Analyzing the Degree of Integration into the Global Production Network of Korean Exports by Trading Partner: 2000-2018

By

CHOI, Yeongwon

THESIS

Submitted to

KDI School of Public Policy and Management

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Abstract

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In the globalized era, vertical specialization is prevalent as countries import intermediate materials to export products. Traditionally, the import content of exports (ICE), referring to the amount of foreign input embodied in one unit of export, has been used to measure the degree of vertical specialization. I use an alternative formula devised by Kim to measure the degree of verticalization, as it considers the simultaneous operation of the foreign sector and the domestic production base when exporting products. This thesis applies the alternative formula and analyzes Korean exports to the US, China, Europe, and the Middle East by means of an input-output analysis, specifically examining the degree of vertical specialization according to the trading partner between 2000 and 2018. This thesis explains the difference in the degree depending on the trading partner based on an industry-level analysis. By calculating the degree of vertical specialization for the computer, motor vehicle, chemical, and machine industries independently, the study shows how major industries affect vertical specialization depending on the trading partner, also presenting how each industry's degree of vertical specialization and export volume determines its degree of vertical specialization with its trading partners.

Keywords: vertical specialization, input-output analysis, import content of exports, industry, Korea

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1. Introduction

There is much contention about how best to explain the factors affecting the rapid economic growth of Korea. One well-known factor is export-led economic growth (Lee & Kim, 2022). Lee and Kim (2022) concluded that the average contribution of net export to Korea's GDP growth from 1960 to 2014 was 30.3 percent, which is substantial. Thus far, many people examined the trade surplus under a mercantilism-based conception, believing that the accumulation of massive amounts of foreign capital will bring about reinvestments.

In the globalized era, people face a new phenomenon: the rise of vertical specialization. According to Hummels et al. (1998), vertical specialization means reliance on foreign intermediate input to produce and export goods from one's home country. Disintegration of production stages across countries based on a comparative advantage became an efficient strategy for firms, allowing us to see trade through the lens of vertical specialization. The degree of vertical specialization matters when analyzing the effects of trade.

The Import content of exports (ICE) is a well-known method for calculating the degree of vertical specialization. Many studies have used ICE to analyze exports from countries. Alternatively, Kim (2021) suggested another measurement method that adds domestic production base to the formula. The present study attempts to use Kim's alternative method to analyze the exports of Korea vis-à-vis four trading partners. To the best of my knowledge, analyzing the degree of vertical specialization according to different trading partners based on the alternative approach has not yet been attempted.

This thesis has five sections. In section two, I introduce the literature on the concept, background, effect, application, and measurement of vertical specialization. In section three, I introduce and compare ICE and the alternative method. In section four, I deal with the data used in the analysis. In section five, based on the results, I analyze the determinants of the

different degrees of vertical specialization by trading partner. In section six, I conclude the paper and present its limitations and implications.

2. Literature Reviews

2.1. Vertical Specialization

The term vertical specialization was coined by Balassa in 1967, though he used it in a different meaning. Balassa (1967, as cited in Gündoğdu, 2015) used it in a more general sense where vertical specialization refers to subdividing the sequential production stages in individual establishments. In relation to this, Krugman (1995) used the expression "slice up the value chain" (p. 332). He claimed that production stages in different locations can lead to more trade. Feenstra (1998) used the term "disintegration of production" (p.31) to explain outsourcing. He focuses on the allocation of production stages by multinational firms.

According to Hummels et al. (2001), vertical specialization differs from outsourcing in that vertical specialization occurs when a country imports intermediate inputs to facilitate the export of products. Thus, the subject is the country and not the firm. In addition, exports which accompany imports of intermediate materials are initiated by the country. According to Hummels et al. (2001), vertical specialization is increasing. They noted that between 1970 and 1990, the growth of vertical specialization composed 30% of the growth of exports in ten OECD countries and in four emerging countries. Also, they found that this growth accounts for approximately 30% of the growth of the ratio of total exports to GDP. Araujo (2009) also revealed that vertical specialization for nearly all OECD countries grew between 1995 and 2005.

There are many arguments to explain the rise of vertical specialization. It is well known that different comparative advantages by countries are crucial factor in the rise of

vertical specialization. Different characteristics of production stages are divided such that one stage is labor intensive and another stage is capital intensive (Nordas, 2003). Which production stage a country uses is based on their comparative advantage.

