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Intra-industry Trade and Production Networks

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Abstract

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1. INTRODUCTION

Previous Literature

A major topic in empirical international trade is the determinants of the proportion of intra-industry trade (IIT). This paper aims to find the determinants of IIT other than distance and country-specific factors, considering the effect of re-imports through vertical foreign direct investment (FDI).

In the existing literature, trade volume can be explained by the gravity equation, in which the determinants of trade volume are GDPs and distance. Hummels and Levinsohn (1995) examined the determinants of IIT in bilateral pairs by panel data (henceforth HL's estimation). They sought to show the consistency with the findings of Helpman and Krugman (1985) (henceforth the H-K model): IIT accounts for a high proportion of trade between countries which have similar sized GDP and similar endowments.[1] However, their results have not been successful. A surprising result is that the high level of IIT can be observed not only in trade among OECD countries but also in trade among non-OECD countries, where inter-industry trade is thought to be significantly greater than intra-industry trade. Hummels and Levinsohn then concluded that ``much intra-industry appears to be specific to country pairs'' and ``distance is especially important to this relationship''. Nevertheless, two questions arise from their results. First, it remains unclear whether the H-K model still has explanatory power in IIT econometric analysis. The other question is what do the country-specific factor and the geographical distance imply.

[1] Grubel and Lloyd (1975) and Balassa (1986) proposed indices for the proportion of IIT and found a high proportion of IIT in trade among developed countries. Applying the H-K model to empirical studies, based on evidence from 14 OECD countries between 1956 and 1981 Helpman (1987) showed that two similar GDP countries tend to have a high proportion of IIT.

HL's estimation seems to have disregarded three important points.[2] First, without considering a remarkable trend in IIT from the 1990s onward, the HL estimation was made separately in OECD-country trade and non-OECD country trade. The HL estimation seems to have regarded the trade between OECD and non-OECD countries as the prima facie fact that it is explained by the Heckscher-Ohlin (HO) model.[3] However, as widely perceived, the currently increasing IIT is between OECD and non-OECD countries (Clark and Stanley (1999); Nilsson (1999)).[4] This increase cannot be explained by the H-K model as well as the HO theorem, and thus two current streams of research have attempted to analyze this phenomenon: one explanation is vertical IIT and the other is fragmentation in the production process.[5]

The second point omitted from the HL estimation is that there still remain some unknown country-specific factors in the IIT estimation. HL achieved good results in fixed effect estimation in panel data analysis, and in the distance term in the OLS estimate in cross-data analysis. Rice et al. (2002) concluded that demand and supply structural similarity in neighbouring countries causes distance to be a major determinant of IIT proportion. However, their explanation seems still to lack generality. A perfect example is Japan: Japan is far from other OECD countries but adjacent to many non-OECD countries, which have totally different supply and demand structures. However, the proportion of IIT in Japan is high, not only in trade with the other

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[2] Debaere (2001) criticized HL's regression for presuming a constant proportion of non-OECD countries in the world and for omitting a high correlation between volume of trade (independent variable) and GDP (dependent variable). As a result of denominating the volume of trade by GDP, he found that a GDP similarity has a negative impact on trade among non-OECD countries.

[3] Evenett and Keller (2003) studied the relationship between IIT explained by the H-K model and inter-industry trade explained by the Heckscher-Ohlin theorem. They grouped country pairs across the GL index and compared the difference in capital ratio among the groups. As a result, they found that the country pairs of high GL index can be seen in the pairs of the smaller difference of capital labour ratio.

[4] Clark and Stanley (1999) found evidence of increased IIT in the United States with developing countries. Also, Nilson's evidence is based on the IIT of the EU with small developing countries.

[5] The pioneering attempt to provide a theoretical framework of fragmentation is by Jones and Kierzkowski (1990). A theory on VIIT was provided by Falvey (1981) and Helpman and Flam (1987). Based on the theory, many empirical works studied how country or industry specific factors affect vertical or horizontal IIT. See Greenaway, Hine and Milner (1994) (1995), and Fukao, Ishido and Ito (2003).

OECD countries but also in trade with other Asian countries (see Figure 5-1). Therefore, this stylized fact tells us that distance is still important in the Japanese case, but the cause is totally different from that of Rice et al. (2002). There seems to exist some other mechanisms explaining the Japanese IIT. One possible mechanism dismissed in HL's estimation is supply side: production networks by multinational firms. [6] Recent work has pointed out a major influence of production networks on international trade (Gould (1994); Rauch (1996); Head and Ries (1998); McLaren (1999); Combes, Lafourcade and Mayer (2003a) (2003b)).

The third point missed in HL's work concerns firm-level behaviours such as multinational firms.[7] This is related to the defect in the H-K model. Helpman and Krugman (1985, Ch. 12) extended the H-K model to the case of multinational firms, but they admitted the limitation that GDP similarity weakens the explanatory power in the presence of the multinational firms, which Markusen and Venables (2000) attempted to overcome.[8] This theoretical vagueness has led to reluctance in horizontal IIT literature to consider the IIT from the viewpoint of various firm-level behaviours such as re-imports by FDI and outsourcing and firm network.

The current literature and this paper

The literature on intra-firm trade provides us with good insight into the current stream of international trade. Antras (2003) presents a wide range of facts on US intra-firm imports.[9] In his

[6] They mentioned using per capita income as a proxy, which has two potential problems. One is "whether per capita income is proxying factor endowments or consumer tastes"; HL said, "The empirical literature has generally interpreted differences in per capita income as a demand side phenomenon."

[7] In discussions on vertical IIT, many empirical studies have considered the effect of FDI on IIT, although many never provide a model to explain it. However, Fukao et al. (2003) provided a model and showed empirically that vertical IIT is promoted by FDI through division of labour.

[8] Marksen and Venables (2000) mentioned that "the presence of multinational corporations weakens the link between the volume of trade and the degree of dispersion in relative size". H-K presumes factor price equalization among homogenous firms, but it does not consider technology and wage gap, which is the main cause of vertical FDI. Also, it cannot clearly show whether FDI promotes two-way trade or not.

[9] Antras (2003) defined intra-firm US imports as (i) US imports shipped by overseas affiliates to their US parents and (ii) US imports shipped to US affiliates by foreign parents.

Figure 2, which originally graphed a positive correlation between intra-firm trade and capital labour ratio, we see that US intra-firm imports are particularly active with many low wage developing countries adjacent to the United States, such as Panama, Mexico and Brazil. The US intra-firm imports in these countries are largely above the trend line between intra-firm trade activity and their capital labour ratios, suggesting that these countries still have some uncaptured factors other than capital labour ratios. The phenomenon is even stronger in Japanese trade. Japanese FDI in Asian countries promotes re-imports to Japan.[10] As Ng and Yeats (2003) suggested, trade in parts and components plays an important role in Asian trade today, and furthermore Japan is becoming a centre of the fragmentation of production process in East Asia.

This paper aims to find determinants of IIT that do not involve the traditional determinants, i.e. distance and country-specific factors. Reflecting the above stylized facts, we focus on Japanese trade in the late 1990s together with HL's estimation, and consider the effect of re-imports through (vertical) FDI on IIT. We extend HL's estimation in two ways. First, we consider the supply side: technology differences, wage gap, and technology transfer by FDI. These factors were dismissed in the HL estimation and were considered as country-specific factors. Second, we focus not only on intra-OECD country trade but also on OECD trade with non-OECD countries simultaneously in a single estimation. One simple model of technology gap and FDI among heterogeneous firms can explain different factors of IIT in intra-OECD country trade and in trade with non-OECD countries.

There are several reasons for analyzing Japan's IIT in the 1990s using econometric methods. The first is to be able to test the generality of previous studies. We can test HL's estimation in the trade between OECD and non-OECD countries simultaneously. Also we can examine the generality of Rice's discussion. The second reason is that Asian trade is the most active in intra-

[10] See Fukao and Hoon (1996) on Japanese re-imports.

firm trade and trade related to FDI in the world, and the fragmentation of production processes largely affects the Japanese trade. Japan is close to Asian countries, and is both a major influence and is in turn strongly influenced by other Asian countries. Furthermore, Japanese firms have strong production networks through FDI, which largely affects Japanese trade (Lawrence, 1991; Okubo 2004; Ando and Kimura 2003; Fukao and Okubo 2004). As a consequence, we find that the technology transfer through Japanese FDI increases IIT: technology transfer promotes the overseas affiliate and increases re-imports to Japan. As a determinant of IIT, the distance and country-specific factors widely used in previous studies can be replaced by technology transfer through vertical FDI.

