The Features and Determining Factors of ICT Intra-Industry Trade: Evidence from the Asia, EU and US Markets

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Abstract

This study investigates the features as well as the determining factors of information and communications technology (ICT), horizontal intra-industry trade (HIIT) and vertical IIT (VIIT) among Asia, the European Union (EU) and the US for the period covering the years 1996 to 2005. The evolution of the HIIT and VIIT of the ICT industry for six pairs of regions indicate that HIIT has dominated VIIT in the ICT industry, which is obviously contrary to the present pattern of world trade.

The empirical results further reveal the principal pattern of the ICT firms' foreign direct investment as facilitating the market rather than seeking efficiency in the host regions. The effect of revealed comparative advantage (RCA) in relation to VIIT and HIIT demonstrates that vertical specialization is significant between Asia and the EU whereas horizontal specialization plays a key role between Asia and the US. The Asian financial crisis significantly promoted VIIT in regard to Asian ICT firms in the US market. Finally, regional trade associations such as the EU and ASEAN have strengthened the vertical specialization of EU ICT firms in Asian countries.

Keywords: ICT industry, foreign direct investment, revealed comparative advantage

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1 Introduction

The ICT industry believes in open, low tariff trade and in a multilateral ruled-based trading system. Hence, most internationalized information and communications technology (ICT) firms have been adjusting well to economic globalization and technology innovation in the last three decades. For example, several European Union (EU), Japanese and US leading ICT firms (e.g., Nokia, Infineon, SONY, Intel, DELL, etc.) have moved their production lines to regions with a comparative advantage in manufacturing (like China, Southeast Asia, Ireland, etc.) to open markets or increase their efficiency. On the other hand, these investment activities have indeed been helpful to the host regions or countries in terms of creating one complete ICT value-added chain. In particular, a few Chinese, Irish, Korean and Taiwanese firms (e.g., Huawei, Samsung, LG, Acer, HTC) have not only created their own brands but have also become one of the worldwide leaders in the ICT industry in terms of particular products such as communications equipment, software, large-scale TFT-LCD, PC/ NB, DRAM, FLASH, etc. We can expect that the global ICT intra-industry trade will be more prosperous in the future due to technology innovation and the spillover effect.

IIT refers to the two-way international trade that has been identified by both exports and imports of different varieties of products within a differentiated product category such as that at the Standard International Trade Classification (SITC) 3-digit or 6-digit level (Balassa, 1966). To further comprehend the characteristics of IIT in the ICT industry, this study focuses on the features of horizontal intra-industry trade (HIIT) and vertical intra-industry trade (VIIT) and the investigation of the factors determining the ICT industry among the regions of Asia, the EU and the US over the period 1996-2005. The Asian region contains seven countries, and the EU contains

15 earlier members due to data source limitations.[1] We utilize the Gartner Dataquest classification and then decompose the ICT industry into the Semiconductor, Electronic components, Optoelectronics and Computer peripheral industries based on the 6-digit ICT products categorization.

Following the earlier literature and characteristics related to the ICT industry, we examine ten determinants to investigate the effect of the HIIT and VIIT in the ICT industry. We have more interesting findings while most of the empirical results are consistent with the theoretical expectations and previous empirical studies. For example, the magnitude and pattern of HIIT and VIIT in the ICT industry among Asia, the EU and the US indicate that the HIIT has dominated the VIIT for the ICT industry which is a different result from that found in the current approach to world trade. From the viewpoint of foreign direst investment (FDI), the Asian, EU and US ICT firms tend to prefer opening market strategies to efficiency seeking. The coefficients of product differentiation in regard to HIIT and VIIT reveal that Asian ICT firms prefer to utilize horizontal specialization strategies in the US and EU markets, but that US ICT firms tend to adopt a vertical specialization strategy in the Asian market. The Asian financial crisis is found to have been significantly helpful in terms of strengthening the HIIT of Asian ICT firms in the US market (Asia-US),[2] whereas trade barriers have a negative influence in relation to VIIT in the Asia-EU pair of regions.

The remainder of this paper is organized as follows. Section 2 presents a review of the relevant theoretical and empirical literature. In Section 3, we provide a description of the data and determinants of HIIT and VIIT. Section 4 features the characteristics

[1] The sample countries are organized as follows. The Asian region includes seven countries: China, Japan, Malaysia, Singapore, South Korea, Taiwan and Thailand; the EU includes Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom.

[2] Asia-US pair of regions refers the US region to be the foreign Asian ICT firms' host market.

and evolution of the HIIT and VIIT indices. Section 5 outlines our empirical model and presents the key empirical results. Section 6 concludes.

2 Literature Background

In the international trade literature, IIT represents the two-way trade in parts and intermediate goods with different brands and quality within the same industry category. It is difficult, however, for this type of IIT to serve as the driving force of IIT either for horizontally differentiated products or vertically differentiated products. Hence, by following Abd-el-Rahman (1991) and Greenaway et al. (1994, 1995) and diverging from the definition of IIT, researchers further decompose IIT into HIIT and VIIT and outline the determining factors of both HIIT and VIIT (Greenaway et al., 1994, 1995; Aturupane et al., 1999; Hu and Ma, 1999; Sharma, 2004; Zhang et al., 2005; Byun and Lee, 2005; Wakasugi, 2007).

Although different forces are seen to be driving HIIT and VIIT, we can know that the factors appear to be more skillful but less mobile in VIIT compared with HIIT based on the definitions of HIIT and VIIT. The early studies indicate that the determining factors such as product differentiation and economic size play important roles in relation to HIIT (Balassa, 1966; Grubel and Lloyd, 1975; Dixit and Stiglitz, 1977; Krugman, 1979, 1980, 1981; Lancaster, 1979; Gavelin and Lundberg, 1983; 1980; Balassa and Bauwens, 1987; Lundberg, 1988; Abd-el Rahman, 1991; Hu and Ma, 1999; Byun and Lee, 2005). For example, horizontal (vertical) product differentiation has a significantly positive influence in relation to HIIT (VIIT), but a negative impact in relation to VIIT (HIIT) (Byun and Lee, 2005). Some empirical papers have suggested that the more similar both economies are in terms of their incomes (GDP) (Bergstrand, 1990; Frahan and Tharakan, 1998; Hu and Ma, 1999),

and in terms of the ratio of capital to labor or the economic development level (Bergstrand, 1990), the higher will be the HIIT. Hu and Ma (1999) pointed out that market structure is one of the principal factors in determining HIIT.

