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## 1. Introduction

Trade and investment flows have been hardly influenced during the current economic crisis. As Inomata and Uchida (2009) argued “The characteristic feature of the crisis is the speed and extent of shock transmission”. What are the main reasons that cause such sharp and extended drop in international trade and investment? Explanations have focused on the synchronised drop in global demand and production across countries and on the reduction in trade credit that has been led to stronger credit constraints for trade than in the domestic market.<sup>1</sup> Other explanations have focused on the sharp drop in prices of traded goods and in particular of oil, relative to non-traded goods. This could have led to a stronger decline in the nominal terms of trade (Bénassy-Quéré *et al.*, 2009).

In addition to the above explanations, a number of recent studies (see Yi, 2009; Escaith *et al.*, 2010) have shown that the strong impact of the Crisis on trade and investment have been amplified by the spread of global supply chains, notably through the growing importance of vertical specialisation (VS) trade. The VS related shock transmission mechanism can be not only explained from demand-side but also supply-side. For example, Uchida and Inomata (2009) examine how the current crisis has changed the nature of production networks in the Asia-Pacific region by using demand-driven input-output model and Asian International Input-Output (AIO) tables (from 1990 to 2008)<sup>2</sup>. In their study, the calculation result of VS indicators shows that the upstream production process of intermediate goods was relatively “resistant” to the influence of the crisis compared with the assembling process. They also show that the extensive production chains of intermediate goods between China and other emerging economies (triangular trade through China) are growing rapidly, which might result in a new formation of production system in the Asia-Pacific region in the near future. On the other hand, Escaith and Gonguet (2009) employ supply-driven I-O model and AIO tables (2000, 2006<sup>3</sup>) to estimate the real transmission effects of a financial shock on five linked economies (China, Japan, Malaysia, Thailand and the United States). This approach is intended to capture that in a recession small initial financial shocks might result in systemic effects because of the conjunction of real supply and demand shocks and of stock-flow financial shocks. Their findings show that Japan was the largest exporter of supply shocks, while Malaysia and Thailand were the biggest importers of these shocks. China on the other hand, became between 2000 and 2006 increasingly an exporter of shocks but was not strongly affected by other countries’ financial shocks, given China’s strong dependence on domestic suppliers.

The purpose of this paper is to utilize both demand-driven and supply-driven I-O model to provide a general format of VS indicators, and then use them to show how the vertical specialization trade has evolved in the Asia-Pacific region during 1990 and 2008. Alternative measures proposed in the paper provide different views of vertical specialization which can be considered as a meaningful supplement to the existing indicators. In addition, the impact of the current crisis on vertical specialization trade is also discussed.

This paper proceeds as follows: Section 2 shows the general format of vertical specialization indicators by using traditional I-O models. Section 3 gives a brief explanation on the data used. Section 4 presents the empirical results of the vertical specialization in Asia-Pacific region. The concluding remarks are given in Section 5.

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\*: IDE-Jetro/OECD, \*\*:OECD

<sup>1</sup> See Auboin, M. (2009). “Trade finance: G20 and follow-up”. VoxEU.org, 5th June.

<sup>2</sup> See IDE-JETRO (2006) for the detail information of Asian International Input-Output Table.

<sup>3</sup> The 2006 AIO table used in Escaith and Gonguet (2009) is an updated table.

## 2. General format of VS indicators measured by I-O model

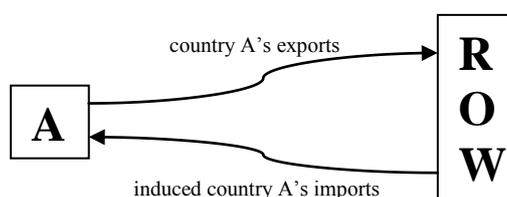
### 2.1 VS indicators based on demand-driven I-O model

The phenomenon of vertical specialization trade can be simply explained as follows: different segments or stages in a production process are rapidly spread or extensively relocated to a range of production sites in multiple countries. For measuring a country's degree of participation in vertical production networks, a number of indicators have been developed. The most widely used indicator based on I-O database is the "import contents of export" proposed by Hummels *et al.* (2001). For simplicity, we call it VS0 which is formulated as

$$VS0^r = M_{\text{imd}}^{\text{or}} (I - A^{\text{r}})^{-1} EX^{\text{ro}} / \underline{EX}^{\text{ro}} \quad (1)$$

where, the subscript  $r$  and  $o$  represent country  $r$  and the rest of the world.  $M_{\text{imd}}^{\text{or}}$  is country  $r$ 's import (imported intermediate goods) coefficient vector ( $1 \times n$ ),  $I$  the identity matrix,  $A^{\text{r}}$  country  $r$ 's domestic input coefficient matrix ( $n \times n$ ),  $(I - A^{\text{r}})^{-1}$  the Leontief inverse matrix,  $EX^{\text{ro}}$  the vector of country  $r$ 's exports ( $n \times 1$ ),  $\underline{EX}^{\text{ro}}$  the total value (scalar) of country  $r$ 's exports. As shown in Figure 1, VS0 represents the directly and indirectly induced imports of intermediate goods by exports, which can also be explained as the value of imported intermediates embodied in country  $r$ 's exports. In this meaning, the VS0 reflects country  $r$ 's degree of participation in international production networks from the viewpoint of the import demander (country  $r$ ). Obviously, if non-competitive type national I-O table is available, the VS0 can be easily calculated.

Figure 1 Import contents of export (VS0)

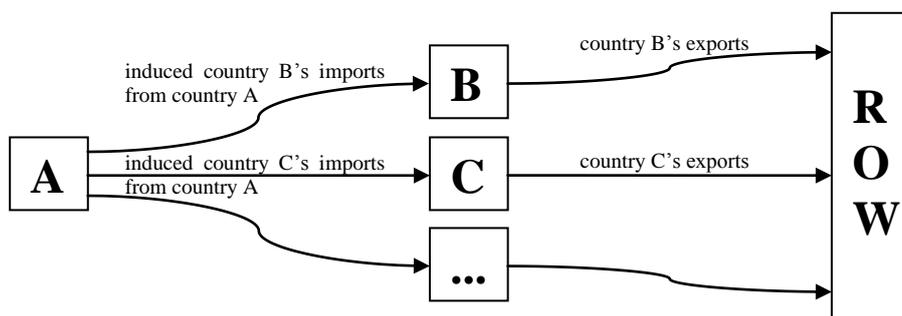


On the other hand, if the vector of imported intermediates by country of origin is available, the following alternative measurement (VA1) proposed by Yi (2003) can also be estimated.

$$VS1^r = \sum_s (M_{\text{imd}}^{\text{rs}} (I - A^{\text{ss}})^{-1} EX^{\text{so}}) / \underline{EX}^{\text{ro}} \quad (2)$$

As shown in Figure 2, the VS1 captures the embodied value of country  $r$ 's exports used as intermediate inputs used to produce exports in other countries. Comparing with the VS0, the VS1 also reflects country  $r$ 's degree of participation in international production networks, but it is from the viewpoint of a supplier (country  $r$ ) of intermediate goods. Therefore this indicator is an alternative measure of countries' participation degree in global value chains, particularly for countries specialising in the first stages of the vertical chain.

Figure 2 Induced intermediate exports (VS1)



In addition, if EX can be separated into intermediate goods and final demand goods, more detailed and preferable measurements of vertical specialization can be given as follows:

$$\begin{aligned}
 VS0^r &= VS0_{\text{imd}}^r + VS0_{\text{fd}}^r \\
 VS0_{\text{imd}}^r &= M_{\text{imd}}^{\text{or}} (I - A^{\text{rr}})^{-1} EX_{\text{imd}}^{\text{ro}} / \underline{EX}^{\text{ro}} \\
 VS0_{\text{fd}}^r &= M_{\text{imd}}^{\text{or}} (I - A^{\text{rr}})^{-1} EX_{\text{fd}}^{\text{ro}} / \underline{EX}^{\text{ro}} \\
 VS1^r &= VS1_{\text{imd}}^r + VS1_{\text{fd}}^r \\
 VS1_{\text{imd}}^r &= \sum_s (M_{\text{imd}}^{\text{rs}} (I - A^{\text{ss}})^{-1} EX_{\text{imd}}^{\text{so}}) / \underline{EX}^{\text{ro}} \\
 VS1_{\text{fd}}^r &= \sum_s (M_{\text{imd}}^{\text{rs}} (I - A^{\text{ss}})^{-1} EX_{\text{fd}}^{\text{so}}) / \underline{EX}^{\text{ro}}
 \end{aligned}$$

Where, subscripts “imd” and “fd” represent intermediate goods and final demand goods respectively.

## 2.2 VS indicators based on supply-driven I-O model

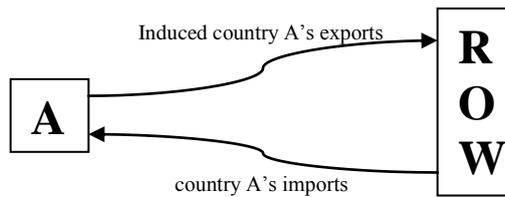
If the demand-driven I-O model is well accepted in the fields of national account and regional economics, the supply-driven model always faces on both critical and supporting comments. Despite there is a restrictive assumption in the supply-driven model, namely each commodity is sold to each sector in fixed proportions, it has been proved that the model can be interpreted as a price I-O model (Dietzenbacher, 1997). In this meaning, these two models may be considered as two sides of one coin, which reflect dual relationship of demand and supply within the same economic system.