Bridgman (2012) claims that decreasing trade costs play an effective role in increasing vertical specialization. He also mentioned that advances in standardized production, communication, technology, financial liberalization processes, and the emergence of multinationals may have affected the rise of vertical specialization (Bridgman, 2012). Nordas (2003) argues that depending on the sector, the determinants of vertical specialization differ. He found that the infrastructure and institutions of the exporting country are more important in labor-intensive industries than in capital-intensive industries

There are many arguments pertaining to the effects of vertical specialization. Cristina et al. (2019) proved that vertical specialization enhances productivity. Kim and Choi (2013) noted that it increased industrial GDP growth in Korea. They concluded that it is profitable for Korea to use a strategy of fragmentation of production across countries.

On the other hand, some claim that the external dependencies of industries are not beneficial. Domingues et al. (2021) noted that vertical specialization combined with weak export potential can cause trade deficits and can increase the ratio of external debt to GDP growth. They suggested that peripheric open economies should take measures such that their national production will not be replaced by imports (Domingues et al. 2021). Some scholars state that vertical specialization increases a country's vulnerability to external shocks. Escaith and Gonguet (2011) found that the global production network also functions as transmission channel of financial shocks by means of credit constraints.

External dependencies due to vertical specialization can at times make countries vulnerable when they depend on a small number of other countries when exporting their core products. For example, Korea experienced difficulties in exporting semiconductors and

display panels due to export controls of intermediate materials by Japan in 2019. Kim (2021) estimated the effect of this. With the assumption that export controls led to a10% decrease of the gross outputs of both semiconductors and display panels, he estimated a reduction of Korea's aggregate GDP of 0.72% (13.6 trillion won).

Many attempts to measure vertical specialization in countries have been taken. They mostly use ICE approach. Dean at al. (2008) analyzed vertical specialization in China in 1997 and 2002 according to different sources, trading partners, sectors, and types of firms. They concluded that total their vertical specialization exceeded 30% in 2002, showing an increase of about 6.5 percentage points from 1997, also finding that vertical specialization was high when China exports to the US, EU, and Canada as opposed to India and other countries (Dean at al., 2007). Also, they found that the main sources of imports are Japan, Taiwan, South Korea, and other Southeast Asian economies and that vertical specialization was high in the plastic products and steel processing areas. (Dean at al., 2007). At the firm' level, foreign-invested enterprises showed high vertical specialization (Dean at al., 2007).

Amador and Cabral (2008) analyzed vertical specialization in Portugal from 1980 to 2002. They calculated the intensity of vertical specialization in Portuguese manufacturing sectors and calculated the contribution rate of the sector vertical specialization intensity and the sector share of total exports relative to changes in the total vertical specialization of the country (Amador & Cabral, 2008). In addition, they calculated vertical specialization when Portugal exports to their main trade partners, finding a high level when Portugal exports to Germany (Amador & Cabral, 2008). Chen and Chang (2006) analyzed South Korea and Taiwan from 1980 to 1995. They calculated the vertical specialization overall as well as the sectoral vertical specialization of each country, finding that vertical specialization growth accounts for 63.75% of the export growth of Korea (Chen & Chang, 2006).

2.2. Measurements of Vertical Specialization

Traditionally, ICE served as the representative index for measuring vertical specialization. ICE refers the total amount of imports incurred by total exports divided by total exports. It is calculated by means of an input-output analysis. Hummels et al. (2001) developed the formula for ICE. They compared certain countries' vertical specialization trends and revealed the contribution of vertical specialization to the growth in the export share of gross output. In addition, the OECD publishes countries' ICE according to different products. For example, the OECD published ICE for the Korean automobiles industry in 2018. Hence, it is possible to compare the degree of vertical specialization between industries.

ICE was used under the generalized concept of the global value chain (GVC) by Koopman et al. (2010). Considering a multi-country, back-and-forth trade environment, they devised the GVC participation and GVC position index. The index includes the degrees of a country's backward and forward participation. ICE was used as foreign value added in relation to exports, showing the degree of backward participation. They explicitly mentioned that foreign value added corresponds to the ICE measurement (Koopman et al. 2010). The trade in value added (TiVA) statistics of the OECD involves decomposing the gross value of exports of one country. It enables the measurement of one country's foreign value added when exporting to a specific trading partner.

Kim (2021) devised the alternative measure used here to analyze vertical specialization. He considered that both the domestic production base and the global production network operate to meet export demands. The main difference is that Kim added the domestic production base to the formula. He found that comparing the operations of the domestic production base and the global production network can indicate the relative degree of vertical specialization, while ICE instead focuses on only the global production network.