On the other hand, since VIIT reflects the qualitative difference in the products exported and imported between both economies and skillful endowments play a key role in product quality (Falvey,1981; Shaked and Sutton,1984; Falvey and Kierzkowski, 1987; Flam and Helpman,1987), some determinants, including educational expenditure and R&D investment, etc., are statistically positive and significant in regard to VIIT (Hu and Ma, 1999).

In the earlier studies, foreign direct investment (FDI) had a significantly positive influence on IIT (Vernon, 1966; Greenaway, 1988; Lee, 1989; Hu and Ma, 1999; Zhang et al., 2005). However, the relationship between FDI and HIIT or VIIT must be dependent on the variety of FDI. If the motivation behind FDI is to open the market, then FDI could substitute for trade. By contrast, efficiency-seeking FDI could facilitate trade. A typical example is that where a few US, Japanese, South Korean and Taiwanese ICT firms' FDI strategies are assisting the Chinese market (Zhang et al., 2005).

Trade barriers could serve to reduce IIT (Sharma, 2004). Controversially, trade liberalization or policies to lower trade barriers have a significantly positive influence on IIT, HIIT or VIIT (Bano, 1991; Zhang et al., 2005). Host countries must produce products with comparative advantage following trade liberalization, and then raise either HIIT or VIIT. However, Byun and Lee (2005) found that the gap in terms of the factor endowment between Asian countries (Japan or Korea) and African countries decreases in regard to HIIT and VIIT whereas the gap in terms of the factor endowments between Asian countries has a contrary impact on HIIT and VIIT. The regional trade arrangements (RTAs) (e.g., the EU and ASEAN) have a positive

influence in relation to VIIT in terms of East Asia's relationship with NAFTA and EU members (Wakasugi, 2007). Rodas-Martini (1998), however, found that the impact of RTAs in relation to IIT is insignificant especially in less developed Central American countries.

Similarly, in accordance with theoretical expectations and empirical studies, geographical distance, trading structure and economic size could affect HIIT and VIIT as well (Hu and Ma, 1999; Thorpe and Zhang, 2005; Zhang et al., 2006). Hu and Ma (1999) found that HIITs between China and 45 other countries are stimulated by economic size. For the East Asian region, Thorpe and Zhang (2005) found that regional integration, economic size and industrial structure adjustments were statistically significant and positive in relation to IIT during the period 1970-1996. Zhang et al. (2005) obtained similar findings in relation to HIIT and VIIT between China and 45 of its trading partners from 1992 to 2001.

3 Data Sources and Determining Factors

The paper investigates the features and determining factors of both HIIT and VIIT in the ICT industry between Asia and the EU and the US, between the EU and Asia, and the US, and between the US and Asia and the EU during the period from 1996 to 2005 utilizing a dynamic panel data analysis. Following the Gartner Dataquest definition, we divide the ICT industry category using the Standard International Trade Classification (SITC) 6-digit level into four sub-industries, namely, the Semiconductor, Electronic components, Optoelectronics and Computer peripheral industries.

After identifying them in the theoretical and empirical literature and extracting them based on the characteristics of the ICT industry, we included seven

determinants in the empirical model, namely, per capita GDP (GDP/POPU)[3], foreign direct investment (inflows and outflows) (FDIin; FDIout), the ratio of R&D to GDP (R&D/GDP), the ratio of expenditure on education to GDP (EDU/GDP), the product differentiation level (HUF), and revealed comparative advantage (RCA). Furthermore, to account for the international trading environment, we also included a set of dummy variables in the estimation that included regional trade agreements (TRAs), the Asian financial crisis (FC) and trade barriers. Table 1 summarizes the definitions of all ten explanatory variables being used.

Table 1 inserted here

4 The Magnitude and Pattern of HIIT and VIIT in Six Pairs of Regions

In this study, in order to comprehend the variations in the patterns of trade flows and avoid the dispersion problem in static status among different regions, we employ a dynamic Grubel-Lloyd index (Brulhart, 1994) to calculate the IIT index as follows:

$$IIT_{ijt} = 1 - \frac{\left| \sum_{i \in A} \sum_{j \in A} \sum_{k=1}^{n} \Delta X_{ijkt} - \sum_{i \in A} \sum_{j \in A} \sum_{k=1}^{n} \Delta M_{ijkt} \right|}{\sum_{i \in A} \sum_{j \in A} \sum_{k=1}^{n} \left| \Delta X_{ijkt} \right| + \sum_{i \in A} \sum_{j \in A} \sum_{k=1}^{n} \left| \Delta M_{ijkt} \right|},$$

where Δ refers to first degree differentiation; X_{kt} and M_{kt} represent exports and imports of the k_{th} sub-industry in period t, respectively; IIT_{ijt} refers to the dynamic IIT index for all k sub-industries between region (country) i and region (country) j in period t where $IIT_{ijt} \in (0,1)$. Furthermore, we disintegrate IIT into HIIT and VIIT following the definitions given in Brulhart (1994) and Thom and McDowell (1999).

[3] The per capita GDP could avoid overestimation problem rather than GDP as the growth rate of GDP is higher than growth rate of population particularly in Asia region.

That is $HIIT_{ijt} = \sum_{k=1}^{n} w_k B_{ijkt}$, where the weight $w_k = |\Delta X_k| + |\Delta M_k| \Big/ \sum_{k}^{n} |\Delta X_k| + \sum_{k}^{n} |\Delta M_k|$ implies the ratio of the k_{th} sub-industry to all n sub-industries; $B_{ijkt} = 1 - |\Delta X_{ijkt} - \Delta M_{ijkt}| \Big/ |\Delta X_{ijkt}| + |\Delta M_{ijkt}|$; and ΔX_{ijkt} and ΔM_{ijkt} represent the variations in exports and imports of the k_{th} sub-industry between region (or country) i and region (or country) j in period t. Thus, we have $VIIT_{ijt} = IIT_{ijt} - HIIT_{ijt}$ since $0 \leq B_{ijkt} \leq 1$.