As mentioned above, the VS0 indicator based on demand-driven I-O model captures the “import contents of export”, which shows how many imports are directly and indirectly necessary for producing exports. It should be noted that the VS0 is based on the Leontief inverse, which represents the backward linkage in interindustrial production chain. On the other hand, in supply-driven I-O model, the forward linkage in interindustrial production chain can be defined by the Ghosh inverse. Therefore, as shown in Figure 3, using the Ghosh inverse, we can easily show how many imports are re-exported or how many exports are induced by the supply of imported intermediates. Here, we introduce an alternative measurement of vertical specialization, and call it “export contents of import”, which can be given as follows:

$$VS0^{r*} = \underline{IM}^{\text{or}}_{\text{imd}} (I - G^{\text{rr}})^{-1} E^{\text{ro}} / \underline{IM}^{\text{or}} \quad (3)$$

Where,  $\underline{IM}^{\text{or}}_{\text{imd}}$  is the vector (1\*n) of imported intermediates of country r,  $G^{\text{rr}}$  the domestic allocation coefficient matrix (n\*n),  $(I - G^{\text{rr}})^{-1}$  the Ghosh inverse matrix,  $E^{\text{ro}}$  country r’s export coefficient vector (n\*1),  $\underline{IM}^{\text{or}}$  the total value (scalar) of country r’s imports.

Figure 3 Export contents of import (VS\*)

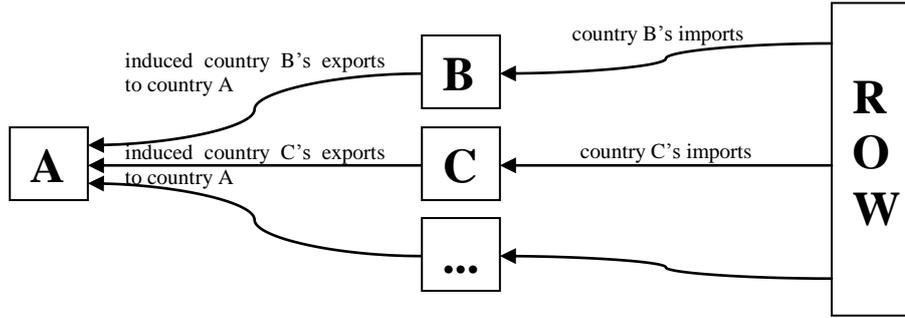


If the vector of exports by country of destination is available, following the relationship between the VS0 and VS1\*, the VS1\* can be written as the form below:

$$VS1^{r*} = \sum_s (\mathbf{IM}_{imd}^{os} (\mathbf{I}-\mathbf{G}^{ss})^{-1} \mathbf{E}^{sr}) / \underline{\mathbf{IM}}^{or} \quad (4)$$

As shown in Figure 4, the  $VS1^*$  captures country  $r$ 's imported intermediates induced by other countries' imported intermediates from the rest of the world.

Figure 4 Induced intermediate imports ( $VS1^*$ )



Similarly, if exports by intermediate goods and final demand goods are available, more detailed measurements can be given as follows:

$$\begin{aligned} VS0^{r*} &= VS0_{imd}^{r*} + VS0_{fd}^{r*} \\ VS0_{imd}^{r*} &= \mathbf{IM}_{imd}^{or} (\mathbf{I}-\mathbf{G}^{rr})^{-1} \mathbf{E}_{imd}^{ro} / \underline{\mathbf{IM}}^{or} \\ VS0_{fd}^{r*} &= \mathbf{IM}_{imd}^{or} (\mathbf{I}-\mathbf{G}^{rr})^{-1} \mathbf{E}_{fd}^{ro} / \underline{\mathbf{IM}}^{or} \\ VS1^{r*} &= VS1_{imd}^{r*} + VS1_{fd}^{r*} \\ VS1_{imd}^{r*} &= \sum_s (\mathbf{IM}_{imd}^{os} (\mathbf{I}-\mathbf{G}^{ss})^{-1} \mathbf{E}_{imd}^{sr}) / \underline{\mathbf{IM}}^{or} \\ VS1_{fd}^{r*} &= \sum_s (\mathbf{IM}_{imd}^{os} (\mathbf{I}-\mathbf{G}^{ss})^{-1} \mathbf{E}_{fd}^{sr}) / \underline{\mathbf{IM}}^{or} \end{aligned}$$

The main difference of  $VS0$  and  $VS0^*$  is that the former captures how export shock (demand shock from outside) affects a country's import demand of intermediate goods by the way of domestic production network, the latter shows how import shock (supply shock from outside) affects exports by the way of domestic supply chains. With the similar manner, the  $VS1$  looks at the upstream production process of production chain from an export supplier's viewpoint,  $VS1^*$  looks at the downstream production process of production chain from an import demander's viewpoint.

### 3. Data

To estimate above indicators introduced, import data by origin and export data by destination are essential. However, in officially published national I-O tables, such information is normally not available. Moreover, to investigate production network in detail, it is more preferable to focus issue on the trade of intermediates, but from national I-O tables or international trade statistics, export data of intermediates is not available. Considering the limitations of national I-O table and international trade data, the AIO tables (1985, 1990, 1995, 2000 and 2008) are used as main data source in the paper.<sup>4</sup>

The AIO table covers 10 endogenous economies, namely, China (C), Indonesia (I), Japan (J), Korea (K), Malaysia (M), Taiwan (N), the Philippines (P), Singapore (S), Thailand (T), the United States (U), and 76 industrial sectors, which accounted for about 45% of the global GDP and 35% of the global population of 2000. The 1985, 1990, 1995 and 2000 tables are survey-based international I-O tables, in which

<sup>4</sup> If trade data by intermediate goods and final demand goods, such as BEC (Broad Economic Categories) data is available for all target countries, national I-O tables are enough to estimate all indicators proposed in the paper rather than using international input-output table.

information concerning inter-country and inter-industrial transactions is constructed from the benchmark I-O tables including import matrices, international trade statistics and the special surveys for the use of imported goods. These surveys provide important information on which domestic industry uses what kind of imported goods and to what extent. Since the official benchmark tables for the mid 2000s are not published for the target economies, the 2008 table is a non survey-based updated database by IDE using previous AIO table, UN Comtrade, and World Trade Atlas<sup>5</sup>. The 2008 table reflects the adjusted international trade structure, which is used to capture the impact of the Crisis (to some extent) on production networks. The 22-sector classification is used in this paper as shown in Appendix 1.

In addition, for the ease of comparison across economies we make some adjustments on the original AIO data: 1) mining sector is excluded in the estimation of VS indicators due to its large and uncertain price changes; 2) international trade of services among the 10 economies is not considered since it is not available in the original AIO data;<sup>6</sup> 3) because detailed information of export and import by origin and destination for exogenous economies is not available, the rest of the Asia-Pacific region is used to replace the rest of the world (subscript “o” used in above equations). This makes the comparison of VS0 and VS1 possible within the Asia-Pacific region.<sup>7</sup>

#### 4. Measurement results

##### 4.1 Import contents of export (VS0)

Figure 5 reports evidence on vertical specialization using the  $VS0_{imd}$  and  $VS0_{fd}$  which are defined as the value of imported intermediates embodied respectively in a country's exports of intermediate and final demand goods for 10 Asia-Pacific economies during 1985 and 2008. When looking at the average across the 10 economies, it is easy to see that in 1990 the  $VS0_{imd}$  and  $VS0_{fd}$  were at very similar level (less than 7%), but from that year onwards, the  $VS0_{imd}$  grew much faster than  $VS0_{fd}$ . This clearly implies that the vertical specialization trade for producing intermediate goods in the Asia-Pacific region has developed rapidly during the period. In addition, between 2000 and 2008, comparing with the slight drop of  $VS0_{imd}$ ,  $VS0_{fd}$  dropped sharply. This may imply that the vertical specialization trade for producing final demand goods seems to be more sensitive to the current economic crisis. When looking at every economy's trend in detail, several main findings can be summarized as follows: 1) There is considerable cross-country variation in the importance of vertical trade: the largest economies, such as China, Japan, Indonesia, and the United States have a lower share of vertical trade, as due to their size they are likely to be able to conduct more stages of production within their borders (possibly across different regions) and their export share of output will be lower because of the larger size of their domestic markets. In contrast, the vertical trade in small open economies, such as Singapore, Malaysia, Taiwan, Thailand, Philippines as well as Korea have a relatively higher share due to their high dependence on the overseas market. 2) During the period, the  $VS0_{imd}$  increased steadily in almost all economies except Malaysia and the Philippines between 2000 and 2008, but the  $VS0_{fd}$  shows very different changing patterns across economies. This implies that different economies have very different selections or strategies in the participant of vertical specialization. For example, the  $VS0_{fd}$  in Taiwan and Korea declined continuously, but their  $VS0_{imd}$  steadily increased. This illustrates that Taiwan and Korea have concentrated their participants of vertical specialization on intermediate goods rather than on final demand goods.

Figure 5 Vertical specialization measured by VS0 (%)

<sup>5</sup> The World Trade Atlas is GIT's (Global Trade Information Services) information system that offers detailed world trade statistics.

<sup>6</sup> Services make up only a relatively small proportion of trade (in 2008 they accounted for 22% of exports and 18% of imports).

<sup>7</sup> However, the production networks related to the rest of the world, such as the linkage with European countries is not evaluated in the paper.

