# Trade Verticality and Structural Change in Industries: The Cases of Taiwan and South Korea

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## Abstract

This paper documents that a significant portion of trade for Taiwan and Korea follows the trend of world trade in moving toward a pattern of vertical specialization (*VS*). Noteworthy is the manufacturing sector, whose VS shares of exports has been steadily increasing and has accounted for more than 90% of the total *VS* shares of manufactured exports. For Taiwan, nearly 57% of the growth in exports is contributed by the growth in *VS*-based trade; for Korea, it is as high as 64%. In the analysis, we compare *VS* shares of exports with or without input-output circulation among domestic industries in an open economy. Using Taiwan as a case study, we further discuss the implications of trade liberalization through tariff reductions for trade verticality.

The last two decades have witnessed a significant portion of world trade moving towards a pattern of "vertical specialization" or "global production sharing" in which trading countries share different stages of manufacturing (see, e.g., Krugman, 1995; Yeats, 1998; Feenstra, 1998; Hummels et al., 2001; Yi, 2003). Meanwhile, trade liberalization that lowers tariffs and technological improvements in transportation that reduce transaction costs have contributed to the growth of world trade, on the one hand, and have modified the pattern of international production and trade toward vertical specialization, on the other. The economies of outward-oriented countries are deeply integrated through international trade with the rest of the world. Also, production activities are increasingly disintegrated or fragmented in that they involve sequential connections of production stages from one to another with each of trading countries specializing in certain stages of production in a vertical relationship.

Vertical specialization in trade arises when the production of an exportable good requires imported intermediate inputs. This type of vertically connected production process involves two or more stages. The seminal work of

Dornbusch et al. (1977) discussed the specialization of trade model with a continuum of final goods. The contributions by Sanyal and Jones (1982), Dixit and Grossman (1982), and Sanyal (1983) further examined issues concerning trade and vertical specialization with multistage production.[1] In earlier 1990s and the decade during which increased globalization and liberalization in trade and investment became prominently important issues in world trade, economists looked at trade issues from the prospective of vertical specialization, outsourcing, or foreign direct investment. The prominent studies include, among others, Krugman (1995), Barry and Bradley (1997), Yeats (1998), Hummels et al. (2001), Görg (2000), Deardorff (2001), Arndt and Kierzkowski (2001), Egger and Egger (2002), and Yi (2003).

Economic integration of a country with the world markets through trade has traditionally been measured by the country's growth in exports and imports as shares of its GDP. However, Hummels et al. (2001) are among the first to analyze empirically economic integration of an export-oriented country with the global markets through the pattern of vertical specialization ($VS$) in trade. One important feature of this type of vertically connected production processes is that it involves the use of imported intermediate inputs, which are combined with local raw or other intermediate inputs, to produce goods for export. In other words, the degree of trade verticality in a sequential production process can be measured by the imported input content of exports.

The sustained and extreme rare type of high-level economic growth experienced by Taiwan and South Korea (hereafter Korea) after WWII has received a great attention of many scholars interested in economic development. The Taiwanese and Korean governments, like those of other developing countries, both adopted an import-substitution policy along with an export-promotion policy in the 1950s and 1960s.[2] The export-led industrialization facilitates industrial takeoff and promotes rapid industrial growth. Both Taiwan and Korea relied heavily on international trade during their growth miracle periods. A large fraction of their exports was produced heavily from imported inputs. From the perspective of $VS$ trade, we attempt to investigate the extent of the vertical linkages in trade and the accompanying changes in the structure of industries in Taiwan and Korea. What were those industries characterized by the highest vertical specialization and also experienced the fastest export growth? Did those industries with the highest vertical specialization levels and/or growth have the fastest output growth? How would trade verticality affect the growth of trade for the two countries? What would be the relationship between changes in the vertically specialized trade and the resulting changes in industrial structures? What would be the relationship between tariff reductions and the degree of vertical specialization?

The empirical results of this paper indicate that vertical specialization in trade plays an important role in the growth of trade for Taiwan and Korea. This suggests that a significant portion of international trade for the two countries in the last two decades has been following the trend of world trade in moving toward the pattern of global production sharing. $VS$ shares of manufacturing

sectors in Taiwan and Korea have been steadily increasing and have accounted for more than 90% of the total $VS$ shares of exports.[3] For Taiwan, the growth in $VS$-based trade contributes 57% of the growth in exports. For Korea, it is as high as 64%. Given that the integration with the global economy through trade has been increasingly deepened for Taiwan and Korea, we expect that merchandise trade by these two countries will continue to move into a higher degree of vertical specialization. This increase in trade verticality implies that Taiwan and Korea will continue to rely heavily on imported intermediate inputs to produce export goods.

In this paper, we compare difference in $VS$ shares of exports for two different scenarios: with and without a multi-stage input-output circulation within domestic industries of an economy. This difference reflects an "indirect" imported input content of exports generated purely from the domestic input-output linkage. We compute such an indirect contribution of $VS$-based trade as a proportion of exports for three major sectors (manufacturing, agricultural, and service) in Taiwan and Korea. Our findings show that the manufacturing sector has the highest share of $VS$-based trade and the associated indirect effect. We also demonstrate that the gradual reductions of tariff rates in Taiwan after 1984 have continuously raised the extent of trade verticality for the economy, particularly its manufacturing industries. This result suggests that trade liberalization through tariff reductions tends to modify the pattern of production toward vertical specialization.

The remainder of the paper is structured is as follows. Section 1 discusses the measurement of trade with vertical specialization. Section 2 shows the empirical results concerning the level and growth of $VS$-based trade. This section also examines for the case of Taiwan the relationship between changes in tariffs and the degree of trade verticality. Section 3 contains concluding remarks.

## 1.   Measurement of vertical specialization in trade

Vertical specialization in trade involves the use of imported intermediate inputs in the production of goods for export. Production activities involve two or more stages in which trading countries create value-added during each of the sequential production stages. In this section, we follow Hummels et al. (1999) and briefly present some measures of trade verticality in terms of imported input content of exports. We further compare the measures for two alternative scenarios: with and without a multiple-stage input-output circulation among domestic industries of an open economy.

Let $M_{ij}$ be the amount of imported intermediate input $i$ use by industry $j$ to produce final good $Y_j$, where $i, j = 1, \ldots, n$ and $i \neq j$. The amount of exports by industry $j$ is denoted as $X_j$. Given that vertical specialization arises in the process where the imported intermediate goods are used to produce products for export, the contribution of the imported inputs to exports for

industry $j$ can be measured by

$$VS_j = \sum_{i=1}^{n} \left( \frac{M_{ij} X_j}{Y_j} \right) = \left[ \sum_{i=1}^{n} \left( \frac{M_{ij}}{Y_j} \right) \right] X_j = \sum_{i=1}^{n} am_{ij} X_j, \tag{1}$$

where $am_{ij} = M_{ij}/Y_j$ is the proportion of imported input $i$ used to produce industry $j's$ output $Y_j$. In the formula, $\sum_{i=1}^{n} (M_{ij}/Y_j)$ or $\sum_{i=1}^{n} am_{ij}$ reflects the proportion of all the imported intermediate inputs required to create gross product $Y_j$, that is, it measures the contributions of the imported interme-diates into $Y_j$. If $X_j$ represents earnings from exports, the dollar amount of foreign intermediate imports required would be $\sum_{i=1}^{n} (M_{ij}/Y_j)$ times $X_j$, that is, $VS_j$. For the special case in which an industry does not use any of the imported inputs ($M_{ij} = 0$) or does not export its output at all ($X_j = 0$), there is no vertical trade relationship and the value of $VS_j$ equals 0.