We adopt the dynamic Grubel-Lloyd index to show the magnitude and pattern of the HIIT and VIIT shares in six pairs of regions including the Asia-EU, EU-Asia, Asia-US, US-Asia, EU-US and US-EU regions.[4] First, the patterns for the HIIT and VIIT of the ICT industry in most of the four pairs of regions demonstrate that HIIT leads VIIT in the ICT industry. Obviously, these results are contrary to the current world trade pattern of VIIT dominating HIIT (Fontagné et al., 2006). In other words, the horizontal product differentiation strategy plays an important role in the ICT industry.

Secondly, as shown in Figures 1 and 2, the shares attributable to HIIT are higher than those attributable to VIIT except in 2003 in Asia-EU. Accordingly, the phenomenon observed within the two-way trade between Asia and the EU also occurs in US-Asia. This means that the EU and US ICT firms prefer horizontal specialization to vertical product differentiation in Asian countries (Figure 2 and Figure 4). Thirdly, Figures 3 and 5 also show HIIT to be higher than VIIT except in 2003 and 2004. The consequences of this are that Asian and EU ICT firms also prefer to export horizontally differentiated products to the US market. However, it needs to be asked

[4] Due to data limitations, the evolution of the HIIT and VIIT shares in the US-Asia region extends from 1997 to 2005; that of the Asia-US and Asia-EU pairs of regions are for the 2000-2005 period while the evolution of the EU-Asia HIIT and VIIT shares covers the period from 1998-2005.

why VIIT is higher than HIIT particularly in 2003 and 2004. This is a topic that requires further study in the future. Finally, the evolution of HIIT and VIIT in US-EU and Asia-EU except in 2003 reveals that horizontal specification is the US and Asian ICT firms' leading strategy in the EU market (Figure 1 and Figure 6).

Figures 1~ 6 inserted here

5 Empirical Model and Results

Based on the definitions of HIIT and VIIT, we construct a cross-sectional panel data dynamic model (1)：

$$\mathrm{HIIT}_{ijt} = \alpha + \beta X_{ijt} + v_{ijt} + u_{ij}, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where $i, j = 1,2,.....,N$, $t = 1,2,.....,T$. The vector $\mathrm{X_{ijt}}$ consists of a set of explanatory variables representing the determinants of HIIT and VIIT from region (country) i to region (country) j in period t. v_{ijt} is an error term; u_{ij} is an unobservable time-invariant random effect from region i to region j, $u_{ij} \geq 0$. That is, autoregression or heteroscedasticity could occur in the regression model. Hence, an autoregression test and Hausman specification test are required.

5.1 Autoregression and Hausman test

Following equation (1), we form two specifications of the panel data regressions as in equation (2) and equation (3) below:

$$\begin{aligned} HIIT_{ijt} = {} & a_0 + a_1 GDPPOPU_{it} + a_2 FDIin_{ijt} + a_3 FDIout_{ijt} + a_4 RD/GDP_{it} + a_5 EDU/GDP_{it} \\ & + a_6 RCA_{ijt} + a_7 HUF_{ijt} + a_8 Barrier_{ijt} + a_9 FC_{ijt} + a_{10} RTA_{ijt} + v_{ijt} + u_{ij} \end{aligned} \quad \ldots. (2)$$

$$\begin{aligned} VIIT_{ijt} = {} & a_0 + a_1 GDPPOPU_{it} + a_2 FDIin_{ijt} + a_3 FDIout_{ijt} + a_4 RD/GDP_{it} + a_5 EDU/GDP_{it} \\ & + a_6 RCA_{ijt} + a_7 HUF_{ijt} + a_8 Barrier_{ijt} + a_9 FC_{ijt} + a_{10} RTA_{ijt} + v_{ijt} + u_{ij} \end{aligned} \quad ,\ldots\ldots. (3)$$

where all variables are defined in Table 1. We include eight pairs of regions of respective HIIT and VIIT from the Asia-EU, Asia-US, US-Asia and EU-Asia among three regions, as shown in Table 2.[5]

In choosing the empirical method to be adapted to each HIIT and VIIT case, we employ the Lagrange multiplier (Breusch and Pagan, 1980) to first test for autoregression. If autoregression exists, then we can choose either the full general least squares method (FGLS) or general method of moments (GMM) to conduct a further estimation. If not, the Hausman test is required to check whether the optimal testing method is the random effects model (REM) or fixed effects model (FEM) together with FGLS. Table 2 reports that REM is adequate for all pairs of regions.

Table 2 inserted here

5.2 Empirical results

After ten determining factors (Table 1) are identified in the literature and extracted from the regional specifications and characteristics of the ICT industry, we perform empirical analyses using REM for HIIT and VIIT for up to four pairs of regions.

5.2.1. HIIT and VIIT of the ICT industry for the Asia-US pair of regions

Table 3 explores consequences of the determinants of HIIT and VIIT for the Asia-US pair of regions. First, per capita GDP is significantly negative in relation to HIIT but positive in relation to VIIT. This result also confirms that the gap in income level between the two economies decreases in HIIT but increases in VIIT (Falvey and Kierzkowski, 1987; Bergstrand, 1990; Frahan and Tharakan, 1998; Byun and Lee, 2005).

We further find that direct investment inflows (FDIin) have a negative and

[5] Due to data source limitations, we can not test the EU and US pair of regions.

statistically significant effect on VIIT and HIIT while foreign direct investment outflows (FDIout) decreases in the case of VIIT, which is consistent with the empirical findings of Greenaway (1988) and Lee (1989). In other words, the results reflect the fact that investment by Asian ICT firms in the US takes place due to a fascination with the market rather than in order to seek efficiency. The per capita GDP is negatively significant in relation to HIIT, but has a positive relationship with VIIT in the Asia-US region, which is similar to the findings of Zhang (2005), and Helpman and Krugman (1985).

A larger ratio of educational expenditure to GDP (EDU/GDP) is observed to have contrasting impacts on the HIIT and VIIT indices, respectively. Since the intensity of education represents the quality of human resources, the results indicate that, the greater the EDU/GDP, the higher that VIIT is and the lower that HIIT is, which is consistent with the findings of Hu and Ma (1999) and Zhang et al. (2005). Product differentiation leads to increases in HIIT, indicating that Asian ICT firms often use product differentiation strategies to opening the market in the US.