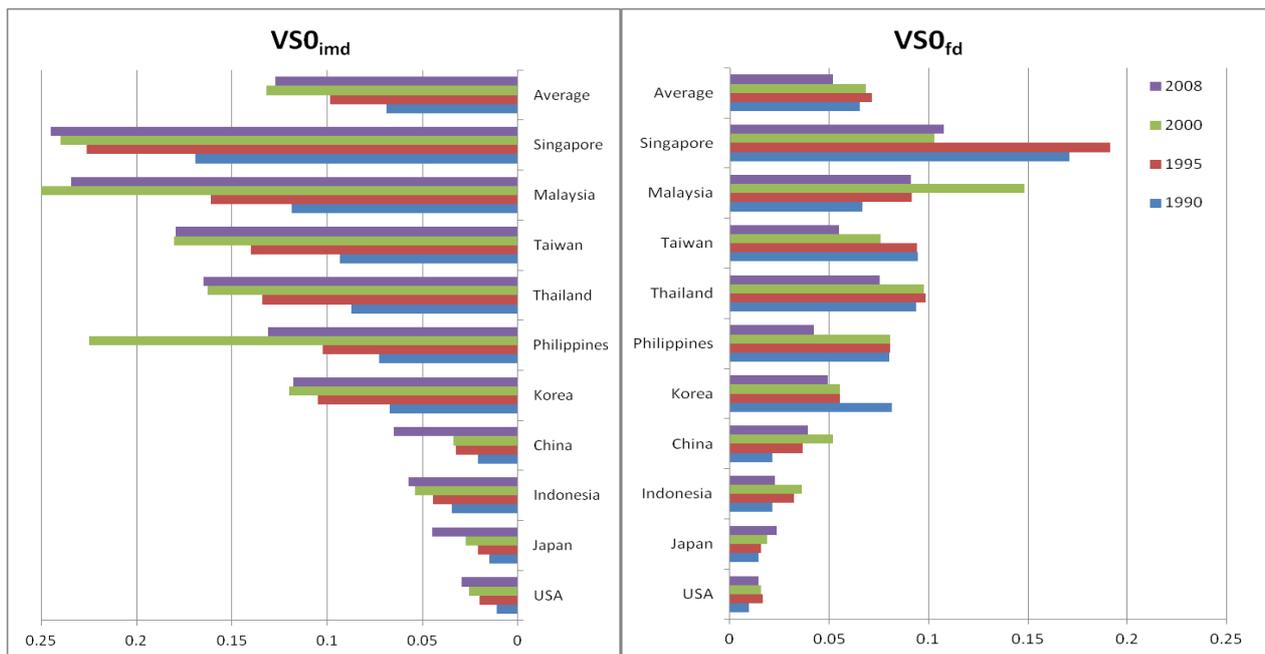
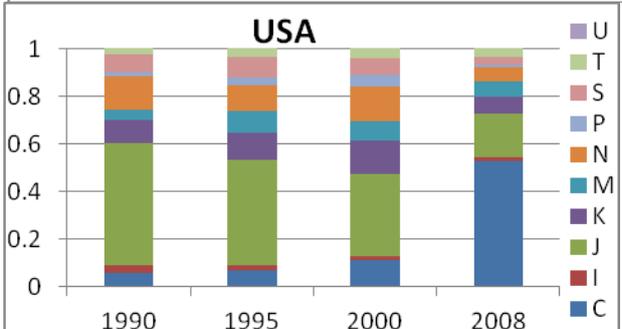
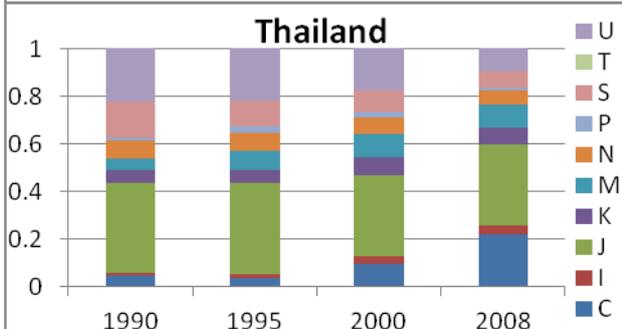
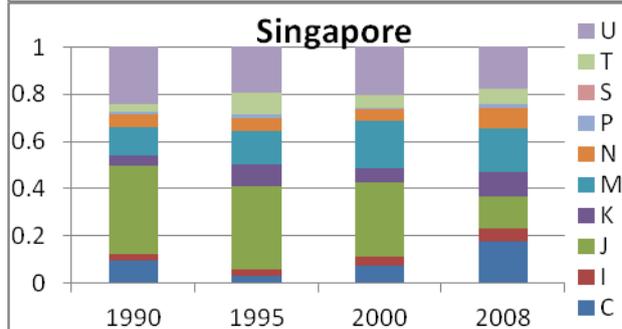
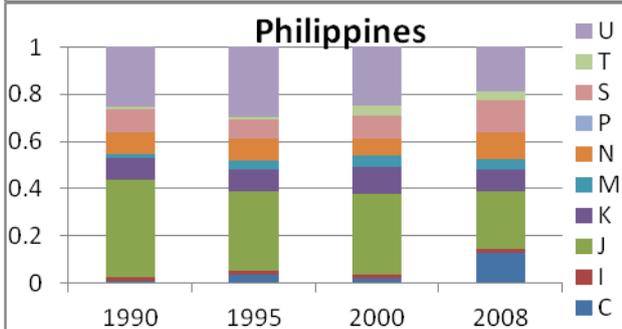
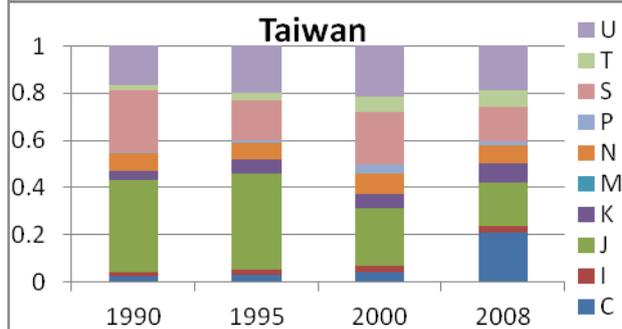
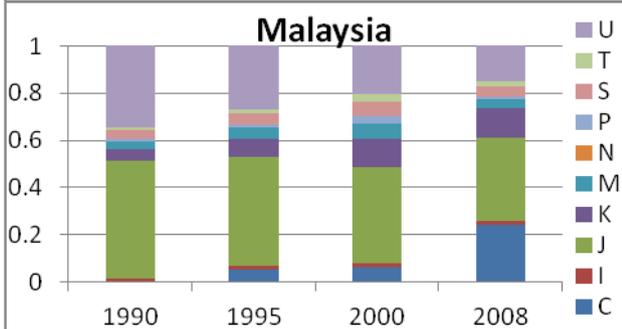
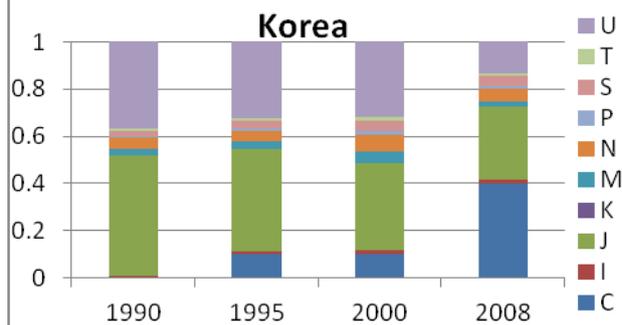
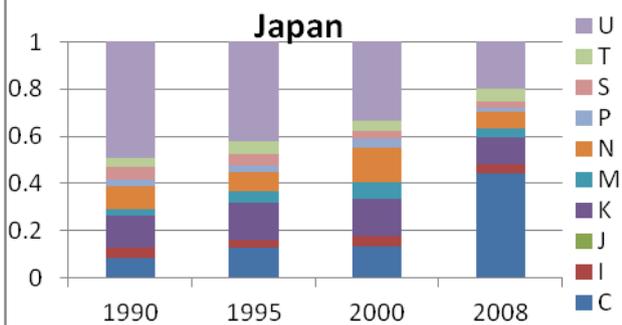
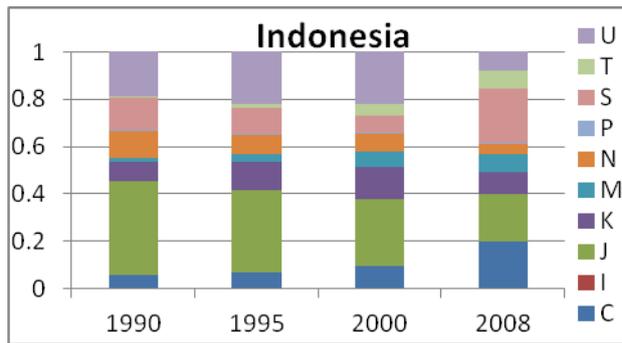
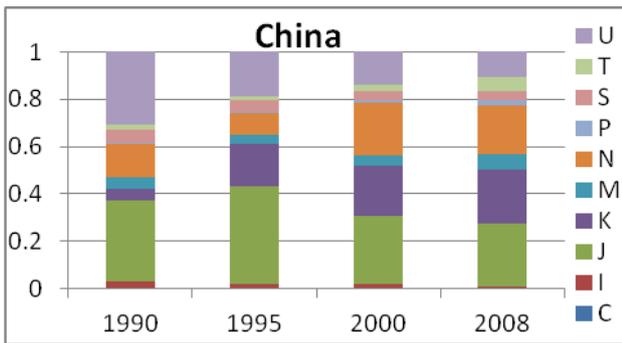


Figure 6 shows detailed component of  $VSO_{imd}$  linkages by country of origin. The main features of the figure can be summarized as follows: 1) the participation rate of the United States' intermediate goods in other economies' (except Taiwan and Singapore) production chains dropped quickly during the period. 2) Japan also lost its share but still maintained dominant role in other economies' production networks. 3) Comparing with declines of the United States and Japan's shares, China enhanced its presence rapidly especially after 2000, and close to or replaced the previous leading role that the United States and Japan have played in the vertical specialization trade of other Asian economies. In this meaning, it can be concluded that China has become an important hub to provide intermediate goods to other economies within the Asia-Pacific region.