The remainder of the paper is organized as follows. The next section describes the basic model explaining FDI and IIT. In Section 3, we conduct an econometric analysis of the determinants of Japanese IIT, and Section 4 presents the paper's conclusions.

2. THE BASIC MODEL

Current trade theory has shed light on the heterogeneous productivities of firms. Melitz (2003) and Helpman, Yeaple and Melitz (2004) modelled different firm behaviours through a reallocation effect in the process of trade liberalization. Baldwin and Okubo (2004) applied their models to economic geography. This section now applies Melitz (2003) and Baldwin and Okubo (2004) to FDI and the volume of trade with a comparative advantage in technology, although our model cannot perfectly cover their features due to the different aim of the analysis. Unlike the Baldwin and Okubo model and the Melitz model, no transport costs are imposed, but instead communication costs between headquarters and overseas affiliates are imposed proportional to the geographical distance. The focus is on the effect of vertical FDI on IIT among heterogeneous firms, considering technology gaps, wage gaps and communication costs.[11]

2.1 General setup

We start from the Martin and Rogers (1995) model, which is often called the footloose capital (FC) model (see Baldwin et al. (2003), Chapter 3). The FC model works with two countries (North and South) and two factors, K (capital) which is mobile and L (labour) which is immobile across countries. Worldwide supplies of capital and labour are fixed. Manufactured goods are produced under increasing returns to scale and monopolistic competition. The fixed cost involves one unit of capital (K) and the variable cost employs **'**a**'** units of labour (L) per unit of output. The implied cost function for typical firm i can be written as:

$$\pi + wa_i x_i$$

where π and w refer to the rewards to capital and labour, a_i is firm i's variable unit input requirement, and x_i is its output. Importantly, the model assumes that capital owners are immobile across countries. Physical capital moves in search of the highest *nominal* reward since its income is spent in the owner's region regardless of where the capital is employed. In other words, all of the capital's reward is repatriated to its country of origin. The preferences of the representative consumer in each country are quasi-linear:

$$U = \int_0^I \mu_i C_i di, \;\; C_i \equiv \left(\int_0^1 c_n^{1-1/\sigma} dn \right)^{1/(1-1/\sigma)}, 0 < \mu < 1 < \sigma$$

where c_n is consumption of each variety in an industry, and σ is the constant elasticity of

[11] Baldwin and Ottaviano (2001) modelled reciprocal trade and FDI, and found that asymmetric equilibrium with one-way flow of FDI does not exist. Greaney (2003) introduced network into Baldwin and Ottaviano's model and found the existence of one-way flow of FDI in the case of an asymmetric network effect across countries.

substitution between the varieties. Here, 'I' represents a large number of industries and n is the number of varieties produced in an industry. I and n are fixed.[12]

2.2 Firm heterogeneity, FDI cost and comparative advantage

The FC model is applied to IIT and multinational firms without transport costs. First, we introduce sunk costs in overseas production, whereas the original FC model considers free mobility of firms and capital between the countries. The multinationals need to pay additional sunk costs by employing labour, subject to beachhead costs: communication costs for the maintenance of overseas production networks. In order to maintain efficient production in overseas affiliates, the parents need to supervise the management and quality control by promoting face-to-face communication between headquarters and the affiliates. The communication by human interaction is conducted by headquarters periodically sending workers and CEOs to the affiliate country. This involves communication costs such as travelling costs.

Second, as in Melitz (2003), we allow firms to have different unit input coefficients, i.e. different a_i's. Then we introduce comparative advantage in varieties between two countries, as shown in Figures 1 and 2. The North has a comparative advantage in some varieties (from 0 to n), whereas the South produces the remainder of varieties (n to 1). The wage is determined by the macro economy and thus it is exogenously given for any industry.[13] This partial equilibrium approach allows us to consider the distribution of firm-level efficiency as part of each country's endowment. Since each firm is associated with a particular unit of capital, it is natural to assign the source of heterogeneity to capital. We assume that each unit of capital in each country is associated with a particular level of productive efficiency as measured by the unit labour

[12] As in the original FC model, since the endowment of capital is fixed and the number of firms in the world is fixed, we need not consider entry and exit.
[13] This is why we assume a very large number of industries.

requirement, ‘a’. The distribution assumed is a uniform distribution. We refer to a firm’s ‘a’ as its level of inefficiency since this is proportional to its marginal cost of production in equilibrium.

2.3 Initial equilibrium

In the standard Dixit-Stiglitz monopolistic competition assumptions on market structure, optimal prices are:

$$p_j = \frac{a_j w}{1-1/\sigma},\ \ p_j{*} = \frac{a_j^* w^*}{1-1/\sigma}\ \ ;\ \sigma > 1$$

where ‘a_j’ is a typical firm’s marginal cost, and each country has a comparative advantage in certain varieties, as shown in Figure 1. σ is the constant elasticity of substitution between any two manufactured varieties within a sector. The operating profit earned by a typical firm in a typical market is 1/σ times firm-level revenue.[14] Accordingly, operating profit in a northern firm is:

$$\pi_j = \frac{\mu E^W (p_j)^{1-\sigma}}{\sigma\Delta} - H$$
$$\Delta \equiv P^{1-\sigma} = \left[\int_0^n p_j^{1-\sigma} dj + \int_n^1 p_j^{*1-\sigma} dj\right] = w^{1-\varsigma}\int_0^n a_j^{1-\sigma} dj + w^{*1-\sigma}\int_n^1 a_j^{*1-\sigma} dj$$

where E^w is world expenditure on the good and the number of varieties in the world, P is the CES price index for all varieties consumed, and H is the beachhead costs for headquarter service. n denotes the boundary of the varieties between northern and southern productions, determined so as to equalize the profits:

(1) $$\pi_j - \pi_j^* = \frac{\mu E^W}{\sigma\Delta}\left(p_j^{1-\sigma} - p_j^{*1-\sigma}\right) = 0$$

Consequently, one relation can be induced from equation **(1):** $a_n w = a_n^* w^*$.

[14] A typical first order condition is p(1-1/σ)=wa; rearranging, the operating profit, (p-wa)c, equals pc/σ.

2.4 Decision-making for firm types: multinational or national

Next we consider multinational firms. In search of higher profits, a firm decides to choose a multinational or a national firm. In the case of choosing multinationals, the firm is required to pay the costs for human interaction between their headquarters and the overseas production plant. The communication costs for multinational firms, M, are assumed to be counter-proportional to the geographical distance. According to Goldberg et al. (2003), the human interaction between headquarters and overseas affiliates is an essential factor for multinationals and thus the FDI is negatively correlated with the costs for human interaction measured by distance and travel costs. The overseas affiliates employ labour at the wage rates in the host countries, and use technology transferred from headquarters in the home country. However, the transfer is imperfect due to the gap in educational levels, circumstances for transfer and government regulations. Thus, the overseas affiliates use technology represented as 'ak' units of labour requirements.

$$\pi_j^{MNC} = \frac{\mu E^W (\tilde{p}_j)^{1-\sigma}}{\sigma\Delta} - H - M$$

where $\tilde{p} = akw*$ and k represents the inverse of technology transfer (k>1). The better the circumstances for technology transfer (k is close to 1), the easier it is for overseas affiliates to operate production using a technology similar to that in the North.[15] On the other hand, if the gap in human capital is large, transfer is imperfect (k is much larger than 1) and less efficient technology is employed. The change in operating profit is denoted as

$$\text{(2)} \qquad \pi_j^{MNC} - \pi_j = \frac{\mu}{\sigma\Delta}\left(\tilde{p}_j^{\,1-\sigma} - p_j^{\,1-\sigma}\right) - M$$

[15] Findley (1978) states that technology transfer through FDI can reduce the technology gap between home and host countries.

If the above equation is positive, firms have an incentive to become multinationals, and vice versa. The larger the positive value in the bracket, the greater the incentive for northern firms to become multinationals: necessary conditions are a large wage gap ($w^*<w$) or a large degree of technology transfer (i.e. k is close to 1). Then, given k, M is progressively lowered in proportion to distance, and firms have more incentive to locate overseas affiliates in neighbouring countries.