The positive impact of the Asian financial crisis on HIIT implies that a financial crisis is helpful to horizontal product differentiation for Asian ICT firms in the US market. The relative comparative advantage has a negative influence on VIIT, indicating, based on the viewpoint of vertical and horizontal specialization, that most Asian ICT firms would prefer to invest in the Asian region directly rather than in the US partly due to the geographic distance and transaction cost elements.

Table 3 inserted here

5.2.2 HIIT and VIIT of the ICT industry in the Asia-EU pair of regions

The empirical results, as reported in Table 4, significantly support the view that assisting the market with product differentiation has become the Asian ICT firms' key strategy in the EU market. Since education intensity positively improves the quality of

human resources, the ratio of educational expenditure to GDP (EDU/GDP) is important in facilitating HIIT but also leads to a reduction in VIIT in the Asia-EU region contrary to Hu and Ma's (1999) empirical results. There are two main reasons for this. One is that the growth rate of EDU/GDP decreases in relation to GDP whereas the growth rate of educational expenditure is less than that of GDP (Figure 7). Hence, the relationship between EDU/GDP and VIIT could be negative while GDP has a positive influence on VIIT. The other reason is that the higher that HIIT becomes, the greater will be EDU/GDP as the EDU/GDP gap between Asia and the EU decreases in EDU/GDP. Thus, based on Hu and Ma's (1999) expectations, the increasing EDU/GDP is helpful to promoting horizontal product competition between Asia and the EU.

Figure 7 inserted here

Table 4 further reveals that the Hufbauer index (a proxy for product differentiation) is positively significant in relation to HIIT but negative in relation to VIIT. The result clearly shows that Asian ICT enterprises prefer an open EU market with horizontally differentiated products. Since the ratio of R&D to GDP is an essential source of comparative advantage in international trade (Krugman and Obstfeld, 1994), this theory suggests that the larger the ratio of R&D to GDP, the higher will be the HIIT and VIIT. In Table 4, the ratio of R&D to GDP has a positive influence in relation to HIIT in line with Sharma's (2004) findings. The consequence of this suggests that R&D investments by Asian ICT firms increase their competitiveness as compared with EU enterprises. The higher the revealed competitive advantage (RCA), the lower the HIIT that could reflect the decline in the degree of horizontal specialization in the Asia-EU pair of regions. The finding that trade barriers and FDIout are both negative and significant in relation to VIIT is consistent with both the theoretical expectations and empirical results (Sharma, 2004;

Bano, 1991).

Table 4 inserted here

5.2.3 HIIT and VIIT of the ICT industry in the US-Asia pair of regions

As shown in Table 5, per capita GDP, FDIin and EDU/GDP have both a negative and significant impact on HIIT that is in line with the results of HIIT for the Asia-US pair of regions. However, the negative coefficient of per capita GDP to VIIT goes contrary to some of the literature (Falvey and Kierzkowski, 1987; Bergstrand, 1990; Frahan and Tharakan, 1998；Byun and Lee, 2005). This could impact the US's ICT firms' market strategies in the Asian region above. However, further studies are required in this regard.

FDIin is statistically negative in relation to VIIT and FDIout has a significantly positive impact on HIIT, indicating that market acquisition is the US's ICT firms' main strategy in the Asian region. That EDU/GDP and R&D/GDP are increasing in relation to VIIT (consistent with Sharma (2004) and Hu and Ma (1999)) and that R&D/GDP is decreasing in relation to HIIT suggest that the greater the technology gap between US and Asian countries, the higher the degree of vertical specialization between both regions.

Compared with the Asia-US and Asia-EU pairs of regions, the significantly positive coefficient of product differentiation in relation to VIIT in the US-Asia pair of regions reflects the US ICT firms' preference for vertical specialization in the Asian market whereas Asian firms prefer horizontal specialization in the EU and US regions. That RCA has a negative influence on VIIT implies that US ICT firms appreciate exports (imports) of horizontally differentiated products to (from) Asia.

Table 5 inserted here

5.2.4. HIIT and VIIT of the ICT industry in the EU-Asia pair of regions

Table 6 reveals that HIIT is stimulated by per capita GDP, a finding that is confirmed

by both theoretical expectations and empirical studies (Hu and Ma, 1999). In addition, EDU/GDP and RCA also have the same influence in relation to HIIT. For example, since the gap in terms of EDU/GDP between the EU and Asian region is small, EDU/GDP will facilitate HIIT rather than VIIT in the EU-Asia pair of regions.

The significantly negative impact of FDIin on VIIT and the positive influence of FDIout on VIIT indicate that opening the market has become the EU ICT firms' principal investment strategy in the Asia market. This result is similar to that in the case of the US ICT firms' investment strategies in Asia. In contrast to the US-Asia pair of regions, the statistically significant and positive coefficient of RCA in relation to VIIT in the EU-Asia pair or regions reveals that the EU ICT firms' strategy of increasing exports serves to strengthen vertical specialization with Asian countries. Finally, while VIIT is stimulated by RTAs (for example, in the EU and ASEAN), RTAs have a positive contribution in terms of enhancing vertical specialization between the EU and Asia, which also confirms Wakasugi's (2007) findings.

Table 6 inserted here

6 Conclusions

In this paper, we feature HIIT and VIIT patterns and investigate the determining factors of HIIT and VIIT in the ICT industry in the Asia, the EU and the US. The trade magnitude and pattern of HIIT and VIIT in the ICT industry indicates that Asian, EU and US ICT firms favor horizontally differentiated products to vertically differentiated products. In other words, a horizontal specialization strategy plays a key role in ICT industry, which is obviously different from the present movement of world trade.

Table 7 summarizes the determinants of HIIT and VIIT in the ICT industry. First,

per capita GDP has a significantly negative impact in relation to HIIT in the Asia-US pair of regions and to HIIT and VIIT in the US-Asia pair of regions but a positive impact in relation to HIIT in the EU-Asia pair of regions and in relation to VIIT in the Asia-EU pair of regions. Some theoretical expectations and empirical studies show that the per capita GDP has a positive effect in relation to HIIT but a negative impact in relation to VIIT. But the impact of the income level in relation to HIIT and VIIT could be positive as the income level represents the scale of the market.

