) A Multi-Country Approach to Factor-Proportions Trade and Trade Costs. *IIIS Discussion* Paper No. 51.

Ng, F. and Yeats, A. (1999) Production sharing in East Asia: who does what for whom, and why? *World Bank Working Paper* 2197, Washington, D.C.

_____ and_____ (2003) Major trade trends in East Asia: what are their implications for regional cooperation and growth. *World Bank Working Paper* 3084, Washington, D.C.

Petrucci, A. and Quintieri, B. (2001) Will Italy survive Globalization? In S. W. Arndt and H. Kierzkowski (eds.) *Fragmentation: New Production Patterns in the World Economy*. Oxford: Oxford University Press.

Rodriguez-Clare, A. (2007) Offshoring in a Ricardian World, *NBER working paper*, 13203.

Ruane, F. and Görg, H. (2001) Globalization and fragmentation: evidence for the electronics industry in Ireland. In S. W. Arndt and H. Kierzkowski (eds.) *Fragmentation: New Production Patterns in the World Economy*. Oxford: Oxford University Press.

Sanyal, K and Jones, R. (1982) The theory of trade in middle products. *American Economic Review*, 72, p. 16 –31.

Wan Jr., H. (2005) Fragmented trade and manufacturing services – examples for a non-convex general equilibrium. *International Review of Economics & Finance*, Vol. 14, No. 3, p. 273-295.

Venables, A.J. (1999) Fragmentation and multinational production. *European Economic Review*, Vol. 43, No.4-6, p. 935-945

Yeats, A. (1997) Just how big is global production sharing? *Work Bank Policy Research Paper*, No.1871.

Yi, K.M. (2003) Can Vertical Specialization Explain the Growth of World Trade? *Journal of Political Economy*, Vol. 111, No. 1, p.52-102.