To measure aggregate trade verticality for a sector with $n$ industries (or for an economy with $n$ sectors), we use the following:

$$VS = \sum_{j=1}^{n} VS_j = \sum_{j=1}^{n} \sum_{i=1}^{n} \frac{M_{ij} X_j}{Y_j} = \sum_{j=1}^{n} \sum_{i=1}^{n} am_{ij} X_j. \tag{2}$$

The aggregate formula $VS$ can be expressed in terms of matrix operation as $VS = uA^M x$ or

$$VS = \begin{bmatrix} 1 \ldots 1 \end{bmatrix} \begin{bmatrix} am_{11} & am_{21} & \cdots & \cdots & am_{n1} \\ am_{12} & am_{22} & \vdots & \vdots & am_{n2} \\ \vdots & \vdots & am_{ij} & \vdots & \vdots \\ \vdots & \vdots & \cdots & \ddots & \vdots \\ am_{1n} & am_{2n} & \cdots & \cdots & am_{nn} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ \vdots \\ x_n \end{bmatrix}, \tag{3}$$

where $u$ is a ($1 \times n$) vector of 1's, $A^M$ is an ($n \times n$) imported coefficient matrix, $x$ is an ($n \times 1$) vector of exports, and $X$ is the country's total export earnings. As discussed above, element $am_{ij}$ of $A^M$ represents the amount of an imported input $i$ used to produce one unit of industry $j$'s output, that is, $am_{ij} = M_{ij}/Y_j.$

As in Hummels et al. (1999), we use input-output (IO) tables that include sector-level data on inputs (distinguishing foreign and domestic sources), gross output, and exports. Because imported intermediate inputs may be used in one or more sectors, whose outputs are further used in other sectors in a sequential way to eventually produce goods for export, we further con-sider the multiple-stage, input-output nature of production activities in the domestic economy of an export-oriented country. In other words, imported inputs may circulate directly and indirectly through several stages of pro-duction within the economy before final goods are produced. In this case, the imported intermediate goods include direct and indirect imported inputs.

Hummels et al. (1999) propose modified $VS^*$ measure as follows:[4]

$$VS^* = uA^M(I - A^D)^{-1}x \tag{4}$$

or

$$VS^* = [1 \ldots 1] \begin{bmatrix} am_{11} & am_{21} & \cdots & \cdots & am_{n1} \\ am_{12} & am_{22} & \vdots & \vdots & am_{n2} \\ \vdots & \vdots & am_{ij} & \vdots & \vdots \\ \vdots & \vdots & \cdots & \ddots & \vdots \\ am_{1n} & am_{2n} & \cdots & \cdots & am_{nn} \end{bmatrix}$$

$$\begin{bmatrix} ad_{11} & ad_{21} & \cdots & \cdots & ad_{n1} \\ ad_{12} & ad_{22} & \vdots & \vdots & ad_{n2} \\ \vdots & \vdots & ad_{ij} & \vdots & \vdots \\ \vdots & \vdots & \cdots & \ddots & \vdots \\ ad_{1n} & ad_{2n} & \cdots & \cdots & ad_{nn} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ \vdots \\ x_n \end{bmatrix}, \tag{5}$$

where all variables are defined as before except $I$, which is the identity matrix, $A^D$, which is an $(n \times n)$ domestic coefficient matrix and $ad_{ij}$ is the element of domestic impact coefficient table $(I - A^D)^{-1}$. The term $(I - A^D)^{-1}$ reflects the multiple-stage nature of a domestic economy because the imported intermediate inputs are sequentially used by all sectors of the economy before they become embodied in production of the final goods for export. Namely, the important feature of the modified $VS^*$ shares of exports is that they allow the imported intermediate goods to circulate through all the sectors of the *domestic* economy.

Given that the issue of interest is changes in the composition of trade, we normalize $VS$ and $VS^*$ by the total exports and use the following:[5]

$$VSS = \frac{VS}{X} = \left(\frac{1}{X}\right)uA^Mx, \tag{6}$$

$$VSS^* = \frac{VS^*}{X} = \left(\frac{1}{X}\right)uA^M(I - A^D)^{-1}x. \tag{7}$$

Using the approximation of $(I - A^D)^{-1}$ by $I + (A^D)^1 + (A^D)^2 + \cdots (A^D)^k$,[6] where $k$ represents $k$-stage input-output circulation among domestic industries, we rewrite the modified $VS$ measure in (4) as

$$VS^* = VS + uA^M[(A^D)^1x + (A^D)^2x + \cdots (A^D)^kx]. \tag{8}$$

It follows that we have

$$\Delta VS = VS^* - VS = uA^M[(A^D)^1 x + (A^D)^2 x + \cdots (A^D)^k x].$$  (9)

Because $VS^*$ and $VS$ respectively are the levels of $VS$-based trade *with* and *without* the domestic input-output linkage, their difference ($\Delta VS$) measures the additional contribution of the $VS$-based trade due to the domestic linkage. In other words, $\Delta VS$ reflects the *indirect* imported input content of exports.[7] In our analysis, we calculate the extra contribution as a percentage of exports.

In the next section, we present the results of $VS$ measures ($VS$ and $VS^*$), $VS^*$ shares of exports ($VSS^*$), and the extra contribution of $VS$-based trade as a proportion of exports ($\Delta VS/X$) for Taiwan and Korea.

## 2. Empirical results

### 2.1. Data sources

We use IO tables from Taiwan and Korea to calculate the level and growth of vertical specialization in trade for several years between 1980 and 1996. Taiwan's IO tables (1981–1996) were obtained from Directorate-General of Budget, Accounting and Statistics, Executive Yuan, Taipei, Taiwan. Korea's IO tables (1970–1995) available on CD-ROM were obtained from Bank of Korea. Because IO tables of the two countries contain different numbers of sectors and have four different categories (large, medium, small, and basic),[8] we propose to calculate various $VS$ measures by using a consistent number of sectors. This approach allows us to conduct a comparison for the same country over different time periods or a comparison between two different countries for the same sector over time. For Korea, we convert data from the small-size category into the large-size category in order to calculate $VS$ measures for 20 sectors.[9] For Taiwan, we convert all of the data using the small-size category into 123 sectors.[10] After having calculated $VS$ measures based on the 123 sectors, we then aggregate those $VS$ measures for 20 sectors.

### 2.2. Sectoral and total $VS$ shares of trade

Table 1 presents $VS^*$ shares of exports (i.e., $VSS^*$) for three major sectors (agriculture, manufacture, and service sectors) and the sum of the $VS^*$ shares for Taiwan and Korea.[11] Not surprisingly, the values of $VSS^*$ for Taiwan have been steadily increasing over time, from 48.32% in 1981 to 69.05% in 1996. For Korea, the values of $VSS^*$ have in general been increasing from 39.62% in 1980 to 63.76% in 1995. The only exception is 1988's 51.47%, but it is more or less close to 1985's 49.05% and 1990's 49.41%.