Secondly, our empirical findings indicate that the magnitude of foreign direct investment (inflows and outflows) is due to the fascination with the market instead of the need to seek efficiency in the host regions. Third, although some studies show that the ratio of R&D to GDP has a positive impact in relation to HIIT and VIIT, our results show the ratio of R&D to GDP to be significantly negative in relation to HIIT in the Asia-US and US-Asia pairs of regions and in relation to VIIT in the Asia-EU pair of regions. One of the main reasons for this is that the ratio of R&D to GDP declines in relation to GDP as the growth rate of GDP is higher than that of R&D expenditure especially in the Asian region. Thus, the ratio of R&D to GDP should have a negative influence in relation to HIIT and VIIT.

Fourth, the higher the ratio of educational expenditure to GDP (EDU/GDP), the lower (higher) the HIIT (VIIT) in the Asia-US and US-Asia pairs of regions whereas the Asia-EU and EU-Asia pairs of regions give rise to contrasting empirical results. Following the theoretical and empirical studies, we reach the following conclusion. On the one hand, EDU/GDP has negative impact in relation to HIIT, but has a positive impact in relation to VIIT between Asia and US in line with the theoretical expectations, i.e., increasing human capital intensity promotes VIIT but lowers HIIT between both regions. On the other hand, the gap in terms of EDU/GDP between Asia and the EU could be small, in which case an increasing EDU/GDP in Asia or

the EU serves to facilitate HIIT in the Asia-EU and EU-Asia pairs of regions.

Fifth, the results of product differentiation for both HIIT and VIIT show that most of our results are consistent with theoretical expectations, having a positive impact in relation to HIIT in the Asia-US pair of regions and in relation to both HIIT and VIIT in the EU-Asia pairs of regions but a negative impact in relation to VIIT in the Asia-US pair of regions. These results imply that Asian ICT firms are likely to utilize horizontal specialization strategies in the US and EU markets while EU firms prefer to adopt vertical specialization strategies as revealed comparative advantage increases.

Finally, the Asian financial crisis has significantly expanded HIIT in the Asia-US pair of regions. Regional trade associations such as the EU and ASEAN have strengthened the VIIT of the ICT industry in the EU-Asia pair of regions while trade barriers have had a negative influence in relation to VIIT in the Asia-EU pair of regions.

Table 7 inserted here

Table 1 An overview of factors affecting HIIT and VIIT in the ICT industry

Variables	Descriptions	Studies	Sources
GDP/POPU	Per capita GDP is a better index than GDP in terms of avoiding estimation bias.	Linder (1961) Falvey and Kierzkowski (1987) Frahan and Tharakan (1998) Byun and Lee (2005) Hu and Ma (1999)	Global insight's world overview
FDIin	Foreign firms' direct investment in host region (country)	Vernon (1966) Greenaway (1988) Lee (1989)	World investment report
FDIout	Foreign firms' withdrawal of investment from host region (country)	Vernon (1966) Greenaway (1988) Lee (1989)	World investment report
R&D /GDP	Government R&D expenditure, not including private enterprise expenditure	Krugman and Obstfeld (1994) Menon, Greenaway and Milner (1999) Sharma (2004)	UIS, S&T database, World Bank, EU website, Annual Report of The Central Bank of China
EDU/GDP	Government expenditure on education not including private education expenditure	Hu and Ma (1999)	IMF
HUF	The Hufbauer index is a proxy for product differentiation, reflecting the degree of vertical differentiation of the products in the ICT industry. $\mathrm{HUF}_{ij}^{k} = \mathrm{SD}_{ij}^{k} / \mathrm{AV}_{ij}^{k}$, SD_{ij}^{k} is the	Grubel and Lloyd (1975) Dixit and Stiglitz (1977) Krugman (1979, 1980, 1981) Lancaster (1979, 1980) Gavelin and Lundberg	WTA

	export standard for n products of region (country) i 's k_{th} industry to region (country) j; AV_{ij}^{k} is average export value.	(1983) Balassa (1966) Balassa and Bauwens (1987) Lundberg (1988) Hu and Ma (1999) Byun and Lee (2005)	
Revealed Comparative Advantage (RCA)	$RCA_{ij} = \frac{X_{ij}^{k} / \sum_{k=1}^{n} X_{ij}}{M_{ji}^{k} / \sum_{ij}^{n} M_{ji}}$, X_{ij} represents total exports of region (country) i to region (country) j; X_{ij}^{k} means total exports of region (country) i to region (country) j of product k; M_{ji} represents total imports from region (country) j to region (country) i; M_{ji}^{k} means total imports from region (country) j to region (country) i of product k.	Balassa (1965, 1979) Yeats (1985) Deardoff (1980) Lee (1995) Rodas-Martini (1998)	WTA
Asian financial crisis (FC)	1997 Asian financial crisis	N/A	dummy
Regional trade arrangements (RTAs)	One kind of international trade association consisting of two or more economies such as the EU and ASEAN.	Frahan and Tharakan (1998) Wakasugi (2007) Thorpe and Zhang (2005)	dummy
Trade Barriers	Including artificial trade barriers (traffic and no traffic distortion), but not including natural trade barriers such as geographic isolation.	Falvey (1981) Matthews (1998) Lee (1989) Bergstrand (1983) Bano (1991) Sharma (2004)	dummy

		Zhang, Witteloostuijn, and Zhou (2005)	

Table 2 Testing results and empirical model adapted

Regions	IIT	Autocorrelation test (Prob> x^2)	Hausman test (Prob> x^2)	Fit empirical model
Asia-US	HIIT	0.1102	0.9422	REM with FGLS
	VIIT	0.0924	0.5525	REM with FGLS
Asia-EU	HIIT	0.0572	0.8536	REM with FGLS
	VIIT	0.0871	0.3445	REM with FGLS
US-Asia	HIIT	0.1418	0.0538	REM with FGLS
	VIIT	0.0852	0.6979	REM with FGLS
EU-Asia	HIIT	0.0884	0.9106	REM with FGLS
	VIIT	0.1917	0.0957	REM with FGLS

Table 3 Empirical results of HIIT and VIIT for the Asia-US pair of region

HIIT			VIIT	
Variable	coefficient	P value	Coefficient	P value
Constant	0.4462301 (0.2388652)	0.062	0.1644753 (0.143123)	0.250
GDPPOPU	-0.0263962** (0.0121408)	0.030	0.0146512*** (0.003003)	0.000
FDIin	-8.92e-06*** (2.51e-06)	0.000	-1.37e-06** (6.94e-07)	0.049
FDIout	0.0000257*** (7.99e-06)	0.001	-0.0000172*** (1.55e-06)	0.000
R＆D/GDP	0.0699152	0.394	0.0073534	0.892