Figure 6 Detailed component of  $VSO_{imd}$  linkage by economy (%)



## 4.2 Induced intermediate exports (VS1)

As mentioned above, VS0 measures the vertical specialization from a viewpoint of a country who is a demander of imported intermediates. In contrast, VS1 captures the value of a country's exports that is used as intermediate inputs to produce the exports of another country. This measure looks at the first stage of the global value chain. Figure 7 shows the calculation results for  $VS1_{ind}$  and  $VS1_{fd}$  respectively. At average level, the  $VS1_{ind}$  grew rapidly so that after 2000 it has been almost two times larger than  $VS1_{fd}$ . This reflects that most economies in the region tend to provide much more intermediate goods when they are involved in other country's vertical linkage for producing the intermediate goods in the next production stage. When looking at the figure in detail, it is easy to understand that 1) unlike the VS0, it seems that the VS1 is independent of country's economic size. 2) For almost all economies, the  $VS1_{ind}$  increased steadily during 1990-2008 (except Singapore and Malaysia's slight drops between 2000 and 2008), the  $VS1_{fd}$  also shows growing tendency during 1990-2000 (except Malaysia). The clear difference between the movements of  $VS1_{ind}$  and  $VS1_{fd}$  reflects their different reactions to the Crisis. It seems that the  $VS1_{fd}$  is more likely to be influenced by external shocks than  $VS1_{ind}$ . 3) China's  $VS1_{ind}$  increased extremely quickly from 2000 to 2008. This also supports the conclusion obtained from Figure 3, that China has been an important hub to provide intermediate goods to other economies for their production of intermediates.

Figure 7 Vertical specialization measured by VS1 (%)

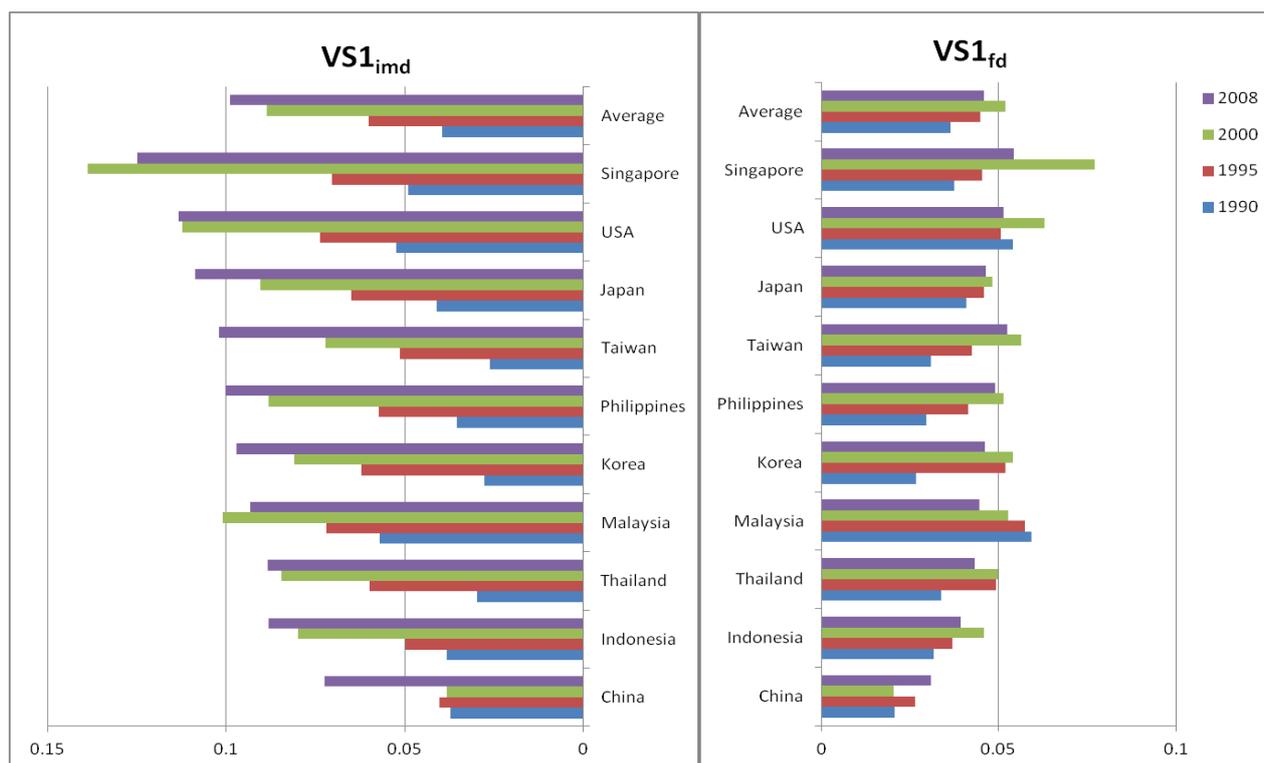
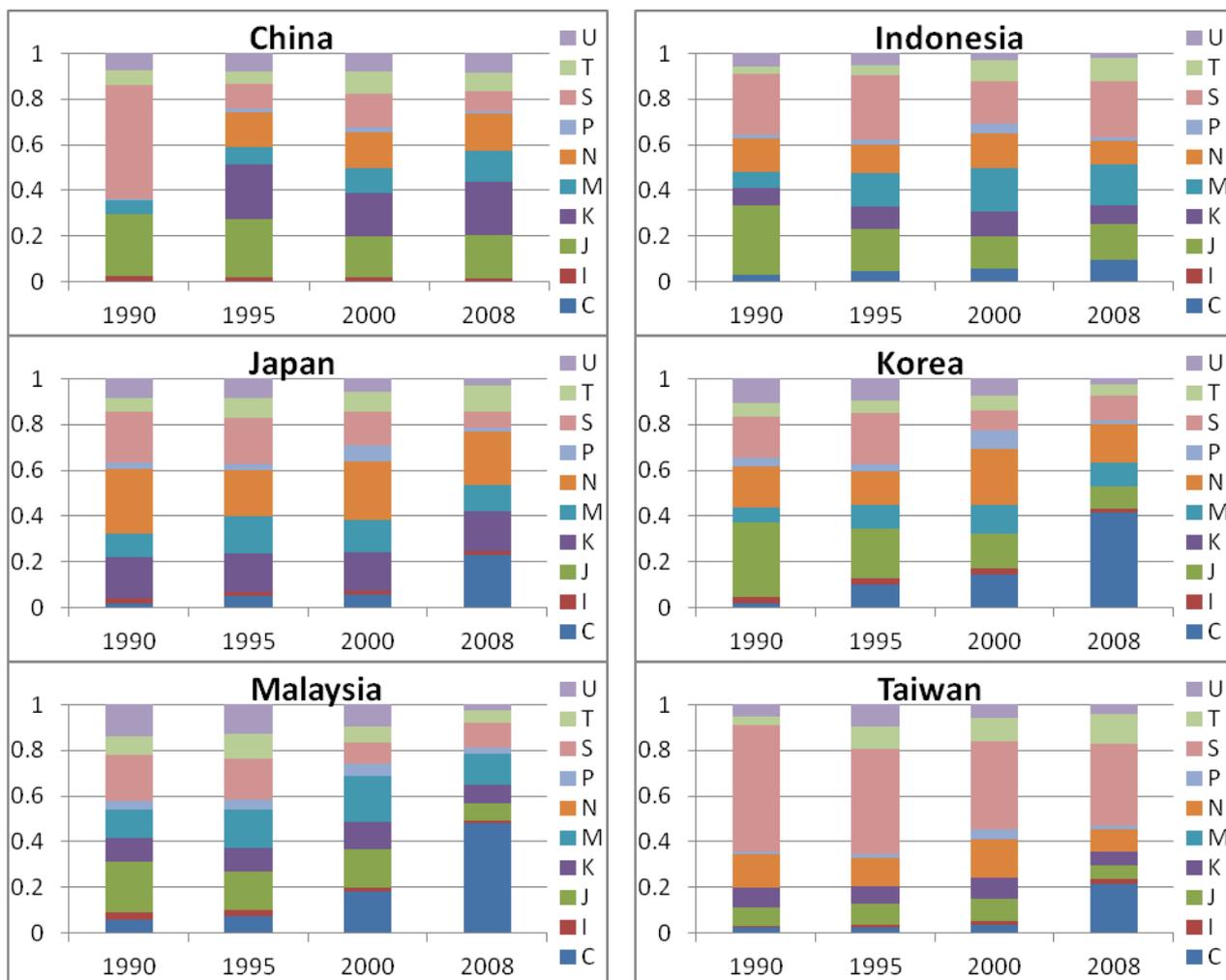
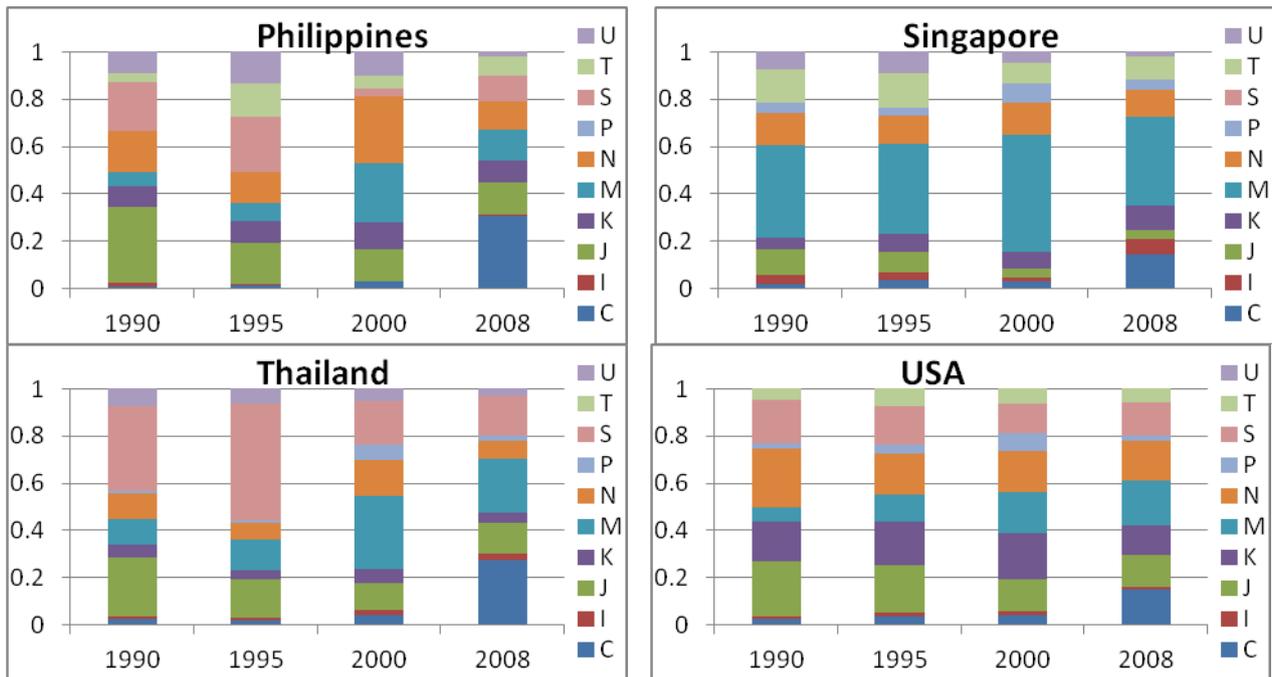