It should be noted that the values of $VS^*$ shares calculated in the present study are greater than those in Hummels et al. (2001). According to their calculations, both Taiwan and Korea have a lower value of $VSS^*$ around

*Table 1.* Sectoral and total $VS^*$ shares (i.e., $VSS^*$).

| | Taiwan | | | | | Korea | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Agri. | Manuf. | Service | $VSS^*$ | Year | Agri. | Manuf. | Service | $VSS^*$ |
| 1981 | 1.88 | 43.30 | 3.14 | 48.32 | 1980 | | 34.27 | 4.35 | 39.62 |
| 1984 | 1.69 | 47.01 | 2.25 | 50.94 | 1983 | 0.68 | 35.91 | 4.14 | 40.73 |
| 1986 | 1.75 | 47.63 | 2.59 | 51.97 | 1985 | 0.73 | 44.75 | 3.57 | 49.05 |
| 1989 | 1.26 | 54.02 | 2.33 | 57.62 | 1988 | 0.61 | 48.54 | 2.32 | 51.47 |
| 1991 | 1.18 | 56.23 | 3.39 | 60.80 | 1990 | 0.64 | 46.42 | 2.35 | 49.41 |
| 1994 | 1.11 | 57.12 | 3.56 | 61.79 | 1993 | 0.44 | 47.12 | 2.28 | 49.84 |
| 1996 | 0.93 | 63.64 | 4.48 | 69.05 | 1995 | 0.41 | 60.31 | 3.04 | 63.76 |
| Growth of $VSS^*$ from 1981 to 1996 | | | 42.9 | Growth of $VSS^*$ from 1980 to 1995 | | | 60.9 | | |

one-third. One reason for such a discrepancy may be due to the way data are aggregated while using the IO tables. Taking the case of Taiwan as an example, we find that a different aggregation approach in terms of the number of sectors would affect the value of $VSS^*$ differently. We calculate $VSS^*$ measures using 39 sectors, 123 sectors, and 150 sectors for Taiwan in 1991 and find that their values are given respectively as 39.19%, 60.8%, and 47.23%.[12] This suggests that the estimates of $VSS^*$ are quite sensitive to the aggregation approach in terms of the numbers of sectors used. Given that our analysis involves the use of time series data, a consistent number of sectors is necessary to have a common base for conducting a comparison over different time periods or across different countries. For Korea, we convert IO tables from the small-size category into those in the large-size category with 20 sectors. In order to compare the degree of trade verticality between Korea and Taiwan, we further transform Taiwan's $VS^*$ shares for 123 sectors into those for 20 sectors.

The last row of Table 1 shows the growth of $VSS^*$ from the first year to the last year of the studying period for each country. Even though the values of VSS* for Taiwan are in general greater than those of $VSS^*$ for Korea, the growth of $VSS^*$ for Korea during the 1980–1995 period is higher than that for Taiwan during the 1981–1996 period. One common feature of trade verticality for Taiwan and Korea is that the $VS^*$ shares of the manufacturing sectors in both countries have steadily been increasing over time. $VS^*$ shares of exports for an individual industry in the manufacturing sector may be quite large.

Tables 2 and 3 show the estimates of the $VS^*$ shares of exports for the three major sectors and their respective industries. Among the nine industries in Taiwan's manufacturing sector, five industries have $VS^*$ shares that account for more than 50% of their exports. These five industries are textiles and leather (4), chemicals and chemical products (7), primary metal products (9), metal products and machinery (10), and miscellaneous manufactured products (11). Korea has four manufacturing industries characterized by a higher value of $VS^*$ shares than other manufacturing industries. These four industries are textiles and leather (4), chemicals and chemical products (7), primary metal products (9), and metal products and machinery (10). The

*Table 2.*   $VS^*$ as a proportion of exports ($VSS^*$) for sectors and industries (Taiwan).

| Sectors | (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1981 | 1984 | 1986 | 1989 | 1991 | 1994 | 1996 | Average |
| **Agriculture** | **26.86** | **29.16** | **28.70** | **29.46** | **30.34** | **29.08** | **30.99** | **29.23** |
| 1. Agriculture, forestry and fisheries | 28.57 | 26.18 | 24.62 | 24.85 | 21.56 | 24.21 | 23.67 | 24.81 |
| 2. Food, beverages and tobacco products | 26.10 | 30.32 | 29.90 | 30.92 | 32.39 | 31.46 | 34.51 | 30.80 |
| **Manufacture** | **54.34** | **56.37** | **57.79** | **64.34** | **68.77** | **71.03** | **80.08** | **64.67** |
| 3. Mining and quarrying | 22.21 | 23.20 | 22.28 | 19.19 | 21.05 | 20.34 | 19.33 | 21.09 |
| 4. Textiles and leather | 48.24 | 48.32 | 50.98 | 45.21 | 46.62 | 45.95 | 51.68 | 48.14 |
| 5. Lumber and wood products | 34.47 | 37.61 | 43.07 | 41.05 | 43.20 | 41.58 | 36.92 | 39.70 |
| 6. Paper, printing and publishing | 43.69 | 40.04 | 37.79 | 37.58 | 47.09 | 45.65 | 45.31 | 42.45 |
| 7. Chemicals and chemical products | 64.47 | 66.74 | 60.27 | 53.76 | 59.08 | 56.27 | 57.99 | 59.80 |
| 8. Nonmetallic mineral products | 27.29 | 30.60 | 26.53 | 22.95 | 26.89 | 26.03 | 27.30 | 26.80 |
| 9. Primary metal products | 48.14 | 58.62 | 56.97 | 53.88 | 55.80 | 54.81 | 54.53 | 54.68 |
| 10. Metal products and machinery | 57.89 | 58.80 | 60.70 | 80.58 | 85.35 | 86.15 | 96.92 | 75.20 |
| 11. Miscellaneous manufactured products | 63.18 | 60.87 | 70.35 | 53.69 | 50.71 | 52.03 | 50.32 | 57.31 |
| **Service** | **23.56** | **20.77** | **22.56** | **19.85** | **23.66** | **22.56** | **25.55** | **22.64** |
| 12. Electric power, gas and water supply | 43.07 | 62.81 | 89.27 | 71.12 | 90.23 | 76.17 | 80.06 | 73.25 |
| 13. Construction | 17.02 | 40.35 | 30.66 | 34.18 | 42.31 | 69.13 | 64.96 | 42.66 |
| 14. Wholesale and retail trade | 22.70 | 17.25 | 17.99 | 16.31 | 21.63 | 17.82 | 20.34 | 19.15 |
| 15. Restaurants and Hotels | 37.38 | 15.68 | 16.37 | 12.89 | 12.08 | 11.09 | 11.69 | 16.74 |
| 16. Transport, Warehousing and communication | 30.27 | 29.24 | 30.75 | 27.46 | 30.37 | 30.17 | 35.45 | 30.53 |
| 17. Finance, insurance, real-estate and business services | 13.33 | 6.79 | 9.52 | 6.99 | 12.76 | 11.84 | 12.20 | 10.49 |
| 18. Public administration and defense | 15.59 | – | – | – | – | – | – | 2.23 |
| 19. Other services | 13.53 | 11.98 | 16.31 | 12.78 | 11.52 | 12.95 | 10.54 | 12.80 |
| 20. Other sector | 27.94 | 41.74 | 25.96 | 25.42 | 19.66 | 27.94 | 25.83 | 27.78 |

patterns of VS-based trade for Taiwan and Korea are quite similar in terms of the manufactured exports during the last two decades.