He used this approach by decomposing gross output and imports into the contributions of the final demand terms (Kim, 2021). He compares the share of gross output incurred by exports to total gross output and the share of imports incurred by exports to total imports (Kim, 2021). This method shows the degree of integration into the global production network in a more comprehensive manner.

Measuring the domestic production base($\mathbf{a}_{ex}^{x}$) and foreign sector($\mathbf{a}_{ex}^{m}$) separately, he analyzed the degree of Korea's integration into the global production network from 1970 to 2018 and concluded that the degree of integration into the global production network increased consistently during this time frame (Kim, 2021). He also calculated the degree of vertical specialization by product level, finding that integration into the global production network decreased in the textile and leather industries in Korea, whereas the importance of the global production network was maintained in the electrical and electronic equipment & components industry (Kim 2021). In addition, he compared the degree of integration into the global production network of several countries from 1995 to 2015 and posited that generally the degree of vertical specialization of the countries increased, though more recently it has decreased (Kim, 2020).

3. Measurement

Here, I attempt to apply the alternative method and analyze Korea's vertical specialization according to different trading partners. To do this, it is necessary to explain the concept of the final demand shock on the supply side. In table 1, Y^d is the final demand and X is the gross output. In addition, U^d and U^m are the domestic intermediate demand and the imported intermediate demand, respectively. A^d is an n×n domestic input coefficient matrix, while A^m is an n×n imported input coefficient matrix.

Based on an input-output analysis (Kim, 2021), if the final demand of exports rises, it leads to the production of intermediate materials. By adding A^d to the final demand, the domestic intermediate demand is determined. By adding A^m to the final demand, the imported intermediate demand can be calculated. The demand for domestic intermediate materials again incurs domestic production and imports of intermediate materials. This is why ΔU^d from the first round and ΔX from the second round are identical. As a result of an endless series of domestic production and imports, total gross output becomes $(I - A^d)^{-1}\Delta Y^d$, while the total import is $A^m(I - A^d)^{-1}\Delta Y^d$, as ΔU^m equals ΔM, which indicates a change in the import level.

Table 1: Effect of final demand on gross output and import

	$\Delta \boldsymbol{X}$	$\Delta \mathbf{U^d}$	$\Delta \mathbf{U^m}$	…
1st round	ΔY^d	$A^d\Delta Y^d$	$A^m\Delta Y^d$	
2nd round	$A^d\Delta Y^d$	$A^d A^d\Delta Y^d$	$A^m A^d\Delta Y^d$	
3rd round	$A^d A^d\Delta Y^d$	$A^d A^d A^d\Delta Y^d$	$A^m A^d A^d\Delta Y^d$	
⋮				
Sum	$(I - A^d)^{-1}\Delta Y^d$	$A^d(I - A^d)^{-1}\Delta Y^d$	$A^m(I - A^d)^{-1}\Delta Y^d$	

Here, the explanation of ICE and the alternative method are based on the concept of demand shock. In equation (1), n denotes the number of industries and ex represents the n×1 export vector. Additionally, m is the n×1 import vector, while x is the n×1 gross output vector; o′ refers to the summing of all amounts in a vector form, and o′ex means the total amount of exports.

(1)

$$\text{ICE} = \frac{o'A^m(I-A^d)^{-1}ex}{o'ex},$$

$$\text{Alternative method} = \mathbf{a}_{ex}{}^{m} - \mathbf{a}_{ex}{}^{x} = \frac{o'A^m(I-A^d)^{-1}ex}{o'm} - \frac{o'(I-A^d)^{-1}ex}{o'x}.$$

In equation (1), ICE shows the share of the total amount of imports generated by exports to total exports. In the alternative method, the left part shows the share of the total amount of imports generated by exports to total imports while the right part indicates the share of the total amount of gross outputs induced by exports to total gross outputs. It compares the foreign sector (left side, a_{ex}^{m}) and domestic production base (right side, a_{ex}^{x}) to derive the relative dependence on the global production network. A higher degree indicates a higher degree of vertical specialization.

As Kim (2021) pointed out, if the current account of a country is in equilibrium, ICE and $\mathbf{a}_{ex}^{m}$ are identical. As Korea's total export volume and total import volume have remained similar for several years, a clear comparison of ICE and alternative method is possible, and it shows that ICE only considers the foreign sector.