	(0.0819565)		(0.0541063)	
EDU/GDP	-0.0784958*** (0.0158485)	0.000	0.0853845*** (0.0135517)	0.000
HUF	0.2160925* (0.1125399)	0.055	-0.1479919*** (0.0440379)	0.001
RCA	0.0136069 (0.0294178)	0.644	-0.12061*** (0.0165834)	0.000
FC	0.1309726*** (0.0428359)	0.002	0.0144167 (0.0377003)	0.702
RTAs	N/A	N/A	N/A	N/A
BARRIER	N/A	N/A	N/A	N/A

Note: 1.*significant at 10%, ** significant at 5%, *** significant at 1%。

2. N/A dropped due to collinearity。

Table 4 Empirical results of HIIT and VIIT for the Asia-EU pair of region

HIIT			VIIT	
variable	coefficient	P value	coefficient	P value
Constant	-0.0596852 (0.1481571)	0.687	1.428228 (0.1969046)	0.000
GDPPOPU	-0.0107479 (0.0124477)	0.388	0.0032857 (0.005546)	0.554
FDIin	-3.63e-06 (2.28e-06)	0.112	-0.0000142* (7.72e-06)	0.065
FDIout	4.12e-06 (6.33e-06)	0.515	1.60e-06 (3.20e-06)	0.616
R＆D/GDP	0.1377269* (0.0723568)	0.057	-0.0108079 (0.0664355)	0.871
EDU/GDP	0.046811*** (0.0168985)	0.006	-0.0451085*** (0.0153958)	0.003
HUF	0.3131042*** (0.0598137)	0.000	-0.4444717*** (0.0862991)	0.000
RCA	-0.0604488*** (0.0056652)	0.000	0.0136941 (0.0155996)	0.380
FC	0.0186655 (0.0447751)	0.677	-0.1174543 (0.1085879)	0.279
RTAs	N/A	N/A	N/A	N/A
BARRIER	-0.1698163 (0.2029882)	0.403	-0.3425365*** (0.1210609)	0.005

Note: 1.*significant at 10%, ** significant at 5%, *** significant at 1%.

2. N/A dropped due to collinearity.

Table 5 Empirical results of HIIT and VIIT for the US-Asia pair of region

HIIT			VIIT	
variable	coefficient	P value	coefficient	P value
Constant	0.3384199 (0.1820796)	0.063	0.0555765 (0.0264907)	0.036
GDPPOPU	-0.0191576*** (0.0045041)	0.000	-0.0030214 *** (0.0013922)	0.030
FDIin	-4.44e-06*** (1.23e-06)	0.000	-2.80e-06*** (4.75e-07)	0.000
FDIout	0.0000215*** (3.24e-06)	0.000	2.05e-07 (9.47e-07)	0.829
R＆D/GDP	0.102316*** (0.0393825)	0.009	0.0353927*** (0.0101713)	0.001
EDU/GDP	-0.0384706*** (0.0130182)	0.003	0.0048709* (0.0036425)	0.181
HUF	0.0774296 (0.1116922)	0.488	0.0547672** (0.0277181)	0.048
RCA	-0.0353329 (0.0764515)	0.644	-0.0440672** (0.0175453)	0.012
FC	N/A	N/A	N/A	N/A
RTAs	N/A	N/A	N/A	N/A
BARRIER	N/A	N/A	N/A	N/A

Note: 1.*significant at 10%, ** significant at 5%, *** significant at 1%.

2. N/A dropped due to collinearity.

Table 6 Empirical results of HIIT and VIIT for the EU-Asia pair of region

HIIT			VIIT	
variable	coefficient	P value	coefficient	P value
Constant	0.1128578 (0.0951271)	0.235	0.1278096 (0.1566454)	0.415
GDPPOPU	0.0101045*** (0.0035204)	0.004	-0.000148 (0.008069)	0.985

FDIin	-2.53e-07 (9.89e-07)	0.798	-2.75e-06** (1.26e-06)	0.030
FDIout	-2.98e-06 (2.47e-06)	0.228	7.32e-06* (4.39e-06)	0.096
R＆D/GDP	-0.1206782*** (0.0209502)	0.000	-0.0674604 (0.0629682)	0.284
EDU/GDP	0.017112* (0.0091658)	0.062	0.0277421 (0.0216337)	0.200
HUF	0.0555073 (0.0769045)	0.470	-0.1281689 (0.0980563)	0.191
RCA	0.0732981** (0.034528)	0.034	0.2685542*** (0.0801774)	0.001
FC	N/A	N/A	N/A	N/A
RTAs	0.0508403 (0.0362209)	0.160	0.3294348*** (0.1134034)	0.004
BARRIER	N/A	N/A	N/A	N/A

Note: 1.*significant at 10%, ** significant at 5%, *** significant at 1%.

2. N/A dropped due to collinearity.

Table 7 The determining factors of the HIIT and VIIT in the ICT industry

	Asia-US		Asia-EU		US-Asia		EU-Asia	
Variable	HIIT	VIIT	HIIT	VIIT	HIIT	VIIT	HIIT	VIIT
GDPPOPU	−	+			−	−	+	
FDIin	−	−		−	−	−		−
FDIout	+	−			+			+
R&D			+		+	+	−	
EDU	−	+	+	−	−	+	+	
HUF	+	−	+	−		+		
RCA	+	−	−				+	+
FC	+							
FTA								+
Barrier				−				