Result 1: Efficient firms are likely to become multinationals in the presence of a wage gap. Firms in the higher wage country are more likely to be multinationals than in the lower wage country. When communication costs gradually reduce due to geographical proximity, the first firms to start overseas operations are those most efficient in the higher wage neighbouring country.

The result that the most efficient firms are likely to become multinationals is consistent with both our study and Helpman et al., regardless of there being no assumption of wage gap in Helpman et al. (2004).[16]

2.5 Final Equilibrium

The cut-off level for multinationals. We define the cut-off variety between nationals and multinationals as m. Then we provide the condition that characterizes m. We note that the emergence of multinationals in the North will change the equilibrium Δ. Δ is replaced by $\tilde{\Delta}$.

[16] Bernard, Redding and Schott (2004) studied heterogeneous firms in the presence of comparative advantage.

$$\pi_j^{MNC} = \left(\frac{\mu E^W}{\sigma}\right)\frac{1}{\tilde{\Delta}} p^{1-\sigma} - H - M,$$
$$\tilde{\Delta} \equiv \int_0^m \tilde{p}_j^{1-\sigma} dj + \int_m^n p_j^{1-\sigma} dj + \int_n^1 p_j^{*1-\sigma} dj$$
$$= w^{*1-\sigma} \int_0^m \tilde{a}_j^{1-\sigma} dj + w^{1-\sigma} \int_m^n \tilde{a}_j^{1-\sigma} dj + w^{*1-\sigma} \int_n^1 a_j^{*1-\sigma} dj$$

The profits between multinationals and nationals are equalized in variety m:

(3) $$\pi_m^{MNC} - \pi_m = \frac{\mu}{\sigma}\frac{1}{\tilde{\Delta}}\left(\widetilde{p_m}^{1-\sigma} - p_m{}^{1-\sigma}\right) - M = \frac{\mu}{\sigma}\frac{1}{\tilde{\Delta}}\left((\tilde{a}_m w^*)^{1-\sigma} - (a_m w)^{1-\sigma}\right) - M = 0$$

where $\tilde{a} \equiv ak, k \geq 1$. The values of k are different across host countries, largely affected by the capability to utilize the transferred technology and by educational level. Northern firms with a's in the range [0,m] have $\pi_m^{MNC} > \pi_m$ and thus become multinationals: they establish overseas production in the South with headquarters in the North. It is important to note that n is unchanged by multinationals, because wage rates are fixed and equation (1) is always satisfied at n:

$$a_n w = a_n^* w^*.$$

Figure 3 plots equation (3) in terms of m and k: a negative correlation. The number of multinationals is positively correlated with technology transfer. More technology transfer (small k) increases the number of multinationals, given M. This implies that more multinationals emerge in the countries with good conditions for technology transfer and a higher educational level, if geographical distances from the home country are the same. Now given k, smaller M increases the number of multinationals. This implies that more multinationals are located in neighbouring countries. This result is consistent with Goldberg et al. (2003).

Result 2: When technology can be transferred easily and affiliated firms can use a similar

technology to the firm based in the home country, multinationals emerge. Ceteris paribus, overseas production is likely to be located in neighbouring countries.

2.6 Volume of Trade

We now calculate the value of exports and imports in the North in the case of a non-multinational firm. The key is to establish overseas production as multinationals and to re-import the products.

(4)
$$EX = \int_0^n r_j dj = \int_0^n \frac{p_j^{1-\sigma}}{\Delta} R dj$$
$$IM = \int_n^1 r_j dj = \int_n^1 \frac{p_j^{1-\sigma}}{\Delta} R dj$$

where R denotes total expenditure on the good (not variety) in the world. Then, the exports and imports in the presence of multinationals are

(5)
$$EX^{MN} = \int_m^n r_j dj = \int_m^n \frac{p_j^{1-\sigma}}{\tilde{\Delta}} R dj$$
$$IM^{MN} = \int_0^m r_j dj + \int_n^1 r_j dj = \int_0^m \frac{p_j^{1-\sigma}}{\tilde{\Delta}} R dj + \int_n^1 \frac{p_j^{1-\sigma}}{\tilde{\Delta}} R dj$$

The first term in IM^{MN} represents re-imports by overseas affiliates.[17]

Symmetric Technology Case

In the symmetric technology case, the relation between the unit labour requirements a and variety index j can be written as specific functions like

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[17] Note that n is fixed even after beginning overseas production, and that R is fixed because the utility function is quasi-linear and capital owners are tied to the country, and thus expenditure on the good is constant.

$$
\begin{aligned}
&a_j = j \\
&a_j = 1 - j \\
&for \ j \in (0,1)
\end{aligned}
$$

if there is no wage gap, n is 0.5 and no wage gap leads to zero in the bracket in equation (2) and always gives a negative value in equation (2) (see Figure 1). This means no incentive for all firms to become multinationals. It can equalize the value of exports and imports, which is equivalent to a maximal amount of IIT. However, this paper assumes a wage gap (w>w*), and thus the boundary of traded good (n) is less than 0.5 (see Figure 2-1). The efficient firms become multinationals in the case of symmetric technology with a large wage gap.[18] The bracket in equation (2) becomes positive, and efficient firms (small 'a') in the higher wage country tend to have a higher value of the first term. This drives a positive value in equation (2), given the level of M. In this case, imports (IM) are always larger than exports (EX) in the North in equation (4). The emergence of multinationals increases imports relatively (IM^{mn}) and decreases exports (EX^{mn}) in equation (5), thus reducing the proportion of IIT.

Result 3: Between two countries with symmetric technology and equal wages, multinationals never emerge. However, in the case of symmetric technology in the presence of a wage gap, multinational firms emerge only in the higher wage country. The increase in the number of multinationals always reduces IIT.

[18] Note that a two-way FDI never occurs.

Asymmetric Technology Case

Next we consider an extreme case, where the North has an absolute advantage in technology in the presence of a wage gap (Figure 2-3).[19] The function for unit labour requirements can be written as

$$a_j = j$$
$$a_j = 2 - j$$
$$for\ j \in (0,1)$$

where j refers to variety index. The efficient northern firms have an incentive to become multinationals. To investigate the final equilibrium, Figure 3 plots equation (3), suggesting that smaller k and smaller M lead to more multinationals. Figure 4 plots the proportion of IIT in terms of k, showing that large and intermediate levels of k increase IIT, but small k decreases IIT.

Result 4: In the case of asymmetric technology and the presence of a wage gap, FDI and technology transfer increase the level of IIT at small and intermediate levels of technology transfer. The level of IIT reaches a maximum level of IIT at a certain level of technology transfer. However, a large degree of technology transfer decreases the level of IIT.

3. Econometric Analysis

[19] See Figure 2-2 for a non-wage case.

3.1 Empirical Strategy

3.1.1 General Ideas

HL's estimation result had several shortcomings. In particular there are still some determinants of IIT that the H-K model cannot explain. In this section, we conduct an econometric analysis and test for the determinants of IIT between Japan and its 24 major trading partners from 1996 through 2000 in order to obtain better results by adding Japanese FDI related factors to the HL regression.[20] Based on the evidence that Japan's IIT is active with Asia as shown in Figure 5-1, we would expect that Japanese FDI could increase IIT together with technology transfer.

3.1.2 Data and descriptive discussion

We regress the panel data on Japan's trade with 24 countries from 1996 to 2000. The 24 countries are composed of major Japanese trading partners in each region: Asia, the Americas, Europe and Oceania. Using the two-digit level of trade data, the GL index is calculated (see the Data Appendix for a list of countries and industries). Figure 5-1 shows that Japan's IIT shares (GL index) with Asia did not fall. The rates with Asia have grown steadily over the period. Moreover, the GL index with some Asian countries has consistently been as high as those with the United States and Europe. For instance, Malaysia, Korea and Taiwan have provided from 0.5 to 0.6; Malaysia reached more than 0.6 in 2000, while the values with the United States and Europe were 0.5 and 0.6 respectively. The most remarkable country is Malaysia, where the value has increased from 0.43 to 0.65 in just four years. The technology transfer data are based on

[20] As seen in the theoretical model, since the only possibility is a one-way FDI under asymmetric technology in the presence of wage gaps, we can focus on one-way flow: Japanese FDI. Also Greaney (2003) suggested that since Japanese firms have strong networks in overseas production, the networks increase Japanese FDI, promote re-imports to Japan, and prevent inward FDI to Japan. The presence of asymmetric production networks leads to a one-way FDI flow (Japanese FDI) rather than bilateral FDI flows.