I attempt to apply the alternative method to Korean exports by trading partner with an explanation via an industry analysis. To decompose the alternative formula by trading partner and industry, I use the matrix 'division method'. The Korean total export amount is divided into the amount of export to each country. The export amount to one country is divided into exports by industry. Hence, the degree of vertical specialization for Korea is the sum of the degree of vertical specialization for each trade partner as expressed by in equation (2), and the degree of vertical specialization for a trade partner is the sum of the vertical specialization for each industry when exporting to the trade partner, as expressed by equation (3).

(2)

$$a_{ex}^{m} - a_{ex}^{x} = \left(\frac{o'A^{m}(I-A^{d})^{-1}}{o'm} - \frac{o'(I-A^{d})^{-1}}{o'x} \right) ex_a + \left(\frac{o'A^{m}(I-A^{d})^{-1}}{o'm} - \frac{o'(I-A^{d})^{-1}}{o'x} \right) ex_b + \left(\frac{o'A^{m}(I-A^{d})^{-1}}{o'm} - \frac{o'(I-A^{d})^{-1}}{o'x} \right) ex_c + \cdots + \left(\frac{o'A^{m}(I-A^{d})^{-1}}{o'm} - \frac{o'(I-A^{d})^{-1}}{o'x} \right) ex_z.$$

$$\left(\frac{o'A^m(I-A^d)^{-1}}{o'm}-\frac{o'(I-A^d)^{-1}}{o'x}\right)ex_a=\left(\frac{o'A^m(I-A^d)^{-1}}{o'm}-\frac{o'(I-A^d)^{-1}}{o'x}\right)ex_{a1}$$

$$+\left(\frac{o'A^m(I-A^d)^{-1}}{o'm}-\frac{o'(I-A^d)^{-1}}{o'x}\right)ex_{a2}+\left(\frac{o'A^m(I-A^d)^{-1}}{o'm}-\frac{o'(I-A^d)^{-1}}{o'x}\right)ex_{a3} \quad \textbf{(3)}$$

$$+\cdots+\left(\frac{o'A^m(I-A^d)^{-1}}{o'm}-\frac{o'(I-A^d)^{-1}}{o'x}\right)ex_{an}.$$

In equations (2) and (3), the lower-case letters beside ex indicates the country, such as the US and China, and small the numbers besides ex_a indicate the industry, such as the automobile and machine industries. In equation (2), based on matrix division, the ex vector is sum of ex_a, ex_b, ex_c, ex_d ... ex_z vector. Thus, total $a_{ex}^m - a_{ex}^x$ is sum of $\left(\frac{o'A^m(I-A^d)^{-1}}{o'm}-\frac{o'(I-A^d)^{-1}}{o'x}\right)*ex_a$,$\left(\frac{o'A^m(I-A^d)^{-1}}{o'm}-\frac{o'(I-A^d)^{-1}}{o'x}\right)*ex_b$, $\left(\frac{o'A^m(I-A^d)^{-1}}{o'm}-\frac{o'(I-A^d)^{-1}}{o'x}\right)*ex_c$ ... and $\left(\frac{o'A^m(I-A^d)^{-1}}{o'm}-\frac{o'(I-A^d)^{-1}}{o'x}\right)*ex_z$. Here ex_{a1} shows the export volume of industry 1 to country 'a'. This vector is filled with zero, except for the first row, which is filled with the actual export volume of industry 1 to country 'a'. By summing up $\left(\frac{o'A^m(I-A^d)^{-1}}{o'm}-\frac{o'(I-A^d)^{-1}}{o'x}\right)*ex_{a1}$, $\left(\frac{o'A^m(I-A^d)^{-1}}{o'm}-\frac{o'(I-A^d)^{-1}}{o'x}\right)*ex_{a2}$, $\left(\frac{o'A^m(I-A^d)^{-1}}{o'm}-\frac{o'(I-A^d)^{-1}}{o'x}\right)*ex_{a3}$ ... and $\left(\frac{o'A^m(I-A^d)^{-1}}{o'm}-\frac{o'(I-A^d)^{-1}}{o'x}\right)*ex_{an}$, vertical specialization when exporting to country 'a' can be determined. This decomposition makes it possible to analyze vertical specialization by trading partner based on an industry analysis.