Figure 8 shows detailed component of  $VS0_{ind}$  linkages by country of destination. The main features of the figure can be summarized as follows: 1) unlike the VS0, the United States just accounts for a small share in  $VS1_{ind}$  for all economies. At the same time, its share decreased in almost all economies. This is because that the United States is not the main demander of intermediate goods provided by Asian economies when the United States uses these goods to producing intermediate exports. 2) Japan is still an important demander of the intermediate goods produced in other Asian economics, but its share has gradually declined during the period. 3) China has become very important demander of intermediate goods

produced in other Asian economies. These goods are used to produce intermediate exports in China. 4) In addition, it is worth to emphasizing that Malaysia also enhanced its presence during the period.

Figure 8 Detailed component of  $VS1_{ind}$  linkage by economy (%)





#### 4.3 Export contents of import ( $VS0^*$ )

As explained above, the  $VS0$  measure is based on demand-driven I-O model, in which exports are considered as exogenous demand from outside. Therefore, the  $VS0$  captures the “import contents of export”. In Contrast, the  $VS0^*$  is based on supply-driven I-O model, in which imports are regarded as exogenous supply from outside. That’s why we call  $VS1$  here the “export contents of import”. Figure 9 shows the vertical specialization measured by  $VS0^*_{imd}$  and  $VS0^*_{fd}$  respectively. At the average level, the change of  $VS0^*$  is very similar to the change of  $VS0$ . In addition, the  $VS0^*$  is also dependent of country’s economic size. When looking at the figure in detail, it is easy to see that there is large cross-country variation in the movement of vertical trade. The main features can be summarized as follows: 1) The  $VS0^*_{imd}$  measures for almost all economies (except the United States) during 1990-2000 grew rapidly. This implies that in the production network for producing intermediates, economies in the region tend to re-export much more imported intermediates to the rest of the region. 2) Different economies were affected by the Crisis at very different degrees. For example, between 2000 and 2008, the  $VS0^*_{imd}$  in some countries (the Philippines, Singapore, and Indonesia) declined very sharply. 2) Both  $VS0^*_{imd}$  and  $VS0^*_{fd}$  for the United States show continues decreasing tendency after 1995. This reflects that the United States’ participation rate in production network of intermediate goods in the region has gradually dropped. 3) Different economies have very different selections or strategies in the participant of vertical specialization. For example, the  $VS0_{fd}$  in Thailand declined continuously, but its  $VS0_{imd}$  steadily increased. This illustrates that Thailand has concentrated its participation of vertical specialization on producing more intermediate goods rather than on final demand goods by using imported intermediate inputs.

Figure 9 Vertical specialization measured by  $VS0^*$  (%)

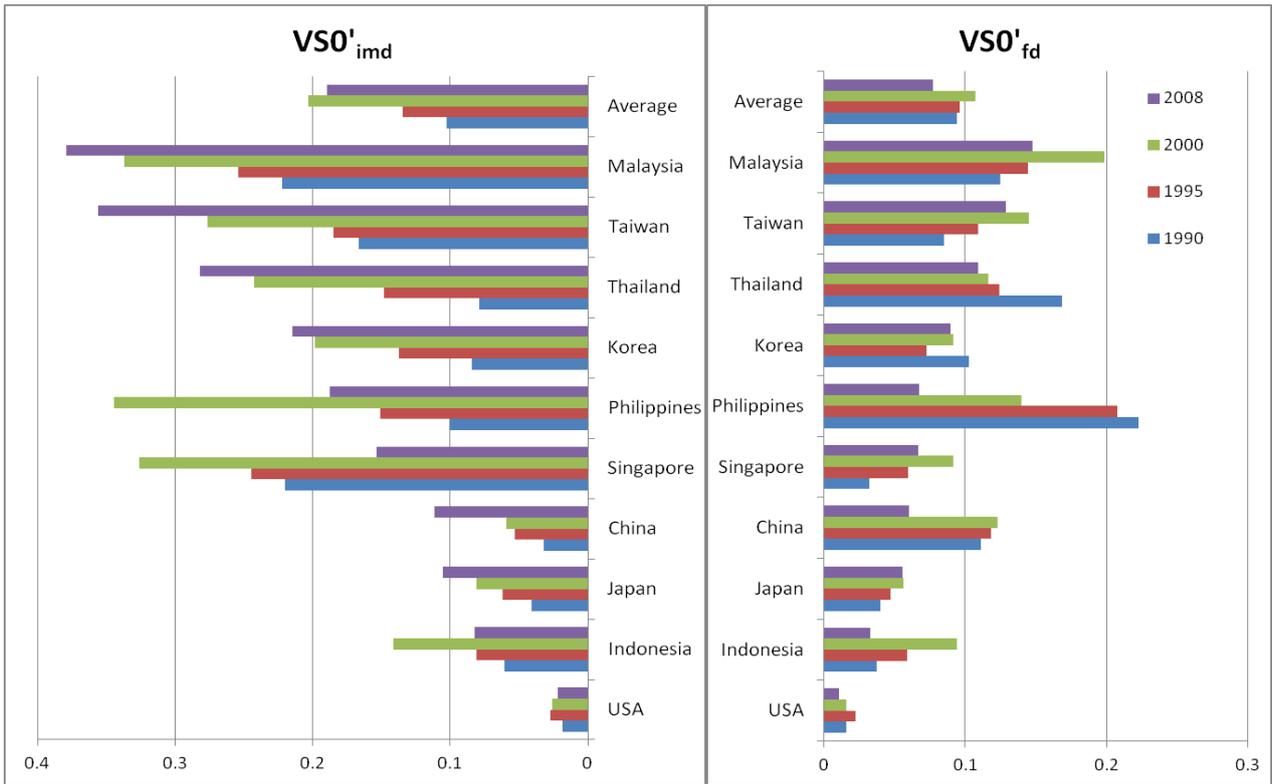
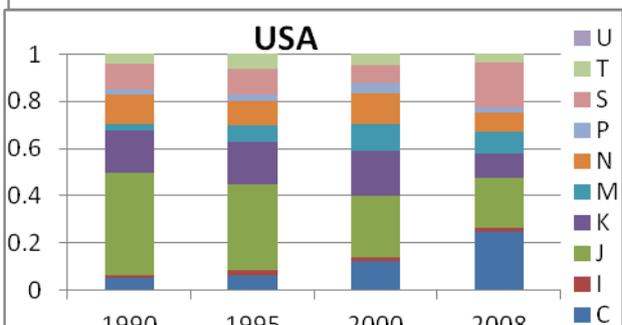
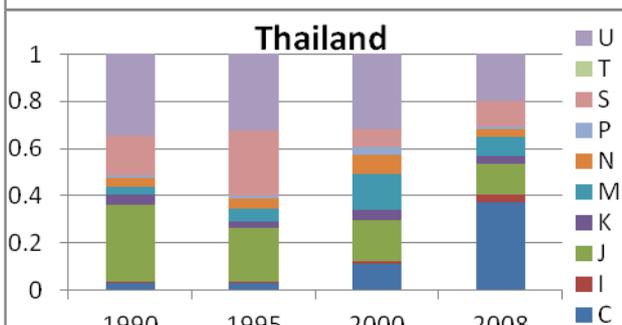
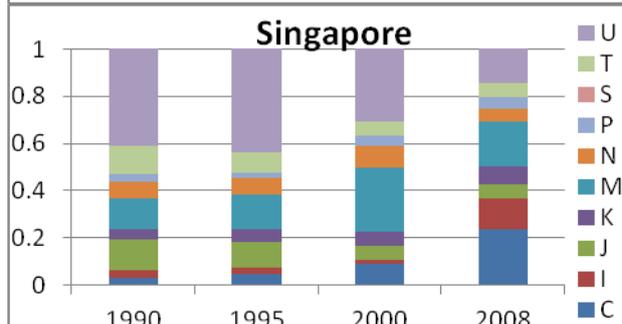
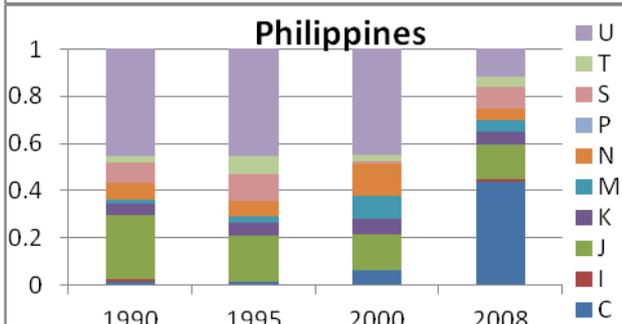
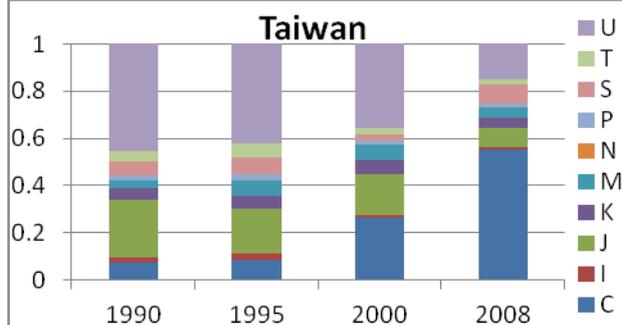
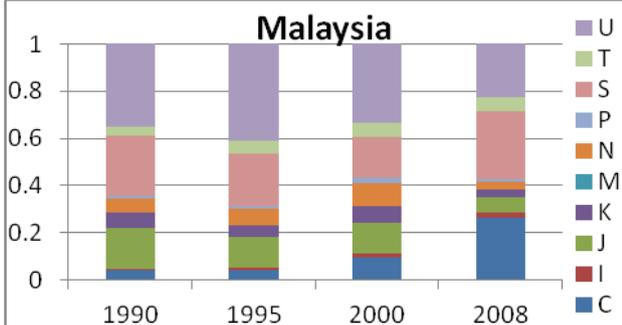
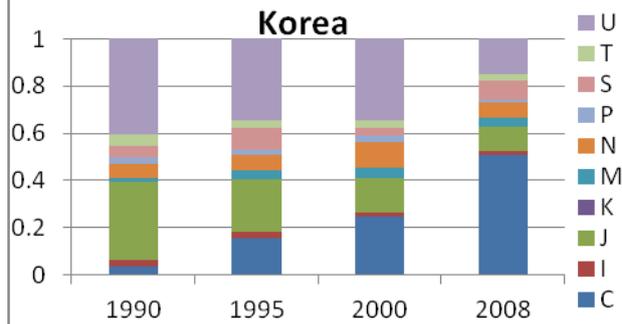
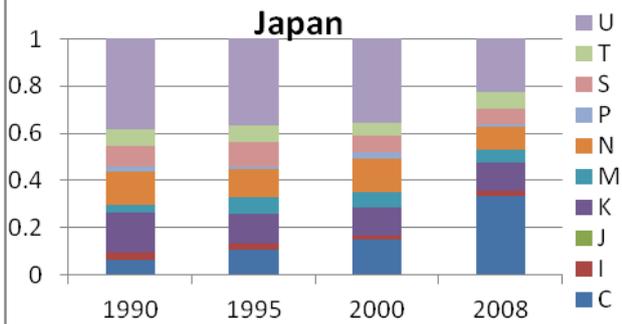
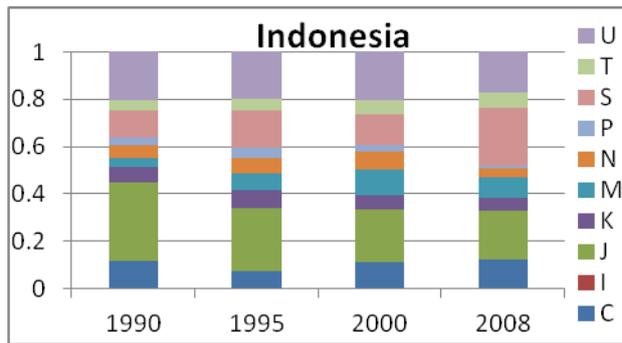
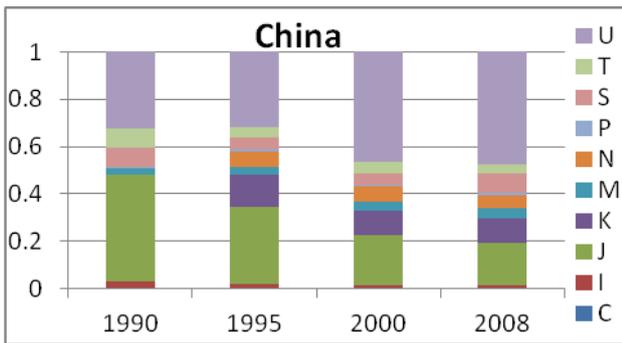