Several other interesting observations from Tables 2 and 3 are worth mentioning. First, the industry that has the most dramatic change in $VS^*$ growth in Taiwan and Korea is metal products and machinery. For Taiwan, this industry's $VS^*$ shares of exports has changed from 57.89% in 1981 to 96.92% in 1996. For Korea, it has changed from 44.33% in 1980 to 91.55% in 1995. The second observation is that except in 1988, the $VS^*$ shares of exports for Korea's chemicals and chemical products industry are greater than one,

*Table 3.* $VS^*$ as a proportion of exports ($VSS^*$) for sector and industries (Korea).

| | | | | | | | | (%) |
|---|---|---|---|---|---|---|---|---|
| Sectors | 1980 | 1983 | 1985 | 1988 | 1990 | 1993 | 1995 | Average |
| **Agriculture** | **16.96** | **15.19** | **18.79** | **16.34** | **16.84** | **16.05** | **16.80** | **16.71** |
| 1. Agriculture, forestry and fisheries | 10.93 | 10.47 | 12.41 | 8.63 | 8.75 | 7.67 | 7.95 | 9.54 |
| 2. Food, beverages and tobacco products | 25.57 | 23.40 | 25.90 | 22.42 | 22.63 | 21.27 | 21.33 | 23.22 |
| **Manufacture** | **48.01** | **49.77** | **59.04** | **61.80** | **59.97** | **60.04** | **76.35** | **59.28** |
| 3. Mining and quarrying | 2.69 | 2.89 | 1.54 | 1.09 | 0.98 | 0.83 | 0.74 | 1.54 |
| 4. Textiles and leather | 45.13 | 40.17 | 45.22 | 42.80 | 42.63 | 33.31 | 31.25 | 40.07 |
| 5. Lumber and wood products | 8.16 | 8.14 | 8.42 | 11.88 | 13.82 | 17.10 | 10.09 | 11.09 |
| 6. Paper, printing and publishing | 18.93 | 17.12 | 18.27 | 20.72 | 18.33 | 16.70 | 20.40 | 18.64 |
| 7. Chemicals and chemical products | 105.27 | 100.30 | 116.65 | 98.20 | 102.66 | 101.89 | 103.78 | 104.11 |
| 8. Nonmetallic mineral products | 9.39 | 8.09 | 9.70 | 10.82 | 10.24 | 8.37 | 10.18 | 9.54 |
| 9. Primary metal products | 41.48 | 37.07 | 40.94 | 49.82 | 47.73 | 41.09 | 43.65 | 43.11 |
| 10. Metal products and machinery | 44.33 | 52.57 | 59.92 | 73.14 | 72.26 | 69.27 | 91.55 | 66.15 |
| 11. Miscellaneous manufactured products | 5.99 | 6.35 | 6.45 | 7.67 | 5.28 | 6.24 | 6.31 | 6.33 |
| **Service** | **19.14** | **17.73** | **17.57** | **13.10** | **12.48** | **12.14** | **16.38** | **15.51** |
| 12. Electric power, gas and water supply | 9.54 | 10.36 | 9.08 | 9.05 | 10.23 | 13.37 | 15.98 | 11.09 |
| 13. Construction | 27.51 | 27.48 | 29.68 | 28.62 | 38.18 | 35.56 | 41.83 | 32.69 |
| 14. Wholesale and retail trade | 13.63 | 11.57 | 11.05 | 11.15 | 10.05 | 9.51 | 9.51 | 10.92 |
| 15. Restaurants and Hotels | 2.59 | 2.48 | 1.85 | 1.72 | 1.90 | 2.13 | 2.32 | 2.14 |
| 16. Transport Warehousing and communication | 23.62 | 22.53 | 23.07 | 18.00 | 15.83 | 16.06 | 17.83 | 19.56 |
| 17. Finance, insurance, realestate and business services | 4.61 | 3.95 | 9.57 | 8.95 | 12.08 | 13.26 | 17.34 | 9.97 |
| 18. Public administration and defense | 12.32 | 12.95 | 9.30 | 9.32 | 7.61 | 7.41 | 7.41 | 9.47 |
| 19. Other services | 13.17 | 12.94 | 9.70 | 9.83 | 9.84 | 12.04 | 15.05 | 11.80 |
| 20. Other sector | 16.89 | 10.45 | 10.39 | 11.04 | 9.84 | 9.03 | 24.79 | 13.20 |

implying that the industry's $VS^*$ value exceeds its export earnings. This occurs when the imported intermediate inputs are intensively used by related sectors of an economy before they become embodied in the production of export goods. In other words, chemicals and chemical products are highly circulated from one sector to another within the domestic economy through the IO framework before being embodied in an exported good. Another observation concerns the Taiwan's service sector. Even though $VS^*$ shares of exports for service sector is no more than a quarter, $VS^*$ shares of exports for an individual industry in the sector may be quite large. For example, the $VS^*$

shares of exports for the construction industry (13) has an average value of 42.66%, while the average value for the electric power, gas and water supply industry is as high as 73.25%.

### 2.3.  Contribution of *VS* growth to export growth

One interesting question that naturally arises concerns the contribution of the growth in *VS*-based trade to the growth in exports. To answer this question, we follow Hummels et al. (2001) to decompose exports into (i) $VS^*$ exports and (ii) non-$VS^*$ exports for the first and last years of the studying period for Taiwan and Korea. $VS^*$ exports involve the use of imported intermediate inputs, while non-$VS^*$ exports involve the use of intermediate inputs domestically produced. We then compute the growth of exports from the first year to the last year, as well as the contribution of the export growth by the growth in $VS^*$. These results are presented in Table 4. For Taiwan, 56.83% of the growth of exports is contributed by growth in $VS^*$. In Korea, growth in *VS* accounts for 63.75% of export growth.[13]

### 2.4.  Indirect imported input content of exports due to domestic IO linkage

Next, we calculate the indirect effect or the extra contribution of *VS*-based trade resulting from a systematic input-output circulation within domestic industries for each country. Tables 5 and 6 present the estimates of the extra contribution as a proportion of exports at the sectoral and industrial levels. Among the nine industries in Taiwan's manufacturing sector, five industries enjoy an extra contribution of $VS^*$ trade that accounts for more than 25% of their exports. These five industries are textiles and leather (4), paper, printing and publishing (6), chemicals and chemical products (7), primary metal products (9), and miscellaneous manufactured products (11). For Korea, three manufacturing industries enjoy an extra contribution of $VS^*$ trade that also accounts for more than 25% of their exports. These three industries are chemicals and chemical products (7), metal products and machinery (10), and miscellaneous manufactured products (11).