4. DATA

These calculations here require a certain dataset, including the export volumes to trade partners by industry, and Leontief's inverse matrix, which is $(I-a^d)^{-1}$ and A^m (a matrix of

the ratio of imported intermediate input to total output by industry) for Korea each year. For the numerator, the scope of export was limited to goods due to difficulties in acquiring trade in services data. The export volume of goods was acquired from Structural Analysis Data of OECD (OECD, n.d.). The bilateral trade volume in goods by industry and end-use were sourced from OECD. By using trade statistics from OECD, I attempted to use the ISIC revision 4 industry classification. As the OECD classifies 45 industries, I merge trade statistics to classify 45 industries.

Regarding the denominator, the total gross output, export and import values were derived from the input-output table of OECD (OECD, n.d.). OECD's input-output table includes both trade in goods and services. As exports in goods incur the production of both goods and services, the denominator includes both services and goods in trade.

Table 2: Industry classification

Number	Name
1	Agriculture, hunting, forestry
2	Fishing and aquaculture
3	Mining and quarrying, energy producing products
4	Mining and quarrying, non-energy producing products
5	Mining support service activities
6	Food products, beverages and tobacco
7	Textiles, textile products, leather and footwear
8	Wood and products of wood and cork
9	Paper products and printing
10	Coke and refined petroleum products
11	Chemical and chemical products
12	Pharmaceuticals, medicinal chemical and botanical products
13	Rubber and plastics products
14	Other non-metallic mineral products
15	Basic metals
16	Fabricated metal products
17	Computer, electronic and optical equipment
18	Electrical equipment
19	Machinery and equipment, nec
20	Motor vehicles, trailers and semi-trailers
21	Other transport equipment
22	Manufacturing nec; repair and installation of machinery and equipment

Number	Name
23	Electricity, gas, steam and air conditioning supply
24	Water supply; sewerage, waste management and remediation activities
25	Construction
26	Wholesale and retail trade; repair of motor vehicles
27	Land transport and transport via pipelines
28	Water transport
29	Air transport
30	Warehousing and support activities for transportation
31	Postal and courier activities
32	Accommodation and food service activities
33	Publishing, audiovisual and broadcasting activities
34	Telecommunications
35	IT and other information services
36	Financial and insurance activities
37	Real estate activities
38	Professional, scientific and technical activities
39	Administrative and support services
40	Public administration and defence; compulsory social security
41	Education
42	Human health and social work activities
43	Arts, entertainment and recreation
44	Other service activities
45	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use

Source: OECD input-output table

Leontief's inverse matrix was found in the OECD data along with the input-output table. A^m was calculated by the author based on the OECD input-output table. I divided the cost of imported intermediate input by gross output for every industry. I set the partner countries and regions as the US, China, Europe, and the Middle East, accounting for approximately 55% of Korean exports in 2018 (Korea International Trade Association [KITA], n.d.). Using the regional criteria of Korea International Trade Association, countries in Europe and the Middle East were chosen. In total, 43 countries were selected from Europe, excluding San Marino and Yugoslavia, and 21 countries were chosen from the Middle East.

Processing the export volume by trading partner and by industry level weas required, and this was possible with OECD's bilateral trade in goods by industry and end-use statistics.

Adjusting trading partners with industry levels was possible in the OECD's website. In addition, I merged the data to classify 45 industries using MS Excel. I calculated and derived the result by means of statistical software for data science (STATA).

5. Results

5.1. Comparison between ICE and alternative method

It is outstanding that $\mathbf{a}_{ex}^{m}$ **,** $\mathbf{a}_{ex}^{x}$ and ICE show similar trends for all trade partners. The Appendix presents a comparison of these trends. In table 3, except for 2015, Korea shows similar values for $\mathbf{a}_{ex}^{m}$ and ICE, as Korea's total export volume and total import volume are similar. However, the direction of the degree of vertical specialization by means of ICE and the alternative method is not always the same. For example, the ICE for China is increasing despite the fact that $\mathbf{a}_{ex}^{m}$ - $\mathbf{a}_{ex}^{x}$ was decreasing between 2005 and 2010. This stresses the necessity of analyzing vertical specialization according to trade partners based on the alternative method.