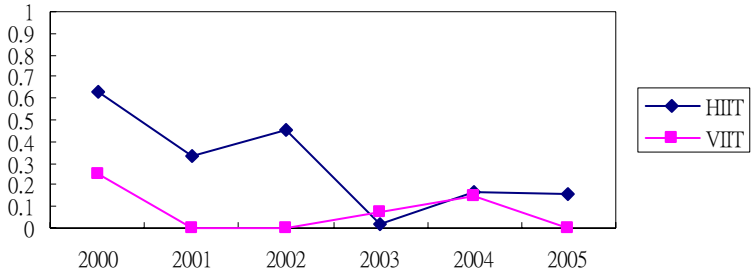

Figure 1 The evolutions of HIIT and VIIT in Asia-EU

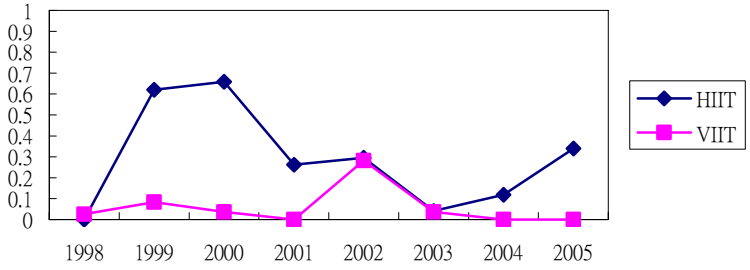

Figure 2 The evolutions of HIIT and VIIT in EU-Asia

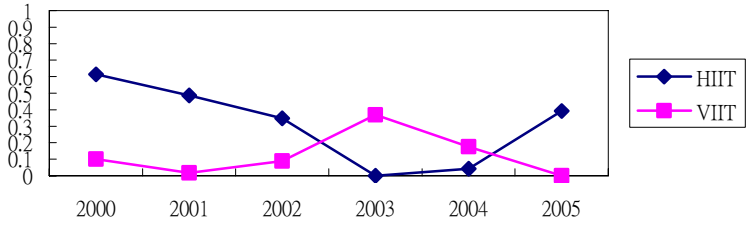

Figure 3 The evolutions of HIIT and VIIT in Asia-US

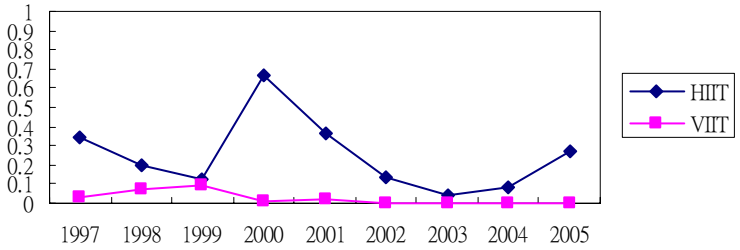

Figure 4 The evolutions of HIIT and VIIT in US-Asia

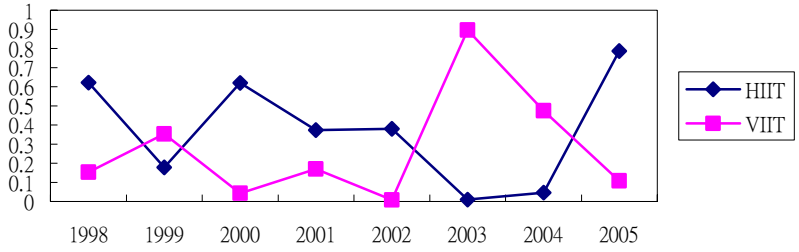

Figure 5 The evolutions of HIIT and VIIT in EU-US

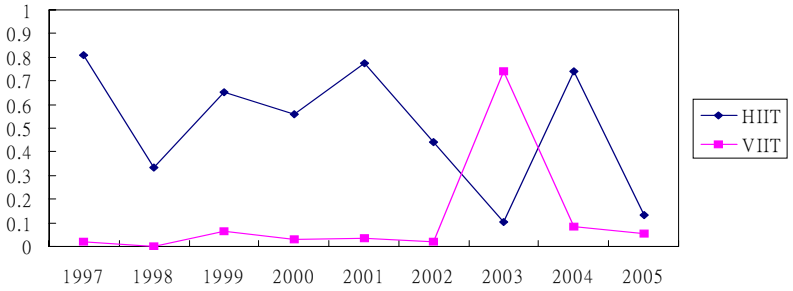

Figure 6 The evolutions of HIIT and VIIT in US-EU

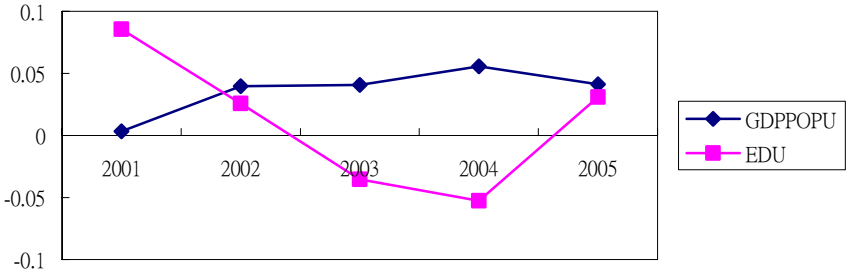

Figure 7 The growth rates of GDP and education expenditure in Asian region

References

Abd-el-Rahman, K. (1991). Firms' Competitive and National Comparative Advantages as Joint Determinants of Trade Composition. *Review of World Economics/ Weltwirtschaftliches Archiv* 127 (1): 83-97.

Aturupane, C., S. Djankov, and B. Hoekman (1999). Horizontal and Vertical intra-industry trade between Eastern Europe and the European Union. *Review of World Economics/ Weltwirtschaftliches Archiv* 135: 62-81.

Balassa, B. (1965). Trade Liberalization and Revealed Comparative Advantage. *Manchester School of Economics and Social Studies* 33: 99-117.

Balassa, B. (1966). Tariff Reductions and Trade in Manufactures among the Industrial Countries. *American Economic Review* 56 (3): 466-473.

Balassa, B. (1979). Intra- Industry Trade and The Integration of Developing Countries in the World Economy. in Herbert Giersch (1979) (ed.),*On the Economic of Intra-Industry Trade.* (Tü bingen:Mohr).

Balassa, B., and L. Bauwens (1987). Intra-Industry Specialization in a Multi-Country and Multi-Industry Framework. *Economic Journal* 97 (December): 923-939.

Bano, S. S. (1991). *Intra-Industry International Trade*. Aldershot, U.K.: Avebury; Brookfield, Vt.: Ashgate.

Bergstrand, J. H. (1983). Measurement and Determinants of Intra-Industry International Trade. Tharakan, P. K. M. (ed.), *Intra-Industry Trade*.

Bergstrand, J. H. (1990). The Heckscher-Ohlin-Samuelson Model, the Linder Hypothesis and the Determinants of Bilateral Intra-Industry Trade. *Economic Journal* 100 (403): 1216-1229.

Brulhart, M. (1994). Marginal Intra-Industry Trade: Measurement and Relevance for the Pattern of Industrial Adjustmen. *Review of World Economics/ Weltwirtschaftliches Archiv* 130 (3): 600-613.