   An examination of Tables 5 and 6 also reveals that the indirect contributions of *VS* trade generated by the domestic input-output circulation are primarily from manufacturing industries. For Taiwan's manufacturing sector as a whole, the extra contribution of VS trade as a proportion of exports is about 25.86%; while for Korea's manufacturing sector, it is about 31.94%. Interestingly, for food, beverages, and tobacco products (2) in Taiwan's agricultural sector, the result of the estimate goes as high as 25.32%.

### 2.5.  The effects of tariff reductions on VS-based trade

One important issue on vertical specialization in trade concerns how the VS-based trade would be affected by trade liberalization through changes in

*Table 4.* VS* growth and trade growth.
(First year, Last year)                                                                 Units: million New Taiwan Dollar / million Korea Won

|  | Gross Output | Export | VS* Export | Non-VS* Export | Export shares of gross Output | Increase in export shares of gross output | VS* Export shares of gross output | Contribution of VS* shares |
|---|---|---|---|---|---|---|---|---|
| **Taiwan** |  |  |  |  |  |  |  |  |
| 1981 | 4,559,835 | 918,599 | 443,828 | 474,771 | 20.15% |  |  |  |
| 1996 | 16,347,269 | 3,614,129 | 2,495,424 | 1,118,705 | 22.11% | 9.74% | 15.27% | 56.83% |
| **Korea** |  |  |  |  |  |  |  |  |
| 1980 | 93,637,524 | 12,467,197 | 4,939,430 | 7,527,767 | 13.31% |  |  |  |
| 1995 | 841,518,563 | 113,852,382 | 72,593,046 | 41,259,336 | 13.53% | 1.62% | 8.63% | 63.75% |

*Table 5.* Extra contribution of *VS** trade due to the domestic input-output linkage (as a proportion of exports for sectors and industries in Taiwan).

| Sectors | (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1981 | 1984 | 1986 | 1989 | 1991 | 1994 | 1996 | Average |
| **Agriculture** | **21.48** | **23.92** | **23.29** | **21.35** | **23.35** | **21.23** | **22.5** | **22.45** |
| 1. Agriculture, forestry and fisheries | 19.91 | 18 | 16.18 | 13.25 | 12.67 | 12.46 | 10.71 | 14.74 |
| 2. Food, beverages and tobacco products | 22.19 | 26.22 | 25.37 | 23.93 | 25.85 | 25.51 | 28.18 | 25.32 |
| **Manufacture** | **26.02** | **28.52** | **28.72** | **24.95** | **26.42** | **21.35** | **25.04** | **25.86** |
| 3. Mining and quarrying | 20.09 | 20.45 | 21.35 | 17.69 | 19.73 | 16.77 | 14.89 | 18.71 |
| 4. Textiles and leather | 33.38 | 34.89 | 34.93 | 29.16 | 29.32 | 26.91 | 28.01 | 30.94 |
| 5. Lumber and wood products | 16.41 | 16.59 | 18.21 | 14.48 | 16.19 | 13.48 | 12.02 | 15.34 |
| 6. Paper, printing and publishing | 29.08 | 28.72 | 26.09 | 20.8 | 27.08 | 26.33 | 25.6 | 26.24 |
| 7. Chemicals and chemical products | 27.43 | 30.95 | 30.31 | 24.38 | 26.71 | 23.29 | 22.92 | 26.57 |
| 8. Nonmetallic mineral products | 19.76 | 22 | 19.57 | 15.69 | 16.31 | 15.62 | 16.82 | 17.97 |
| 9. Primary metal products | 29.9 | 39.15 | 34.95 | 23.23 | 25.03 | 25.96 | 25.37 | 29.08 |
| 10. Metal products and machinery | 22.24 | 24.62 | 26.15 | 24.9 | 26.27 | 19.2 | 25.24 | 24.09 |
| 11. Miscellaneous manufactured products | 30.57 | 29.3 | 29.12 | 23.76 | 25.93 | 24.43 | 25.49 | 26.94 |
| 12. Electric power, gas and water supply | 12.21 | 12.53 | 11.94 | 9.63 | 9.59 | 8.41 | 9.13 | 10.49 |
| 13. Construction | 40.92 | 23.17 | 23.35 | 20.51 | 22.89 | 20.41 | 22.71 | 24.85 |
| **Service** | **7.8** | **27.28** | **26.67** | **24.08** | **26.37** | **22.66** | **21.66** | **22.36** |
| 14. Wholesale and retail trade | 8.57 | 7.76 | 7.31 | 6.65 | 8.08 | 7.11 | 7.06 | 7.51 |
| 15. Restaurants and hotels | 32.16 | 14.35 | 14.91 | 11.11 | 10.79 | 9.78 | 10.38 | 14.78 |
| 16. Transport warehousing and communication | 15.78 | 17.5 | 15.75 | 12.08 | 10.51 | 8.41 | 9.31 | 12.76 |
| | 15.78 | 17.5 | 15.75 | 12.08 | 10.51 | 8.41 | 9.31 | 12.76 |
| 17. Finance, insurance, realestate and business services | 10.15 | 5.74 | 6.17 | 5.16 | 8.49 | 7.62 | 7.6 | 7.28 |
| 18. Public administration and defense | 14.94 | – | – | – | – | – | – | 2.13 |
| 19. Other services | 12.11 | 10.4 | 12.33 | 9.51 | 9.19 | 7.96 | 8.25 | 9.96 |
| 20. Other Sector | 19.4 | 32.92 | 19.1 | 18.75 | 13.84 | 19.99 | 23.96 | 21.14 |

trade barriers such as tariff reductions. Hummels et al. (1999) demonstrate that even small reductions in trade barriers (such as transport costs and tariffs) would modify international production and trade toward vertical specialization. It would have policy implications for gradual trade liberalization in terms of tariff reductions if we would be able to show the trend between tariffs and the degree of trade verticality.

To be consistent with the various estimates of *VS** shares calculated from IO tables, we hope to obtain tariff data from those same tables. Taiwan's IO tables make it possible to do so. We make use of the transaction tables and compute the differences in the values of imported goods and services with

*Table 6.* Extra contribution of *VS\** trade due to the domestic input-output linkage (as a proportion of exports for sectors and industries in Korea).