Japan's receipts from technology exports and Japan's payments for technology imports, taken from the Balance of Payments (Bank of Japan). The technology transaction with Japan has some noticeable features. As seen in Table 3, Japan's receipts from technology exports definitely outstrip Japan's payment for technology imports with most foreign countries. The third column of Table 3 represents the export–import ratio, which is much higher in Asian countries than in the other countries. In spite of a ratio of less than 5 in Europe and North America apart from Canada and Australia, the ratios in Asia are much larger. We can also observe a huge amount of technology transfer to other Asian countries from Japan (Figure 5-2). From these stylized facts, the high value of Japanese technology exports to Asia seems to correlate with the Japanese vertical FDI. For this reason, the technology exports may be related to Japanese FDI and may help explain the current surge of Asian IIT.

3.1.3 Regressions

First of all, we test the traditional hypothesis that IIT diminishes with distance.

$$GL_t^i = c + \beta_1 Diff_t^{\,i} + \beta_2 GDP_{\max t}^{\;ij} + \beta_3 GDP_{\min t}^{\;ij} + \beta_4 DIST^{\,i} \qquad (6)$$

$$GL_t^i = c + \beta_1 Diff_t^{\,i} + \beta_2 GDP_{\max t}^{ij} + \beta_3 GDP_{\min t}^{ij} + \sum \beta_k \,\mathrm{Re}\,gion_k \qquad (7)$$
$$where\;\; k = NAFTA, EU, ASIA$$

where DIFF refers to GDP per capita differences between Japan and country i. GL is the GL index for each trading partner i with Japan in each year, GDPmax is the GDP in the country which has the greater GDP, while GDPmin is the GDP in the country with the smaller GDP, and DIST refers to distance from Japan to country i.[21] If the H-K model is generally correct, the coefficients of GDPmax should be negative and those of GDPmin should be positive, which

[21] See Appendix for detail on definitions.

means that the GDP similarity enhances IIT, and DIFF should be negative, which implies similar endowments increase the proportion of IIT. Next, our hypothesis that technology transfer leads to an increase in IIT is tested by the following equation:

(8) $$GL_t^i = c + \beta_1 DIFF_t^i + \beta_2 GDP_{\max t}^{ij} + \beta_3 GDP_{\min t}^{ij} + \beta_4 TECH_t^i$$

where TECH represents the sum of Japan's technology payments and receipts with each country.[22] This estimation gives an overview of the relationship between technology transfer and IIT, hypothesizing that a two-way technology trade increases IIT.

To investigate more rigorously, the variable of technology transfer should be limited only on the technology exports by Japanese parents to Japanese affiliates, because TECH covers all kinds of technology transactions**,** not only FDI-related technology trade but also any other transaction. However, our model describes that technology transfer by multinationals increases IIT. Thus the equation is replaced by:

(9) $$GL_t^i = c + \beta_1 DIFF_t^i + \beta_2 GDP_{\max t}^{i} + \beta_3 GDP_{\min t}^{i} + \beta_4 TECHJPNAFF_t^i$$

where TECHJPNAFF is technology transfer related to Japanese FDI.

Next, we check robustness by means of some proxies for TECHJPNAFF. The candidate for the proxies is the number of workers and CEOs sent to overseas affiliates, JPN workers, who promote technology transfer. One way of thinking is that technology licensing needs to be associated with some help by Japanese workers in the overseas affiliates, or that the Japanese workers promote the transfer of technology and help improve productivity. The other way of thinking is increasing productivity through face-to-face communication. The Japanese workers, JPN workers, can be a major factor in the contribution to technology improvement in the overseas affiliates. The human communication in the overseas affiliates plays the role of transfer

[22] Wakasugi (1997) also attempted the HL estimation including macro level data on technology trade, but technology transaction did not significantly affect the GL index.

of tacit knowledge, know-how and a number of techniques for management, production control and R&D. Thus a total number of dispatched Japanese workers and CEOs to each host country is used. The other possible proxy is total sales of affiliates, SALES, representing the activity of overseas affiliates. As shown in the theoretical model in the last section, a good environment for technology transfer in a host country attracts multinational firms and, as a consequence, total sales of multinationals in the host country increase.

Finally, the background for technology transfer should be analysed in more detail. Since the extent of technology transfer is limited by human capital and educational level in each host country, we introduce another factor: education level. The gap in average years of schooling between Japan and its trade partners can be regarded as technology capacity and potential capability in host countries. The less gap in educational years with Japan leads to more appropriate circumstances for technology transfer, and thus it could affect the technology transfer in multinationals.

(10) $$GL_t^i = c + \beta_1 DIFF_t^i + \beta_2 GDP_{\max t}^{\ i} + \beta_3 GDP_{\min t}^{\ i} + \beta_4 SALES_t^i + \beta_5 EDU_t^i$$

where EDU represents the gap in years of schooling of the total population.

3.2 Regression results

We employed Generalized Least Square (GLS) in pooled data analysis. Then, Feasible GLS with heteroscedasticity across panels was used, in which the variance for each of the panels is presumed to be different but does not allow cross-sectional correlation. The regressions 1-(1) to 3-(2) in Table 1 report the results for equations (6) and (7). As in traditional estimations, IIT significantly diminishes with distance. In particular, the coefficients of Asia dummies are higher than those of Europe and NAFTA dummies. This reflects the evidence that the trade with neighbouring countries has a higher proportion of IIT. Further, we can see that some country-specific factors exist other than the similarity of factor endowments and GDPs. However, a problem is that all GDPmaxs are significantly positive, while they are expected to be negative in the HK model. The positive coefficients in GDPmax and GDPmin do not imply that GDP similarity increases IIT, which contradicts the prediction in the H-K model. The other factors seem to affect this contradicted result.

Then, regressions 4 to 5(4) in Table 1 report the result of equations (8) and (9). The coefficients of TECH and TECHJPNAFF are significantly positive. As our model implies, technology transfer by Japanese multinational firms increases re-imports and then enhances IIT. Reflecting our model, this empirical evidence only corresponds to the case of an intermediate or small degree of technology transfer in the presence of technology asymmetry and wage gap. Using TECHJPNAFF, all variables are significant with reasonable signs. As the H-K model predicts, GDP and factor endowment similarity increase IIT; then**,** as our model predicts, technology transfer by multinationals increases IIT.

Next, the regressions for robustness are shown in 5(1) to 6(3) in Table 1. The results are consistent with the previous regressions. The more Japanese workers and CEOs sent to the Japanese overseas affiliates, the more know-how and tacit knowledge the Japanese firms transfer or promote the transfer of. The coefficients on total sales are also significantly positive. The expansion of the activities by Japanese-affiliated firms increases the IIT with Japan. Further, we apply instrumental variable methods to TECHJPNAFF in order to solve for its measurement error problem. Both results in 5-(3) and 5-(4) are consistent with those of the FGLS panel estimations: technology transfer by the Japanese affiliates increases IIT. Overall, all the other coefficients are reasonable and significant. This confirms that technology transfer using Japanese-affiliated firms' micro data allows the HK prediction: the similarity of GDP and factor endowments increases the proportion of IIT.

Finally, 7-(1) to 7-(3) in Table 1 report results for estimation (10). The results are consistent with our model: EDUs are significantly negative in all estimations. A small difference of human capital with Japan can promote Japanese FDI, the activity of Japanese affiliates, and technology transfer. Reflecting our model, the degree of technology transfer is not particularly large: a small or intermediate level of transfer increases IIT, whereas large-scale technology transfer decreases IIT.

3.3 The data qualifications and further estimations

Although the previous regressions provide us with good insight, some data qualification is necessary in TECHJPNAFF and JPN workers. Under the assumption of the same price per licence, TECHJPNAFF is induced by Japan's receipts from technology exports weighted by $\frac{The\ number\ of\ license\ via\ FDI}{The\ total\ number\ of\ license}$. What is worse, the figures for the number of licences are available every three years, i.e. 1996 and 1999 in our sample. Thus, the ratios employed by the previous regressions are assumed to have grown up at constant rates over time. "JPN workers" has a similar qualification. The data on the average number of Japanese workers and CEOs per affiliate are available every three years, 1996 and 1999, though the number of overseas affiliates is available every year. These assumptions seem to be quite strong. To check the reasonability of the assumptions, the following two strategies are used. One is that the same equations are regressed only using data in 1996 and 1999, in order to eliminate the above assumptions of constant rates of growth. The results are reported in Table 2, which are almost the same as previous estimation results: positive coefficients of TECHJPNAFF and JPN workers. Also, almost the same values of coefficients can be observed: 0.064 for TECHJPNAFF (0.063 in the full sample) and 0.096 for JPN worker (instead of 0.091 in the full sample). In sum, from these results, we can say that the assumptions in the previous estimations are not harmful and the regression results are not unreasonable.