Byun, J. J., and S. H. Lee (2005). Horizontal and Vertical Intra-Industry Trade: New Evidence From Korea, 1991-1999. *Global Economy Journal* 5 (1): Article 3.

Deardorff, A. V.(1980). The General Validity of Law of Comparative Advantage. *Journal of Political Economy* 88: 941-957.

Dixit, A., and J. Stiglitz (1977). Monopolistic Competition and Optimum Product Diversity. *American Economic Review* 67 (3): 113-130.

Falvey, R. E. (1981). Commercial Policy and Intra-Industry Trade. *Journal of International Economics* 11 (4): 495-511.

Falvey, R. E., and H. Kierzkowski (1987).Product Quality, Intra-Industry Trade and (Im) perfect. In H. Kierzkowski (ed.).*Protection and Competition in International Trade*: Essays in Honor of W. M. Corden, Oxford: Basil Blackwell.

Flam, H., and E. Helpman (1987). Vertical Product Differentiation and North-South

Trade. *American Economic Review* 77 (5): 810-822.
Fontagn e′ , L., M. Freudenberg, and G. Gaulier (2006). A System Decomposition of World Trade into Horizontal and Vertical IIT. *Review of World Economics* 142(3): 459-475.
Frahan, B. H. D., and J. Tharakan (1998). Horizontal and Vertical Intra-Industry Trade in the Processed Food Sector. Selected paper for the 1998 American Agricultural Economics Association Annual Meeting Salt Lake City, USA.
Gavelin, L., and L. Lundberg (1983). Determinants of Intra-Industry Trade: Testing Some Hypotheses on Swedish Trade Data. in P. K. M. Tharakan (ed). *Intra-Industry Trade*.
Greenaway, D. (1988). *Economic development and international trade*. Macmillan Education London.
Greenaway, D., R. C. Hine, and C. Milner (1994). Country-specific factors and the pattern of horizontal and vertical intra-industry trade in the UK. *Review of World Economics/ Weltwirtschaftliches Archiv* 130:77-100.
Greenaway, D., R. C. Hine, and C. Milner (1995). Vertical and Horizontal Intra-Industry Trade: A Cross-Industry Analysis for the United Kingdom. *Economic Journal* 105 (403): 1505-1518.
Grubel, H. G., and P. J. Lloyd (1975). *Intra-Industry Trade: The Theory and Measurement of International Trade in Differentiated Products*. London: MacMillan.
Helpman, E. and P. Krugman (1985). *Market Structure and Foreign Trade. Increasing Returns, Imperfect Competition, and the International Economy*. Cambridge MA/ London: MIT Press.
Hu, X. L., and Y. Ma (1999). International Intra-Industry trade of China. *Review of World Economics/ Weltwirtschaftliches Archiv* 135: 82-101.
Krugman, P. (1979). Increasing Returns, Monopolistic Competition, and International Trade. *Journal of International Economics* 9 (4): 469-479.
Krugman, P. (1980). Scale Economics, Product Differentiation and the Pattern of Trade. *American Economic Review* 70 (5): 950-959.
Krugman, P. (1981). Intra-Industry Specialization and the Gains From Trade. *Journal of Political Economy* 89 (5): 959-973.
Krugman, P., and Obstfed, M. (1994). *International Economics*, 3rd edition, HarperCollins College, NY.
Lancaster, K. (1979).*Variety, Equity and Efficiency*. Oxford: Basil Blackwell.
Lancaster, K. (1980). Intra-Industry Trade under Perfect Monopolistic Competition. *Journal of International Economics* 10 (2): 151-175.
Lee, J.(1995). Comparative Advantage in Manufacturing as a Determinant of Industrialization: The Korean case. *World Development* 23(7):1195-1214.
Lee,Y. S. (1989). A Study of the Determinants of Intra-Industry Trade among the

Pacific Basin Countries. *Review of World Economics/ Weltwirtschaftliches Archiv* 125 (2): 346-358.
Linder, S. B. (1961). *An Essay on Trade and Transformation*. New York: John Wiley and Sons.
Lundberg, L. (1988). The Role of Comparative Costs for Determining Inter- and Intra-Industry Trade with Developing Countries. *European Economic Review* 32 (9): 1699-1710.
Menon, G., Greenaway, D. and Milner, C (1999). Industrial Structure and Australia-UK intra-industry trade. *Ecoomic Record*, 75(228): 19-27.
Mattews, K. (1998). Intra-Industry Trade: An Australian Panel Study. *Journal of Economic Studies* 25 (2-3):.84-97.
Rodas-Martini, P. (1998). Intra-Industry Trade and Revealed Comparative Advantage in the Central American Common Market. *World Development* 26 (2): 337-344.
Shaked, A., and J. Sutton (1984). Natural Oligopolies and International Trade in H. Kierzkowski (ed.). *Monopolistic Competition and International Trade.* Oxford: Clarendon Press.
Sharma, K. (2004). Horizontal and Vertical Intra-Industry Trade in Australian Manufacturing: does trade liberalization have any impact? *Applied Economics* 36: 1723-1730.
Thom, R., and M. Mcdowell (1999). Measuring marginal intra-industry trade. *Review of World Economics/ Weltwirtschaftliches Archiv* 135: 48-61.
Thorpe, M., and Z. Zhang (2005). Study of the measurement and determinants of intra-industry trade in East Asia. *Asian Economic Journal* 19 (2): 231-247.
Vernon, R. (1966). International Investment and International Trade in the Product Cycle. *Quarterly Journal of Economics* 80 (2): 190-207.
Wakasugi, R. (2007). Vertical Intra-industry Trade and Economic Integration in East Asia. *Asian Economic Papers* 6 (1): 26-39.
Yeats, A. J. (1985). On the Appropriate Interpretation of the Revealed Comparative Advantage Index: Implications of a Methodology Based on Industry Sector Analysis. *Review of World Economics/ Weltwirtschaftliches Archiv* 121: 61-73.
Zhang, J., A.V. Witteloostuijn, and C. Zhou (2005). Chinese Bilateral Intra-Industry Trade: A Panel Data Study for 50 Countries in the 1992-2001 Period. *Review of World Economics/ Weltwirtschaftliches Archiv* 141 (3): 510-540.