| Sectors | 1980 | 1983 | 1985 | 1988 | 1990 | 1993 | 1995 | Average |
|---|---|---|---|---|---|---|---|---|
| **Agriculture** | **11.48** | **10.19** | **12.78** | **10.51** | **10.64** | **9.53** | **9.47** | **10.66** |
| 1. Agriculture, forestry and fisheries | 9.22 | 8.75 | 10.31 | 7.22 | 7.17 | 6.34 | 6.61 | 7.95 |
| 2. Food, beverages and tobacco products | 14.69 | 12.69 | 15.52 | 13.10 | 13.12 | 11.51 | 10.94 | 13.08 |
| **Manufacture** | **24.12** | **24.54** | **28.56** | **32.94** | **35.74** | **34.83** | **42.86** | **31.94** |
| 3. Mining and quarrying | 2.51 | 2.55 | 1.51 | 1.04 | 0.93 | 0.78 | 0.72 | 1.43 |
| 4. Textiles and leather | 29.38 | 24.04 | 29.10 | 25.94 | 26.51 | 18.78 | 15.93 | 24.24 |
| 5. Lumber and wood products | 1.79 | 1.97 | 2.08 | 2.32 | 2.83 | 3.63 | 2.28 | 2.42 |
| 6. Paper, printing and publishing | 7.78 | 8.42 | 8.21 | 9.13 | 7.88 | 6.97 | 8.37 | 8.11 |
| 7. Chemicals and chemical products | 28.93 | 23.62 | 30.17 | 27.39 | 29.18 | 28.72 | 30.70 | 28.39 |
| 8. Nonmetallic mineral products | 7.18 | 4.84 | 5.17 | 4.89 | 4.62 | 4.67 | 5.54 | 5.27 |
| 9. Primary metal products | 24.39 | 22.18 | 24.09 | 26.75 | 26.00 | 22.83 | 23.38 | 24.23 |
| 10. Metal products and machinery | 24.71 | 31.02 | 33.92 | 45.08 | 50.74 | 48.84 | 58.74 | 41.86 |
| 11. Miscellaneous manufactured products | 23.49 | 23.17 | 25.39 | 23.68 | 29.91 | 27.35 | 30.03 | 26.15 |
| 12. Electric power, gas and water supply | 3.26 | 3.63 | 3.96 | 4.34 | 2.94 | 2.04 | 1.74 | 3.13 |
| 13. Construction | 8.36 | 8.82 | 5.51 | 2.85 | 3.23 | 4.47 | 5.11 | 5.48 |
| **Service** | **10.98** | **10.57** | **11.28** | **8.07** | **7.64** | **7.81** | **9.05** | **9.34** |
| 14. Wholesale and retail trade | 10.95 | 8.63 | 9.05 | 8.77 | 7.48 | 6.43 | 8.06 | 8.48 |
| 15. Restaurants and hotels | 2.18 | 2.07 | 1.56 | 1.47 | 1.31 | 1.71 | 1.72 | 1.72 |
| 16. Transport warehousing and communication | 12.17 | 12.74 | 13.97 | 9.62 | 8.20 | 9.42 | 8.79 | 10.70 |
| 17. Finance, insurance, realestate and business services | 3.83 | 3.43 | 8.05 | 8.04 | 10.76 | 11.38 | 16.10 | 8.80 |
| 18. Public administration and defense | 6.63 | 6.26 | 5.98 | 7.09 | 5.24 | – | – | 4.46 |
| 19. Other services | 11.90 | 11.28 | 8.41 | 7.88 | 7.70 | 8.40 | 11.74 | 9.61 |
| 20. Other Sector | 5.32 | 5.33 | 5.95 | 5.30 | 8.29 | 7.52 | 9.68 | 6.77 |

and without tariffs. Because data on tariffs are not available from Korea's IO tables, we use Taiwan as a case study to examine the relationship between changes in tariffs and trade verticality. Figures 1–4 illustrate show changes in (i) total VS\* shares of exports and (ii) sectoral *VS\** shares of exports are related to changes in tariff rates over the examination period of time. An inspection of Figures 1 and 3 reveals the general trends that *VS\** shares of exports for the economy and for the manufacturing sector have been increasing when tariff rates were gradually reduced after 1984. These findings suggest that trade liberalization through tariff reductions would tend to change the pattern of
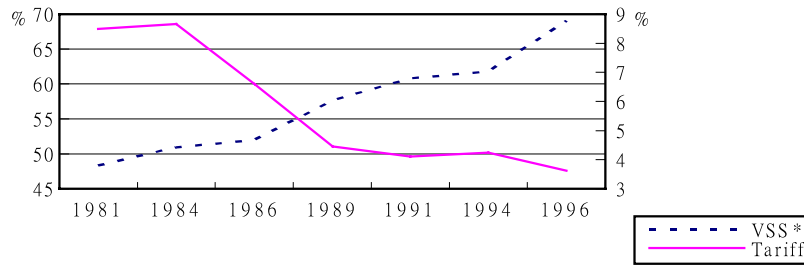
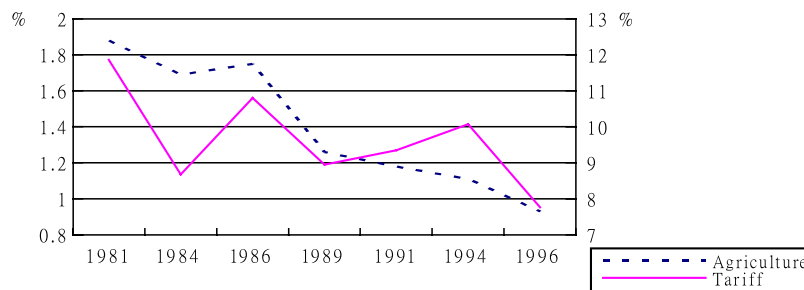*Figure 1.*   *VS*\* shares and tariff rates (Taiwan).



*Figure 2.*   Agricultural sector's *VS*\* shares and tariff rates (Taiwan).

production toward vertical specialization (Hummels et al., 1998, 1999; and Yi, 2003).

## 3.   Concluding remarks

The extent of an export-oriented country's integration with the world markets via trade is traditionally measured by growing trade shares of output. Recent studies in the literature analyze this issue from an alternative approach by identifying international integration through trade in the form of vertical specialization. The study by Hummels et al. (1999) is among the first in this direction of empirical research. This concept of trade verticality involves multiple stages of processes with countries specializing in parts of the stages in a vertical trade relationship. This type of sequential production processes and the resulting trade require the use of imported inputs, which are combined with local raw or intermediate goods, to produce final products for export.

   Based on the notion of vertical specialization in trade, we use IO tables from Taiwan and Korea to analyze the nature of trade in vertical specialization and the accompanying changes in the structure of industries. Our empirical results indicate that vertical specialization in trade plays an important
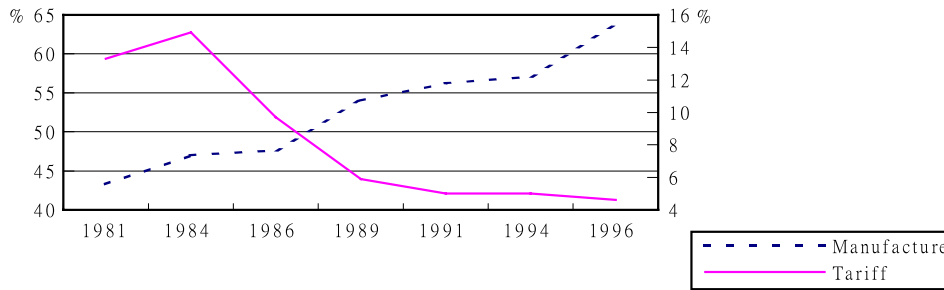
*Figure 3.*   Manufacturing sector's *VS** shares and tariff rates (Taiwan).
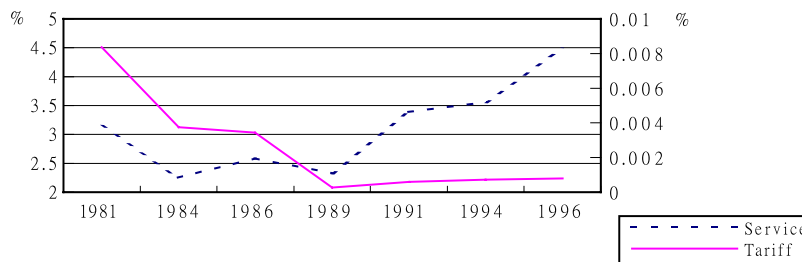