4. CONCLUSIONS

Recent years have seen a remarkable increase in IIT between OECD and non-OECD countries. Previous studies have sought to explain this phenomenon using VIIT and fragmentation rather than the HK model. By contrast, our paper stays with the HK model and the HL estimation methodology but expands the model and methodology by considering heterogeneity of firm productivity and technology transfer related to FDI. Introducing technology transfer through FDI into the HL estimation methodology can explain the current IIT well. Favourable circumstances for technology transfer in host countries such as a small difference in educational level enhance FDI, which in turn increases re-imports. In the presence of wage and technology gaps, IIT increases when the degree of technology transfer is sufficiently small, but a large degree of technology transfer decreases IIT. Our estimation of Japanese IIT patterns suggests that although gaps in technology and wages exist with other Asian countries, the technology transfer through FDI is not large scale. In addition, technology transfer via the vertical FDI is an alternative determinant to distance and country-specific factors in gravity equations. Furthermore, if the technology transfer corresponds to production networks, we can suggest that production networks promote IIT.

DATA APPENDIX

The components of foreign countries:

Asia: South Korea, Hong Kong, Taiwan, China, the Philippines, Thailand, Singapore, Malaysia, Indonesia, India
Europe: UK, Germany, the Netherlands, France, Belgium-Luxembourg, Italy, Spain, Switzerland
Americas: USA, Canada, Mexico, Brazil
Oceania: New Zealand, Australia

The components of industries

This classification is based on Ministry of Economy, Trade and Industry (METI) categories.

Foodstuffs, raw materials and mineral fuels, textile goods, non-metal mineral products, light industrial products, chemical goods, general machinery, electrical machinery, transport equipment, and precision instruments.

Definitions and data sources of each variable used in the regression analysis

GL_t^i **(from 0 to 1)**

The variable GL_t^i is defined as the share of IIT in total trade between Japan and each trading partner i in each year t. GL refers to the Grubel and Lloyd index, defined as $GL^i = 1 - \frac{\sum_i |EX_i - IM_i|}{\sum_i |EX_i + IM_i|}$, where I represents industry. We used Japan's bilateral trade data for every year at the 2-digit level as in the above mentioned categories of industries.

GDPMAX and GDPMIN (unit: USD million, 1995)

GDPmax represents the logarithm of the GDP of the country with the larger GDP, and vice versa in GDPmin.
The data on GDP are taken from the International Energy Annual 2001, Energy Information Administration.

DIFF (unit: USD, 1995)

DIFF refers to per capita income differences, which is the logarithm of the absolute value of GDP per capita. To process GDP per capita, GDP data are divided by population. The population data are from the International Energy Annual 2001 (Energy Information Administration).

DIST (km)

The variable DIST is the logarithm of the geographical distance between the capital of the trading partner and Tokyo.

Regional Dummies (0 or 1)

The variables are composed of three dummies: Asia dummy, NAFTA dummy, Europe dummy.
Asia dummy and Europe dummy represent the component countries in each area.
NAFTA dummy represents the trade with the United States, Canada and Mexico.

TECH (unit: USD million, 1995)

TECH is the logarithm of the summation of bilateral technology trade between Japan and each trading partner. The data are receipts and payments of loyalty fees. The data are taken from the Balance of Payments (Bank of Japan).

TECHJPNAFF (unit: USD million, 1995)

This variable is defined as the technology exports of Japanese affiliates. TECHJPNAFF is induced using the number of licences as follows:

$$TECHJPNAFF_t^i = TechEX_t^i * \frac{license_{FDI}}{license_{total}} \frac{1}{GDP_t^i}$$

where TechEX is Japan's receipts from technology exports taken from the Balance of Payments (Bank of Japan), licenseFDI represents the number of licences from parents to their affiliates, while all-licensing refers the total number of licences by Japanese firms to foreign firms, and GDP refers to the host country GDP, taken from the International Energy Annual 2001. Note that the loyalty fee for each licence is assumed to be the same. All license data are from the Basic Survey of Overseas Activities (METI). TECHEX is taken from the Balance of Payments (Bank of Japan).

JPNWORKERS (number of persons)

The variable is defined as the total number of Japanese workers and CEOs that parent companies in Japan send to their affiliates.

$$JPNWORKERS_t^i = JPNWORKERS_{average_t}{}^i * NAFF_t^i$$

where NAFF represents the number of Japanese affiliates. NAFF is available every year. JPN WORKERSaverage refers to the average number of Japanese workers and CEOs across Japanese overseas affiliates. This figure is available only every three years (1996 and 1999), and we thus assume a constant growth rate for each period.

$$JPNWORKER_{average_t}^{i} = \text{growth rate}*(t-1996)*JPNWORKERS_{average_{1996}},$$

where growth rate is induced by JPNWORKERS in 1996 and 1999. JPNWORKERS and NAFF are taken from the Basic Survey of Overseas Business Activities by METI.

SALES (USD million, 1995)

The variable is a proxy of technology as the activity of Japanese affiliates. The average sales across Japanese overseas affiliates in each host country, SALESaverage, and the number of affiliates in each host country, NAFF, are available each year. The data are taken from the Basic Survey of Overseas Business Activities by METI. To induce SALES, the total sales are denominated by GDP in the host country:

$$SALES_t^i = \frac{SALES_{average_t}^{i} * NAFF_t^i}{GDP_{host}}$$

EDU (unit: year)

The variable represents the gap in years of schooling between the trading partner and Japan in each year. The schooling year is an average of all people and is drawn from the Barro-Lee Data Set: International Schooling Years and Schooling Quality (www.worldbank.org)

REFERENCES

Ando,M and Kimura,F (2003) “The formation of international production and distribution networks in East Asia”, *NBER Working Paper* 10167.

Antras, P (2003) "Firms, Contracts, and Trade Structure", *The Quarterly Journal of Economics,* 188 (4): pp.1375-1418.

Balassa, B (1986) " Intra-industry Trade among Exporters of Manufactured Goods" in D. Greenaway and P.Tharakan eds. *Imperfect Competition and International Trade,* Brighton, pp108-128.

Baldwin, R.E. and T.Okubo (2004) “Heterogeneous firms, agglomeration and economic geography: selection and sorting”, *CEPR discussion paper* 4602.

Baldwin, R.E. and Ottaviano, G.I.P (2001) "Multiproduct Multinationals and Reciprocal FDI Dumping", *Journal of International Economics,* 54: pp.429-448

Baldwin, R.E., R. Forslid, P Martin, G.Ottaviano, and F. Robert-Nicoud (2003) *Economic Geography and Public*

Policy, Princeton University Press.

Bernard, A, S.Redding, and P.Schott (2004) “Comparative advantage and heterogeneous firms”, *NBER working paper series* 10688.

Combes, P, M.Lafourcade and T.Mayer (2003a) "Can Business and Social Networks Explain the Border Effect Puzzle?", *CEPR Discussion Paper* 3750.

Combes, P, M.Lafourcade and T.Mayer (2003b) "The Trade Creating Effects of Business and Social Networks: Evidence from France, mimeo.

Clark,D and D.Stanley (1999) "Determinants of Intra-Industry Trade between Developing countries and the United States", *Journal of Economic Development*, 24 (2): pp.79-95.

Debaere, P (2001) "Monopolistic Competition and Trade, Revisited: Testing the Model without Testing for Gravity", mimeo, University of Texas, Austin.

Evenett, S.J. and W. Keller (2002) "On Theories Explaining the Success of the Gravity Equation", *Journal of Political Economy* 110, (2): pp.281-316.

Falvey, R (1981) "Commercial Policy and Intra-industry Trade", *Journal of International Economics* 11, pp495-511.

Feenstra, R.C. (1998) "Integration of Trade and Disintegration of Production in the Global Economy *"Journal of Economic Perspectives*, 12: pp.31-50.

Findley, R (1978) “Relative Backwardness, Direct Foreign Investment, and the Transfer of Technology: A simple dynamic model”, *Quarterly Journal of Economics*, 62: pp.1-16.