Figure 10 shows detailed component of  $VSO^*_{imd}$  linkages by country of destination. The main features of the figure can be summarized as follows: 1) The United States is still very important demander of intermediate goods produced in other Asian economies. However, its share declined rapidly in almost all economies' vertical trade (except China's). Comparing to Figure 9, it is clear that the United States' imports of intermediate goods provided by Asian economies are mainly used to fulfil its own domestic demand rather than export demand. 2) Japan is still dominant partner of other economies in their vertical supply chains. However, its share decreased gradually over the period. 3) China has become the most important destination country of other economies' re-exported imports.

Figure 10 Detailed component of  $VSO^*_{imd}$  linkage by economy (%)



#### 4.4 Induced intermediate imports ( $VS1^*$ )

From equation (4), it's easy to see that the  $VS1^*$  captures the embodied value of a country's imports induced by other countries' imported intermediates. Comparing with the  $VS0^*$ , the  $VS1^*$  also reflects a country's degree of participation in international production networks, but it looks at the downstream production process of production chain. Figure 11 shows the estimation results for  $VS1_{imd}^*$  and  $VS1_{fd}^*$  respectively. At the average level, it shows very similar pattern as seen in  $VS0^*$ , namely, the degree of vertical specialization for producing intermediate goods grew much faster and then became higher than the VS degree of producing final demand goods. However, when looking at the  $VS1^*$  by economy, it seems that this measure is no longer dependent of country's economic size. The main features of the figure can be summarized as follows: 1) during 1990 and 2000, the  $VS1_{imd}^*$  grew up rapidly in all economies. This implies that the vertical specialization had been developed both in depth and scale. However, between 2000 and 2008, the  $VS1_{imd}^*$  for Malaysia, Taiwan, the United States and Japan dropped sharply. This means that these economies' intermediate imports are easy to be affected by the change of other economies' imports during the Crisis by the way of supply-driven production chains. 2) The  $VS1_{fd}^*$  shows very unsteady movement. This is mainly because that the induced exports of final demand goods are relatively sensitive to the external shock caused by imported intermediates. At the same time, there is more variation in the  $VS1_{fd}^*$  across economies. For example, the United States'  $VS1_{fd}^*$  has the largest level, but declined during the period. In contrast, Indonesia's figure went up rapidly.

Figure 11 Vertical specialization measured by  $VS1^*$  (%)