*Figure 4.*   Service sector's *VS** shares and tariff rates (Taiwan).

role in the growth of trade for Taiwan and Korea. A significant portion of international trade for Taiwan and Korea in the last two decades appears to be following the trend of the world trade in moving toward the patterns of global production sharing. Noteworthy is the manufacturing sector, whose *VS** shares of exports has been steadily increasing and has accounted for more than 90% of the total $VS^*$ shares of exports. For Taiwan, nearly 57% of the growth in exports is contributed by the growth in VS-based trade; for Korea, it is about 64%. We have calculated as a proportion of exports the indirect or extra contribution of VS-based trade resulting from input-output circulation among the domestic industries of each country. The results indicate that the manufacturing sector generally enjoys the highest indirect contribution relative to other major sectors. We have also found that gradual reductions of tariffs in Taiwan have raised the degree of trade verticality for the economy, particularly the manufacturing industries.

As economic integration with the globe economy through trade has been increasingly deepened for Taiwan and Korea, merchandise trade for these two countries would continue to move into a higher degree of vertical specialization in production. This increase in trade verticality implies that Taiwan and Korea will continue to rely heavily on imported intermediate inputs to produce export goods. It seems that China is going through a very similar

growth process right now. Consequently, the computing detailed industry-level $VS^*$ measures over time for Taiwan and Korea could shed some light on the export boom that was part of their growth miracle, as well as provide hints about what is happening and what will happen in China.

## Appendices

*Table A-1.* IO tables in terms of the number of sectors.

| | Taiwan | | | | | Korea | | | |
| | The number of sectors | | | | | The number of sectors | | | |
| Year | Large | Medium | Small | Basic | Year | Large | Medium | Small | Basic |
|---|---|---|---|---|---|---|---|---|---|
| 1964 | | 55 | | | | | | | |
| 1966 | | 76 | | 241 | 1970 | | 56 | 153 | |
| 1969 | | 76 | | 241 | 1973 | | 56 | 153 | |
| 1971 | | 76 | | 301 | 1975 | | 60 | 164 | 392 |
| 1974 | | 76 | | 301 | 1978 | | 60 | 164 | |
| 1976 | | 99 | | 394 | 1980 | 19 | 64 | 162 | 396 |
| 1979 | 49 | 99 | | 394 | 1983 | 19 | 64 | 162 | 396 |
| 1981 | 29, 39, 49 | 99 | 123 | 422 | 1985 | 20 | 65 | 161 | 402 |
| 1984 | 29, 39, 49 | 99 | 123 | 422 | 1986 | 20 | 65 | 161 | |
| 1986 | 29, 39, 49 | 99 | 123 | 487 | 1987 | 20 | 65 | 161 | |
| 1989 | 29, 39, 49 | | 123 | 496 | 1988 | 20 | 65 | 161 | |
| 1991 | 39 | | 150 | 569 | 1990 | 26 | 75 | 163 | 405 |
| 1994 | 39 | | 150 | 569 | 1993 | 26 | 75 | 163 | |
| 1996 | 49 | | 160 | 596 | 1995 | 28 | 77 | 168 | 402 |

*Table A-2.* $VS^*$ value for sectors and industries (Taiwan).

| Sectors | 1981 | 1984 | 1986 | 1989 | 1991 | 1994 | 1996 |
|---|---|---|---|---|---|---|---|
| | | | (unit: million New Taiwan Dollar) | | | | |
| **Agriculture** | **17,285** | **22,115** | **28,549** | **24,022** | **26,750** | **30,995** | **33,481** |
| 1. Agriculture, forestry and fisheries | 5,678 | 5,555 | 5,537 | 4,887 | 3,604 | 8,466 | 8,308 |
| 2. Food, beverages and tobacco products | 11,607 | 16,560 | 23,012 | 19,136 | 23,147 | 22,529 | 25,173 |
| **Manufacture** | **397,708** | **616,832** | **779,250** | **1,031,156** | **1,270,944** | **1,595,988** | **2,299,864** |
| 3. Mining and quarrying | 56 | 57 | 47 | 97 | 117 | 154 | 269 |
| 4. Textiles and leather | 83,747 | 120,838 | 151,381 | 140,801 | 155,819 | 151,087 | 192,092 |
| 5. Lumber and wood products | 13,821 | 18,462 | 27,753 | 23,344 | 20,995 | 16,829 | 13,372 |
| 6. Paper, printing and publishing | 2,579 | 1,968 | 3,467 | 4,626 | 8,742 | 10,083 | 13,076 |
| 7. Chemicals and chemical products | 91,425 | 130,557 | 129,247 | 125,371 | 164,573 | 188,044 | 228,188 |
| 8. Nonmetallic mineral products | 3,658 | 7,435 | 7,212 | 6,693 | 8,060 | 7,121 | 8,008 |
| 9. Primary metal products | 20,356 | 15,079 | 13,975 | 19,426 | 23,904 | 36,372 | 55,022 |

*(Continued on next page)*

*Table A-2.  (Continued)*

| Sectors | 1981 | 1984 | 1986 | 1989 | 1991 | 1994 | 1996 |
|---|---|---|---|---|---|---|---|
| 10.  Metal products and machinery | 182,031 | 253,144 | 341,309 | 644,598 | 822,112 | 1,121,091 | 1,723,707 |
| 11.  Miscellaneous manufactured products | 36 | 69,294 | 104,859 | 66,201 | 66,621 | 65,206 | 66,130 |
| **Service** | **28,836** | **29,515** | **42,447** | **44,544** | **76,707** | **99,416** | **162,079** |
| 12.  Electric power, gas and water supply | 22 | 63 | 131 | 70 | 169 | 532 | 596 |
| 13.  Construction | 2,275 | 8 | 1 | 1 | 4 | 3 | 2,306 |
| 14.  Wholesale and retail trade | 10,999 | 9,111 | 11,247 | 11,815 | 20,555 | 20,764 | 37,610 |
| 15.  Restaurants and hotels | 2,160 | 2,315 | 3,166 | 2,855 | 2,804 | 4,580 | 5,998 |
| 16.  Transport warehousing and communication | 9,880 | 14,591 | 24,262 | 25,765 | 45,853 | 62,859 | 98,347 |
| 17.  Finance, insurance, realestate, and business services | 1,554 | 952 | 1,622 | 1,522 | 5,746 | 6,233 | 10,000 |
| 18.  Public administration and defense | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19.  Other services | 914 | 762 | 1,055 | 1,082 | 469 | 1,269 | 1,130 |
| 20.  Other Sector | 1,030 | 1,714 | 961 | 1,434 | 1,107 | 3,175 | 6,092 |
| Total *VS* value | **443,829** | **668,462** | **850,246** | **1,099,722** | **1,374,401** | **1,726,399** | **2,495,424** |