Fukao, K (2000) Nikkei Genti Houjin ha Ajia no Tuuka Keizai Kiki ni ikani Taiousitaka- micro data ni motoduku jissyou bunseki (How do the Japanese oversea affiliates take actions toward Asian financial and economic crises? -An empirical study based on micro-data), M. Aoki and J. Teranishi ed. *Tenkanki-no higashi Ajia to Nihon Kigyou* Ch.8, Toyo keizai shinpousya.

Fukao, K and C.Hoon (1996) Chokusetsu Toshi Sakikoku no Kettei Yoin Nitsuite: Wagakuni Seizougyou Nikansuru Jisho Bunseki (On the determinants of the Location Decision in Direct Investment Abroad: An Empirical Analysis on Japan's Manufacturing Industry) *Financial Review*, 38, Policy Research Institute, Ministry of Finance, Japan

Fukao, K, H. Ishido, and K.Ito (2003) `Vertical Intra-Industry Trade and Foreign Direct Investment in East Asia', *Journal of the Japanese and International Economies*, 17: pp.469-506.

Fukao, K and T.Okubo (2004) `Why has border effect declined? Role of Networks in East Asia', *Discussion paper series 21, COE RES Center of Excellence Research on Economic Systems*, Hitotsubashi University, Tokyo.

Gould, D (1994) "Immigrant Links to the Home Country: Empirical Implications for U.S. Bilateral Trade Flows", *Review of Economics and Statistics*, 76: pp.302-316.

Goldberg, M A., R L. Heinkel, and M D.Levi (2003) "Foreign Direct Investment: The human dimension", *CUER Working Paper* 03-01, centre for urban economics and real estate, University of British Columbia.

Greaney, T (2003) "Reverse Importing and Asymmetric Trade and FDI: A Network Explanation", *Journal of International Economics,61* (2): pp.453-465.

Greenaway, D, R.Hine, and C.Milner (1994) "Country-specific Factors and the Pattern of Horizontal and Vertical Intra-industry Trade in the UK", *Weltwirtschaftliches Archiv*, 130 (1): pp77-100.

Greenaway, D, R.Hine, and C.Milner (1995) "Vertical and Horizontal Intra-industry Trade: A Cross Industry Analysis for the United Kingdom", *Economic Journal,* 105: pp1505-1518.

Grubel, H.G. and J.P.Lloyd (1975) *Intra-Industry Trade: The Theory and Management of International Trade in Differentiated Products*, Mcmillan, New York.

Head, K and Ries, J (1998) "Immigration and Trade Creation: Empirical Evidence from Canada", *Canadian Journal of Economics,* 31: pp.47-62.

Helpman, E (1987) `Imperfect competition and international trade: Evidence from fourteen industrial countries', *Journal of the Japanese and International Economies,* 1: pp.62-81.

Helpman, E and H,Flam (1987) "Industrial Policy under Monopolistic Competition", *Journal of International Economics*, 22: pp.79-102.

Helpman, E and P.Krugman (1985) *Market Structure and Foreign Trade*, The MIT Press, Cambridge, MA.

Helpman, E., M. Melitz, and S.Yeaple (2004) "Export vs. FDI with heterogeneous firm", *American Economic Review,* 94(1): pp.300-316.

Hummels, D and J. Levinsohn (1995) `Monopolistic competition and international trade: Reconsidering the evidence', *Quarterly Journal of Economics*, 110: pp.797-836.

Lawrence, R (1991) "Japan's Different Trade Regime: An Analysis with Particular Preference to Keiretsu", *Journal of Economic Perspectives*, 7(3): pp.3-19.

Martin, P and C. Rogers (1995) "Industrial Location and Public Infrastructures", *Journal of International Economics,* 39: pp.347-368.

Markusen, J and A. Venables (2000) "The theory of endowment, intra-industry and multi-national trade", *Journal of International Economics,* 52: pp.209-234.

McLaren, J (1999) "Supplier Relations and the Market Context: A Theory of Handshakes", *Journal of International Economics,* 48: pp.121-138.

Melitz, M (2003) "The Impact of Trade on Intra-industry Reallocations and Aggregate Industry Productivity", *Econometrica*, vol71: pp.1695-1725.

Ng, F and A. Yeats (2003) `Major Trade Trends in East Asia', *World Bank Policy Research Working Paper* 3084.

Nilsson, L (1999) "Two-way Trade between Unequal Partners", *Weltwirtschaftliches Archiv*, vol 135 (1): pp 102-127.

Okubo, T (2004) `Border Effect in the Japanese Market -A gravity model analysis', *Journal of the Japanese and International Economies,* 18: pp.1-11.

Rauch, J (1999) "Networks versus Markets in International Trade", *Journal of International Economics*, 48: pp.7-35.

Rice, P, M. Stewart, and A.J. Venables (2002) "Geography of Intra-industry Trade: empirics" *CEPR discussion paper series*, No. 3368.

Wakasugi, R (1997) `Missing factors of intra-industry trade: Some empirical evidence based on Japan', *Japan and the World Economy,* 9: pp.353-362.