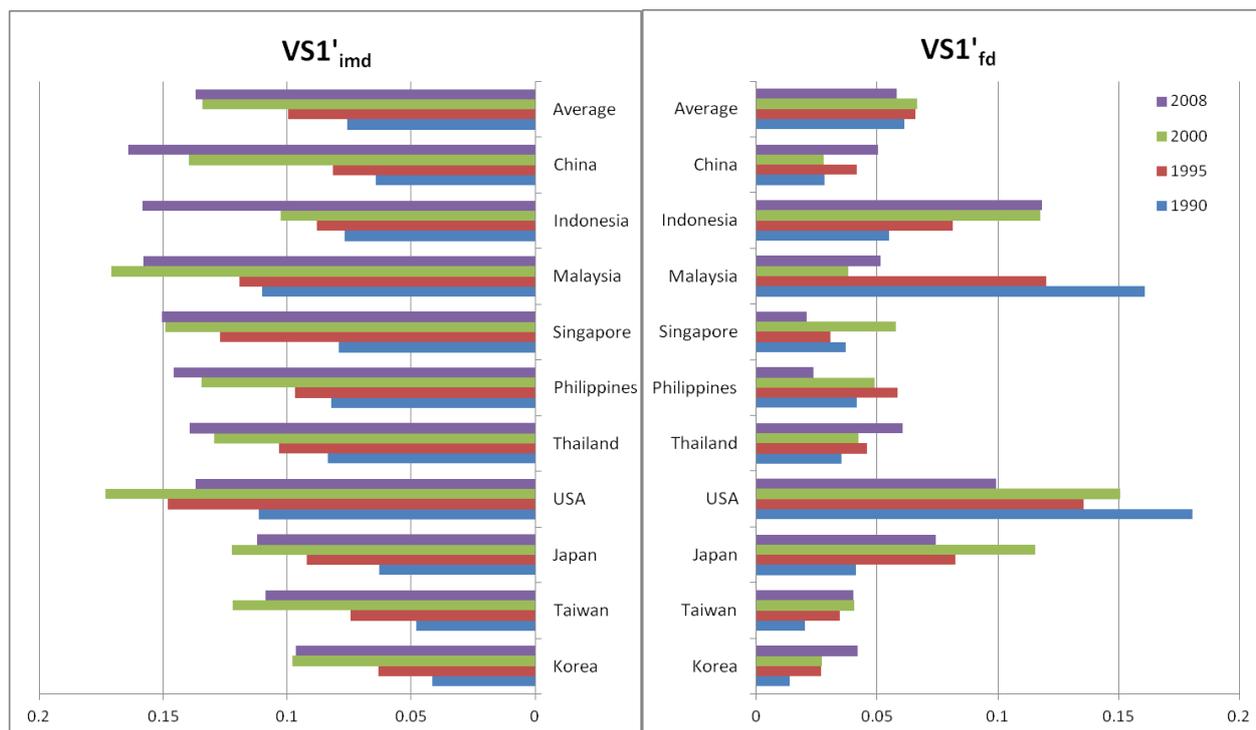
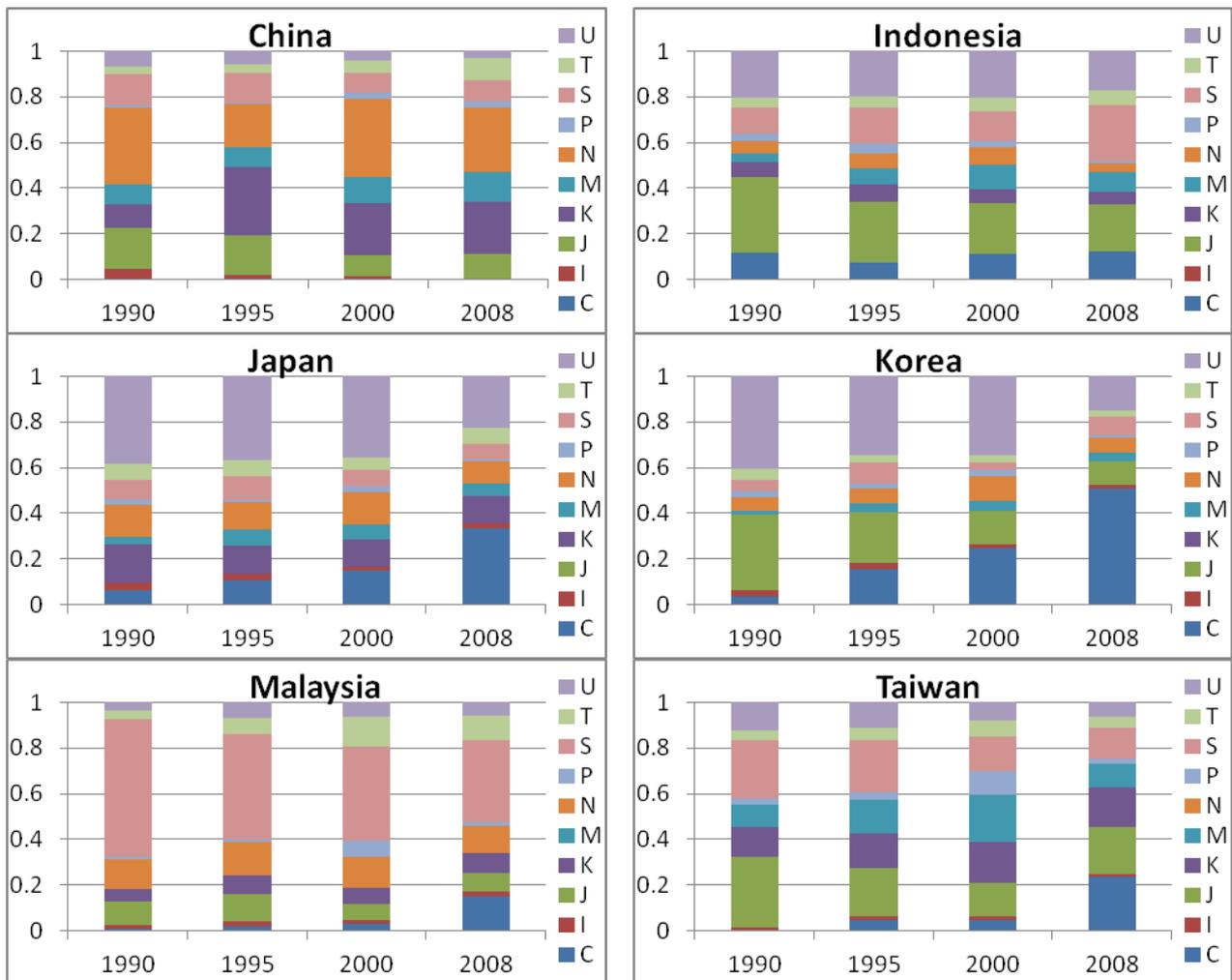
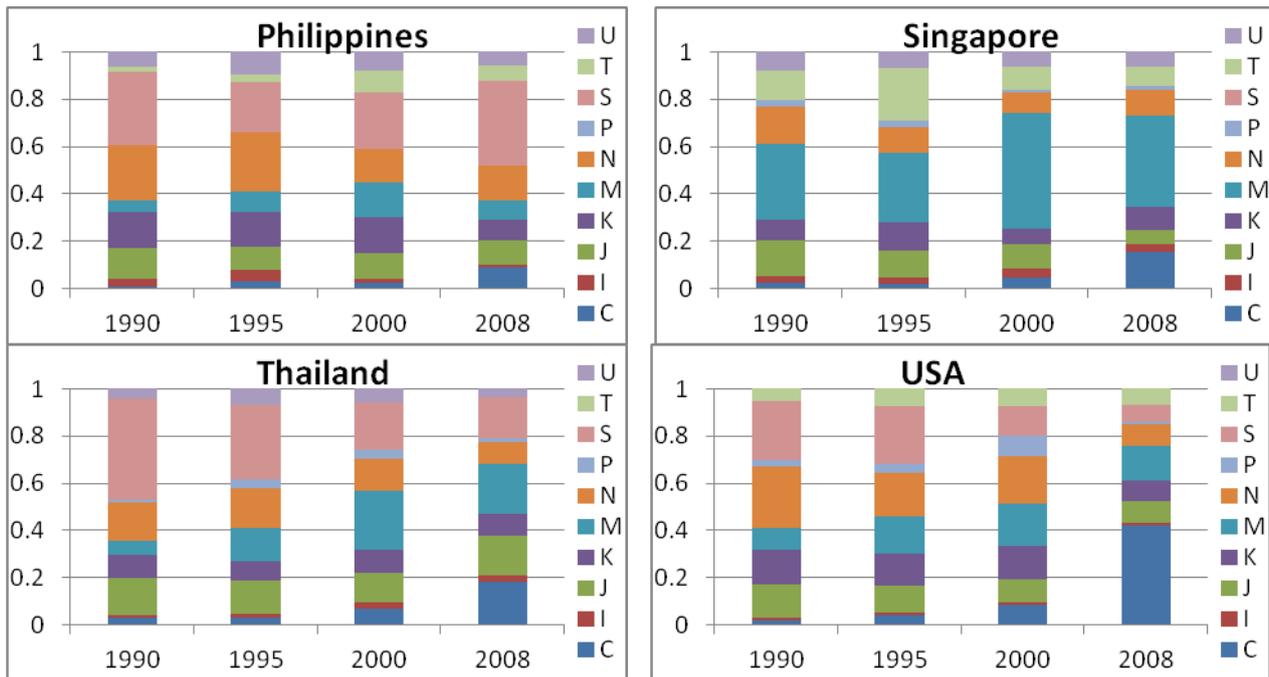


Figure 12 reports the component of  $VS1_{imd}^*$  by country of origin. The main features of the figure can be summarized as follows: 1) the United States has very high shares in Japan and Korea's vertical supply chains, but its share dropped rapidly due to China's increasing component. This implies that Japan and Korea tended to use more intermediate goods produced in China by the way of vertical supply chain. 2) unlike previous VS measures, Taiwan and Korea's components in China's  $VS1_{imd}^*$  have closed to or become

larger than Japan's. This clearly reflects that these two economies have been China's most important suppliers of intermediate goods. 3) China's share increased rapidly especially after 2000 in almost all economies' vertical supply chain. This also supports the conclusion provided before that China has become a very important hub for supplying intermediate goods to the rest of the region. 4) For ASEAN countries, it is easy to see that Singapore has become the most important partner of Indonesia and still is a dominant supplier of Malaysia and the Philippines; Malaysia enhanced its presence in Thailand's vertical supply chain and still plays an important role on Singapore.

Figure 12 Detailed component of VS1\*<sub>imd</sub> linkage by economy (%)





#### 4.5 How has the vertical specialization chain evolved in the Asia-Pacific region?

For investigating the evolvement of vertical specialization in the Asia-Pacific region during 1990 and 2008, we plot vicarious VS measures introduced above in Figure 13. In the upper left of the figure, the movement of two demand-driven type VS ( $VS0_{imd}$  and  $VS1_{imd}$ ) measures for all economies over 1990 and 2000 are illustrated. It is easy to see that 1) the vertical specialization in the Asia-Pacific region had developed rapidly during the period, since both  $VS0_{imd}$  and  $VS1_{imd}$  grew up for almost all economies. 2) The  $VS1_{imd}$  grew much faster than  $VS0_{imd}$  for the developed economies like the United States and Japan. This implies that these two economies joined in the vertical production chain by mainly providing more intermediate goods to other economies rather than import more intermediates from outside. This is not difficult to be understood since during 1990 and 2000 the outsourcing and FDI flows from developed countries to developing countries experienced much boosted development. As a result, the United States and Japan tended to provide more intermediates to their outsourcing or FDI target countries. 3) Both  $VS0_{imd}$  and  $VS1_{imd}$  increased rapidly for other Asian economies, with the exception of China. This clearly reflects that the production networks inside the region have become more complex since the Asian economies tended to not only import more intermediates from outside but also provide more intermediates to other economies. 4) The  $VS0_{imd}$  for China shows little increasing tendency, but its  $VS1_{imd}$  remained stagnant. This means that China had not completely involved in the vertical production network of the Asia-Pacific region until 2000. There are various reasons to explain this, but the most important one is that China was not WTO member over the period.