*Table A-3.  VS\* value for sectors and industries (Korea).*

| Sectors | 1980 | 1983 | 1985 | 1988 | 1990 | 1993 | 1995 |
|---|---|---|---|---|---|---|---|
| | | | | (unit: million New Taiwan Dollar) | | | |
| **Agriculture** | **12,504** | **14,788** | **20,117** | **30,778** | **33,925** | **33,638** | **46,829** |
| 1 Agriculture, forestry and Fisheries | 4,735 | 6,472 | 6,992 | 7,155 | 7,366 | 6,169 | 7,501 |
| 2 Food, beverages and tobacco products | 7,768 | 8,317 | 13,126 | 23,624 | 26,559 | 27,469 | 39,328 |
| **Manufacture** | **427,266** | **775,330** | **1,240,474** | **2,449,494** | **2,467,583** | **3,627,788** | **6,866,357** |
| 3 Mining and quarrying | 152 | 127 | 59 | 63 | 70 | 59 | 44 |
| 4 Textiles and leather | 134,309 | 185,013 | 272,179 | 440,575 | 565,864 | 490,113 | 510,503 |
| 5 Lumber & wood products | 2,237 | 1,281 | 1,164 | 2,746 | 3,398 | 2,589 | 978 |
| 6 Paper, printing and publishing | 1,741 | 1,812 | 2,394 | 6,300 | 6,223 | 8,555 | 20,493 |
| 7 Chemicals and chemical products | 129,637 | 213,840 | 400,947 | 543,197 | 449,618 | 821,067 | 1,292,863 |
| 8 Nonmetallic mineral products | 2,254 | 2,475 | 2,575 | 5,321 | 4,258 | 3,827 | 4,924 |
| 9 Primary metal products | 41,618 | 55,533 | 65,500 | 128,406 | 137,882 | 183,682 | 237,022 |
| 10 Metal products and Machinery | 112,375 | 309,942 | 487,639 | 1,305,253 | 1,291,524 | 2,108,228 | 4,788,409 |
| 11 Miscellaneous manufactured products | 2,943 | 5,307 | 8,019 | 17,633 | 8,748 | 9,669 | 11,121 |
| **Service** | **54,173** | **89,350** | **99,037** | **117,268** | **124,751** | **175,642** | **346,118** |
| 12 Electric power, gas and water supply | 126 | 286 | 215 | 202 | 298 | 378 | 467 |

*Table A-3.    (Continued)*

| Sectors | 1980 | 1983 | 1985 | 1988 | 1990 | 1993 | 1995 |
|---|---|---|---|---|---|---|---|
| 13 Construction | 632 | 3,180 | 5,164 | 4,900 | 3,971 | 1,543 | 2,505 |
| 14 Wholesale and retail trade | 11,152 | 16,476 | 17,968 | 32,985 | 34,481 | 45,098 | 41,625 |
| 15 Restaurants and Hotels | 289 | 535 | 551 | 1,843 | 1,157 | 2,191 | 65 |
| 16 Transport Warehousing and communication | 39,954 | 65,568 | 70,721 | 67,901 | 70,137 | 101,426 | 185,534 |
| 17 Finance, insurance, real-estate and business services | 318 | 274 | 1,720 | 3,260 | 6,007 | 10,602 | 26,103 |
| 18 Public administration and defense | 57 | 255 | 167 | 122 | 374 | 0 | 0 |
| 19 Other services | 132 | 506 | 1,095 | 2,881 | 1,415 | 2,958 | 9,131 |
| 20 Other Sector | 1,513 | 2,271 | 1,437 | 3,174 | 6,911 | 11,446 | 78,488 |
| Total $VS^*$ value | **493,943** | **879,468** | **1,359,629** | **2,597,540** | **2,626,259** | **3,837,068** | **7,259,305** |

# Notes

1. Sanyal and Jones (1982) were the first to extend the model of Dornbusch, Fisher, and Samuelson (1977) to examine and characterize the multi-stage production of trade verticality.
2. Both Taiwan and Korea adopted local contents requirements and tariffs for parts and components to protect their domestic markets in the 1950s and 1960s. See, e.g., Hattori and Sato (1997), Okuda (1997), and Sato (1997) for extensive discussions on issues concerning the economic development in Taiwan and Korea.
3. *VS* shares of exports are the shares of total exports in vertical specialization in trade. A formal definition of the *VS* shares will be presented in Section 1.
4. We use superscript * to represent the case of the multiple-stage, input-output production activities in the domestic economy of an export-oriented country.
5. Development economists frequently adopted an approach similar to equation (7) when measuring the import content of exports. See, for example, Kubo et al. (1986). Their main focuses, however, were on balance of payment subjects and various implications for trade growth and industrialization, rather than issues on vertical specialization.
6. For a detailed analysis on the inverse of the so-called "Leontief matrix" by approximation, see the classic work by Waugh (1950).
7. Hummels et al. (1999) addressed this concept in their paper. We present a formal formulation of the measure.
8. See A-1 in the Appendices.
9. When converting data from the small-size category into the large-size category for Korea, we have to re-calculate the imported coefficient matrix, $A^M$, the transactions table at producers' price ($A^D$), and the inverse of the matrix of domestic input-output coefficients $(I-A^D)^{-1}$ for 20 sectors. The corresponding tables converted from the small-size category into the large-size one for Korea are available upon request from authors.
10. For the years 1991, 1994, and 1996 of Taiwan, we convert 150 and 160 sectors into 123 sectors. Again we need to re-compute $(I-A^D)^{-1}$ for these 123 sectors. The corresponding tables converted from 150 and 160 sectors are also available upon request.
11. In A-2 and A-3 in the Appendices, we present detailed calculations of the *VS* measures for goods and services in all of the 20 sectors for Taiwan and Korea (in their respective currencies).
12. One possible explanation is that the element of domestic impact coefficients $(I-A^D)^{-1}$ for different sectors does not have a consistent pattern (either increasing or decreasing with the number of sectors). Another possible explanation is that the $VS^*$ shares are defined as the $VS^*$ measure divided by total exports. Using different sectors of $VS$ to normalize total exports may cause an inconsistent pattern of $VSS^*$.

13. Hummels et al. (1998) analyzed the growth in exports due to increases in the degree of vertical specialization in trade for some OECD countries. They found that for Canada and Netherlands, nearly one-half of this growth was due to VS-based trade. For France, Denmark and the U.K., it was about one-quarter to one-third. But for the U.S., Australia, and Japan, the amount was even smaller.
14. Taiwan's IO tables are published by Directorate-General of Budget, Accounting and Statistics, Executive Yuan, Taipei, Taiwan. It offers two different versions of transaction tables of imported goods and services. One table records import values including tariffs whereas the other table reports only import values excluding tariffs. We calculate the differences between the import values with and without tariffs to obtain tariffs for the 123 sectors. We then calculate tariff rates for the three major sectors (agricultural, manufacturing, and service sectors), as well as for all the sectors taken together. Taiwan's IO tables are available online at: http://www.dgbas.gov.tw/lp.asp? ctNode=671&CtUnit=404 &BaseDSD=7.

## Acknowledgement

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