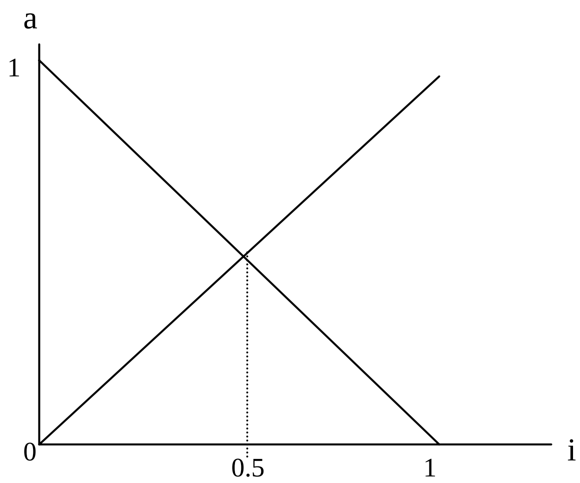

Figure 1:Technology and Comparative Advantage

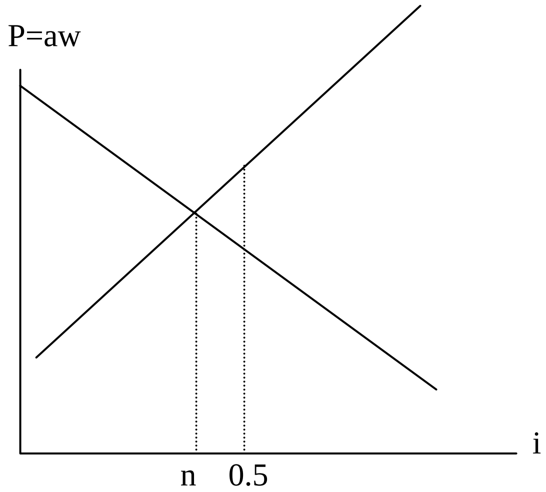

Figure 2-1: Symmetric Technology and Wage Gap

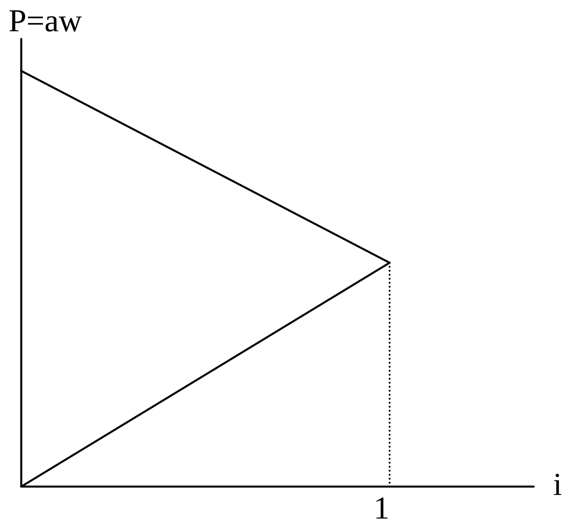

Figure 2-2: Asymmetric Technology and No Wage Gap

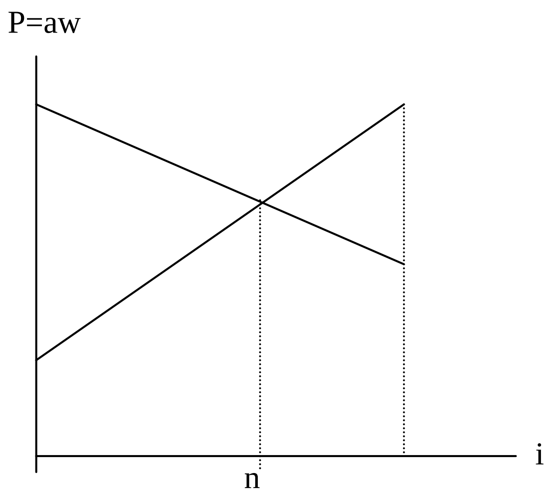

Figure 2-3: Asymmetric Technology and Wage Gap

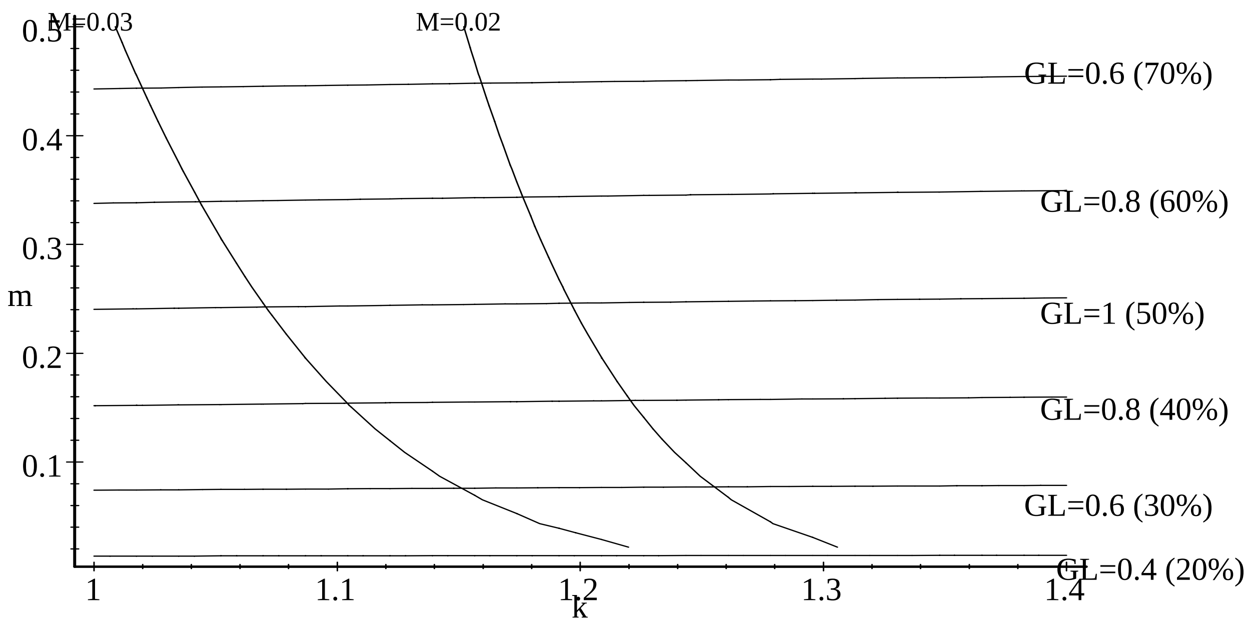

Figure 3: FDI and Technology Transfer

The percentages in parentheses represent import ratios in northern trade.
GL refers to the Grubel-Lloyd Index. Since our model is a partial equilibrium analysis,
we induce the index by assuming that all industries, I, have the same structure, or assume one good trade world.