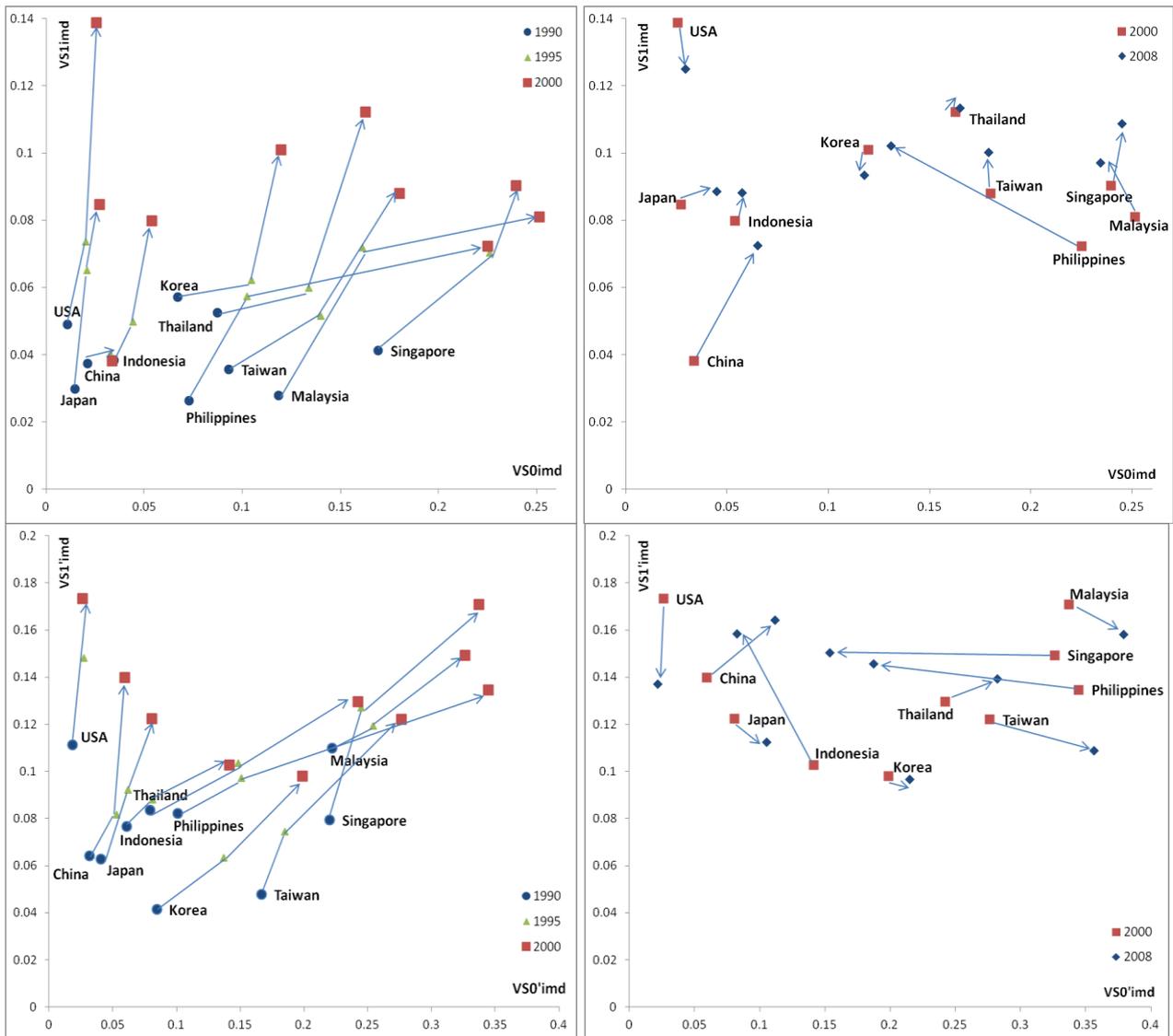
In the upper right of Figure 10, the movement of  $VS0_{imd}$  and  $VS1_{imd}$  for all economies over 2000 and 2008 are illustrated. The main features can be summarized as follows: 1) comparing with the upper left of the figure, there are not distinct changes for all economies except the Philippines and China. The Philippines's  $VS0_{imd}$  declined sharply. It can be considered a kind of "regression" or "readjustment" since the same measure for the Philippines during 1990 and 2000 experienced extremely fast increase. On the other hand, both  $VS0_{imd}$  and  $VS1_{imd}$  for China grew up very rapidly. This implies that after the participant of WTO, China has certainly involved in the vertical supply chain of the region and began to play more important role not only as a demander of imported intermediates but also as a provider of intermediate goods. 2) Even if the impact of the Crisis, the  $VS1_{imd}$  measures for most economies (except the United States and Korea) still increased to some extent. This reflects the continuously deepening production

network within the region since more economies tend to enhance their participation share in the vertical supply chain as a provider of intermediate goods.

As mentioned in the previous sections,  $VS0^*_{imd}$  and  $VS1^*_{imd}$  is based on supply-driven I-O model, which can provide different views of vertical specialization. It is because that the  $VS0^*_{imd}$  can captures the “export contents of import” of intermediate goods, and the  $VS1^*_{imd}$  shows how many imported intermediates of a country are from other countries’ imported intermediates. From the lower left of Figure 10, it is easy to see that 1) the vertical supply chains of the Asia-Pacific region had experienced very quick development during 1990 and 2000, since both  $VS0^*_{imd}$  and  $VS1^*_{imd}$  grew up for all economies in the region. 2) The  $VS1^*_{imd}$  grew much faster than  $VS0^*_{imd}$  for the three largest economies, namely the United States, Japan and China. This implies that the length of vertical supply chains related to these three economies had increased rapidly since much more imported intermediates of these economies are from other economies’ imports. However, their imported intermediates were mainly used for domestic demands since their  $VS0^*_{imd}$  were relatively lower. 3) Much more imported intermediates were used to produce exports of intermediate goods in all Asian economies, since their  $VS0^*_{imd}$  grew very fast during the period. At the same time, their  $VS1^*_{imd}$  measures also show increasing tendency. This implies that the length of vertical supply chains related to these economies had also increased.

When looking at the lower right of Figure 10, very dynamic movement can be confirmed: 1) China and Thailand still enhanced their participation levels of vertical supply chain over 2000 and 2008. 2) Japan, Korea, Taiwan and Malaysia show similar movements, namely their  $VS1^*_{imd}$  declined to some extent, but  $VS0^*_{imd}$  continuously increased, especially for Malaysia and Taiwan. 3) The  $VS1^*_{imd}$  for the United States dropped sharply. Since the 2005 or 2007 I-O tables for most economies are not available at present, it is difficult to identify the impact of the Crisis on vertical specialization. However, it is clear that the rapid rise of Chinese economy after its WTO accession caused a great structural change of production networks in the Asia-Pacific region. This can be easily confirmed from the change of China’s component in all VS measures (Figure 6, 8, 10, 12) .

Figure 13 Evolvement of vertical specialization (%)



## 5. Conclusions

Using both demand-driven and supply-driven I-O models, a full set of vertical specialization indicators is proposed in this paper. Applying these indicators to Asian International Input-Output tables, detailed structural changes of production network within the Asia-Pacific region during 1990 and 2008 can be clearly illustrated. The measurement results show that

- 1) The depth and scale of vertical specialization chain in the Asia-Pacific region have experienced apparent increase during 1990 and 2000 for all economies. Each economy in the region not only tended to provide more intermediate goods to other economies, but also tended to use more other economies' intermediate inputs in its production process.
- 2) China enhanced its participation ratio in global supply chains rapidly after its WTO accession by not only importing more intermediates from other Asian economies, but also exporting more intermediates for assembly in other Asian economies. China's rise after 2000 has been the most important power that changes the geographical configuration of the region's production network.
- 3) The United States' importance in other Asian economies's production system declined rapidly during 2000 and 2008. In contrast, the cross-national participation of production network among Asian economies has become more extensive and complex. This implies that in the near future, Asian region covering East

Asia and ASEAN will be more integrated or blocked, where China seems to be a new regional hub of Asia's production network.

4) Due to the data limitation, it is difficult to identify the "pure" impact of the Crisis on the production network of the region. However, comparing the very different movements of vertical specialization indicators between the period of 1990-2000 and 2000-2008, the impact of the Crisis can be conjectured to some extent. Since global supply chains may have been among the key mechanisms in transferring the crisis, they might also become vehicles to transmit the recovery when the global economy picks up again.

Several important limitations of the indicators used in the paper should be addressed. The first limitation is due to the sector aggregation. In particular, the sector classification used in the is quite aggregated (22 sectors describe the whole economy). This implies that it is impossible to distinguish whether the estimated vertical specialization indicator is a smoothed average of the true product level vertical specialization (as within the sectors some exported goods might use the imported intermediates very intensively while non-exported goods might not use imported intermediates at all), or if it overestimates the true level of vertical specialization (if within a sector imported intermediates are used in the production of products for domestic use while exported goods are only made with domestic intermediates). Alternatively, the problem could be mitigated by having a more detailed sector classification, but cannot be fully solved unless detailed information on each step of the value chain for each good is available. The second limitation is from the trivial assumption made in I-O based indicators, namely both domestic and foreign firms and both firms that produce goods for domestic use and those that produce goods for export (e.g. processing manufacturing in China) use imported intermediates with the same intensity in their production process. In order to relax this assumption, detailed I-O table with separated ownership of firm (sector) should be estimated. However, at present it is very difficult to be done due to the data availability.

#### Appendix 1: Sector classification

001	Agriculture
002	Forestry
003	Fishery
004	Crude petroleum and natural gas
005	Other mining
006	Food, beverage and tobacco
007	Textile, leather, and the products thereof
008	Wooden furniture and other wooden products
009	Pulp, paper and printing
010	Chemical products
011	Petroleum and petro products
012	Rubber products
013	Non-metallic mineral products
014	Metals and Metal products
015	Machinery
016	Transport equipment
017	Other manufacturing products
018	Electricity, gas and water supply
019	Construction
020	Trade and transport
021	Other services
022	Public administration

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