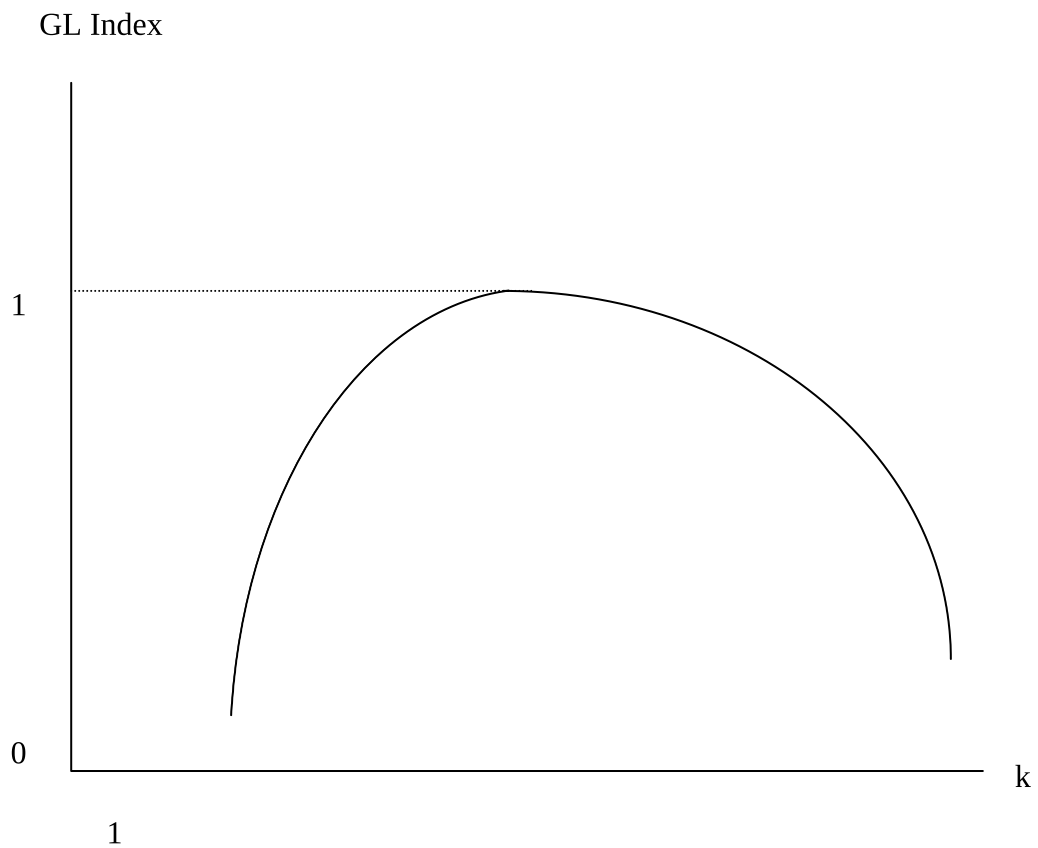

Figure 4 GL Index and Technology Transfer

Figure 5-1
Share of Japanese intra-industry trade
1996-2000

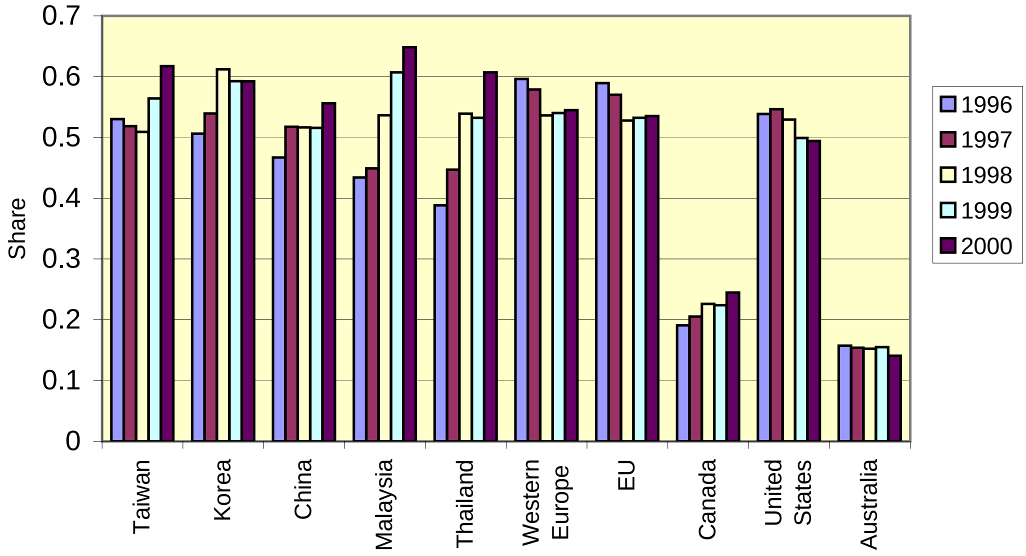

Figure 5-2. Technology transfer to Asian countries
1992-2000

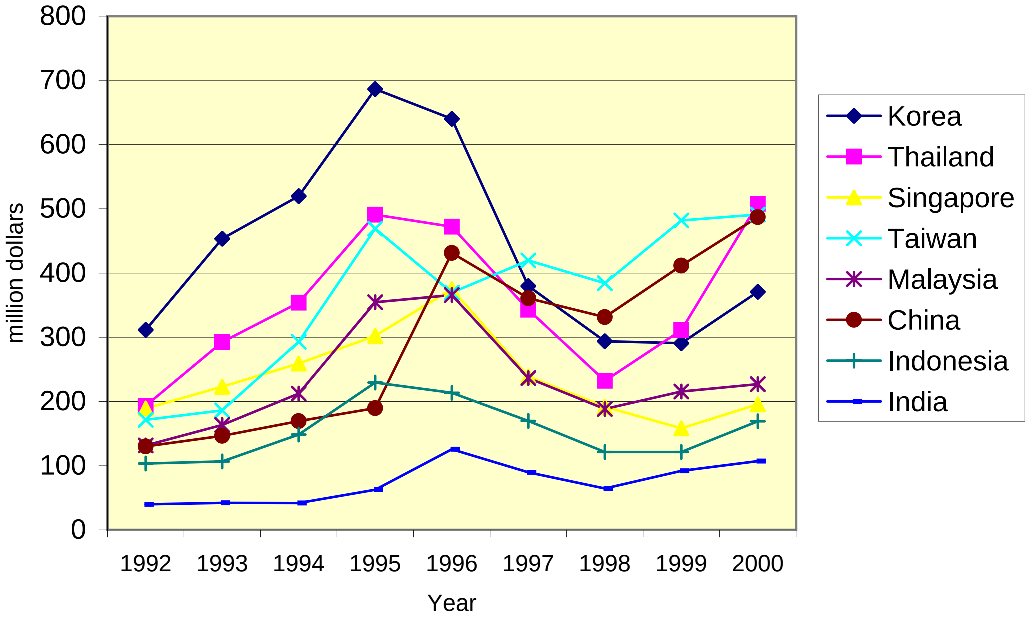

Table 1 Regression Results

Dependent variables : GL index

	1-(1)	1-(2)	2-(1)	2-(2)	3-(1)	3-(2)	4	5-(1)	5-(2)	5-(3)	5-(4)	6-(1)	6-(2)	6-(3)	7-(1)	7-(2)	7-(3)
DIFF	-0.014	-0.017	-0.034	-0.034	-0.02	-0.004	0.002	-0.017	-0.02	-0.026	-0.027	-0.05	-0.046	-0.039	-0.008	-0.033	-0.034
	[-3.35]**	[-2.50]**	[-3.70]**	[-4.52]**	[-0.88]	[-0.62]	[0.64]	[-3.70]**	[-2.82]**	[-2.98]**	[-2.99]**	[-5.03]**	[-5.12]**	[-4.36]**	[-1.94]**	[-3.53]**	[-3.91]**
GDPmax	-0.029	0.342	0.54	0.493	0.12	0.195	-0.424	-0.306	-0.11	-0.215	-0.237	-0.439	-0.478	-0.443	-0.2	-0.418	-0.391
	[3.67]**	[3.11]**	[7.63]**	[5.75]**	[2.21]**	[2.10]**	[-9.15]**	[-4.73]**	[-1.09]	[-1.97]**	[-2.10]**	[-9.42]**	[-8.57]**	[-7.33]**	[-2.84]**	[-8.33]**	[-6.10]**
GDPmin	0.026	0.021	0.016	0.02	0.027	0.023	0.001	0.089	0.067	0.0818	0.0848	0.021	0.075	0.081	0.081	0.008	0.066
	[2.84]**	[1.54]	[3.33]**	[2.38]**	[3.58]**	[2.03]**	[0.20]	[13.26]**	[5.22]**	[5.82]**	[5.88]**	[2.84]**	[11.02]**	[11.42]**	[10.49]**	[1.25]	[8.87]**
DIST	-0.111	-0.112															
	[-12.02]**	[-6.02]**															
Asia			0.325	0.271													
			[18.77]**	[9.61]**													
Europe			0.273	0.254													
			[19.67]**	[10.70]**													
NAFTA			0.081	0.07													
			[4.82]**	[3.27]**													
TECH							0.081										
							[14.44]**										
TECHJPNAFF								0.063	0.056	0.076	0.08			0.02	0.069		
								[12.33]**	[6.18]**	[7.33]**	[7.28]**			[1.62]*	[12.07]**		
JPN Workers												0.091				0.104	
												[13.64]**				[17.97]**	
Sales													0.052	0.038			0.054
													[11.39]**	[3.82]**			[12.42]**
EDU															-0.029	-0.033	-0.027
															[-4.92]**	[-8.20]**	[-5.34]**
constant	-3.328	-4.05	-8.102	-7.402	-1.794	-2.933	6.478	4.746	1.932	3.619	3.966	6.824	7.268	6.767	3.252	6.487	5.998
	[-3.01]**	[-2.65]**	[-7.36]**	[-5.76]**	[-2.29]**	[-2.21]**	[9.51]**	[4.98]**	[1.31]**	[2.23]**	[2.36]**	[9.31]**	[8.55]**	[7.52]**	[3.13]**	[8.46]**	[6.23]**
Num of sa	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
Log Likelih	99.296		139.831		88.641		116.386	99.47				107.075	103.898	103.575	105.388	124	110.099
Chi-2	198.25		1572.58		62.43		721.65	405.02				524.44	331.3	446.05	294.35	1004.59	422.41
R-squared		0.243		0.418		0.066			0.234	0.213	0.205						
F		16.85		48.15		15.84			23.28	27.14	27.54						
	FGLS	GLS	FGLS	GLS	FGLS	GLS	FGLS	FGLS	GLS	IV	IV	FGLS	FGLS	FGLS	FGLS	FGLS	FGLS

Notes:The numbers in parentheses are t-statistics in pooled OLS and GLS estimations, and are z-values in panel regressions.

FGLS represents cross-sectional time-series FGLS regression in panel data analysis and GLS refers to regression with robust standard errors in pooled data analysis.

The instrument variables are JPNWORKERS and SALES for the estimation 5-(3) and JPNWORKERS, SALES and EDU for 5-(4). The instrumented variables are TECHJPNAFF in both estimations.

* : Significant at 10% level.

**: Significant at 5 %.

Table 2 Robustness for the Results by FGLS

Dependent variables : GL index

	8-(1)	8-(2)	8-(3)
DIFF	-0.026	-0.073	-0.061
	[-3.76]**	[-6.20]**	[-6.47]**
GDPmax	-0.346	-0.439	-0.504
	[-2.87]**	[-5.80]**	[-5.71]**
GDPmin	0.021	0.011	0.074
	[1.84]*	[1.54]	[8.00]**
TECHJPNA	0.064		
	[7.64]**		
JPN Workers		0.096	
		[13.66]**	
Sales			0.052
			[10.03]**
constant	5.506	13.043	7.824
	[3.08]**	[6.12]**	[5.98]**
Num of sa	48	48	48
Log Likelih	41.185	47.579	47.032
Chi-2	88.39	323.8	157.69

Notes:the numbers in parentheses are z-values in panel regressions.
* : Significant at 10% level.
**: Significant at 5 %.

Table 3 Japan's Technology Receipts and Payments (2000)

Country	TECHEX	THCHIM	Ex Ratio
Korea	371	9.96	37.21
China	487	19.54	24.93
Taiwan	491	1.02	481.33
Thailand	508	0.00	--
Singapore	196	15.47	12.65
Malaysia	227	0.00	--
Indonesia	169	0.00	--
India	107	2.27	47.17
United King	612	124.59	4.91
Sewden	18	86.29	0.21
Netherlands	170	170.43	0.99
France	173	138.63	1.25
Germany	121	185.09	0.66
Switzerland	30	179.90	0.17
Italy	52	14.86	3.50
Canada	965	19.22	50.21
United State	4,458	3056.27	1.46
Australia	84	7.00	11.99

unit : USD million

Ex Ratio = TECHEX/TECHIM

Source:Survey of Research and Development
(Ministry of Public Management, Home Affairs,
Post and Telecommunications)