Table 3: Comparison between ICE and alternative method by trading partner

(Unit: %)

YEAR	The US				CHINA			
	$\mathbf{a}_{ex}^{m}$	$\mathbf{a}_{ex}^{x}$	$\mathbf{a}_{ex}^{m}$ - $\mathbf{a}_{ex}^{x}$	ICE	$\mathbf{a}_{ex}^{m}$	$\mathbf{a}_{ex}^{x}$	$\mathbf{a}_{ex}^{m}$ - $\mathbf{a}_{ex}^{x}$	ICE
2000	5.98%	6.32%	-0.34%	5.85%	3.24%	2.97%	0.27%	3.17%
2005	4.30%	4.25%	0.05%	4.17%	6.87%	5.94%	0.93%	6.67%
2010	3.63%	3.68%	-0.05%	3.57%	8.73%	8.28%	0.45%	8.60%
2015	4.15%	4.41%	-0.26%	3.66%	8.27%	8.02%	0.25%	7.30%
2018	3.58%	3.85%	-0.27%	3.36%	8.15%	7.73%	0.42%	7.65%

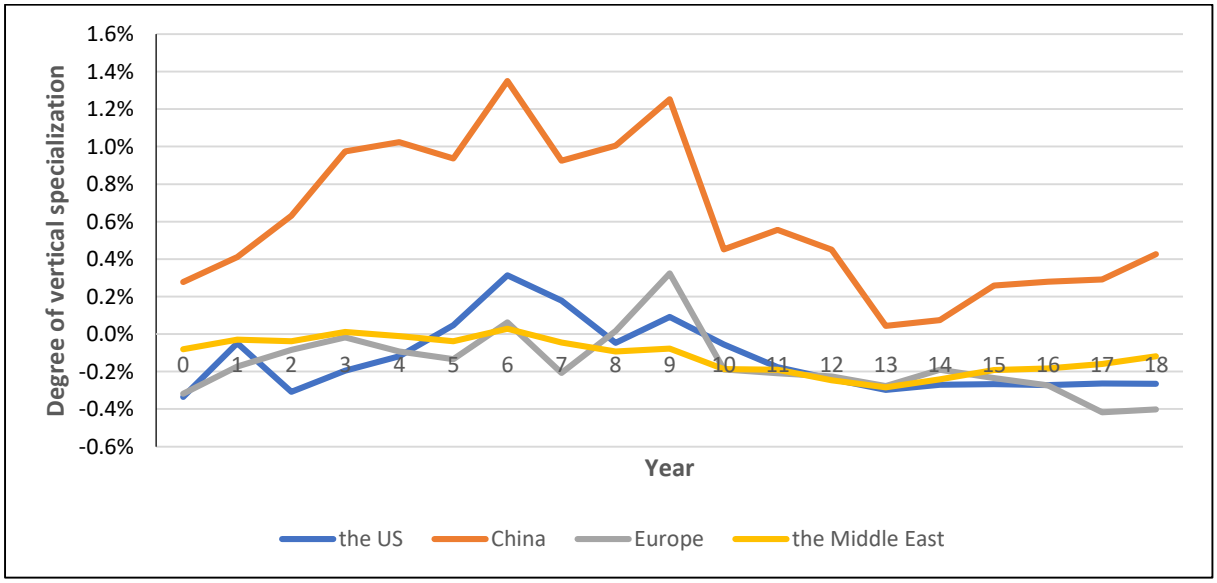
YEAR	Europe				The Middle East			
	a_{ex}^{m}	a_{ex}^{x}	a_{ex}^{m} - a_{ex}^{x}	ICE	a_{ex}^{m}	a_{ex}^{x}	a_{ex}^{m} - a_{ex}^{x}	ICE
2000	4.41%	4.73%	-0.32%	4.31%	1.18%	1.26%	-0.08%	1.16%
2005	5.36%	5.49%	-0.13%	5.20%	1.24%	1.27%	-0.03%	1.20%
2010	5.04%	5.22%	-0.18%	4.96%	2.00%	2.19%	-0.19%	1.97%
2015	3.97%	4.21%	-0.24%	3.50%	1.75%	1.95%	-0.20%	1.55%
2018	3.66%	4.06%	-0.40%	3.44%	1.07%	1.18%	-0.11%	1.00%

Table 3 shows how $\mathbf{a}_{ex}^{m}$ and $\mathbf{a}_{ex}^{x}$ by trading partner changed. In 2000, a_{ex}^{m} for the US is 5.98% and a_{ex}^{m} for China is 3.24%, indicating the amounts of total imports generated by exports to the US were 1.8 times more than that to China. In addition, a_{ex}^{x} for the US is 6.32% and a_{ex}^{m} for China is 3.24%, showing that the amount of total gross output induced by exports to the US were nearly double that to China. In 2019, both the amount of total imports generated by exports to China and amount of total gross output induced by exports to China were more than double the corresponding values to the US.

5.2. Comparison between partner countries

In figure 1, it shows how $\mathbf{a}_{ex}^{m}$ - $\mathbf{a}_{ex}^{x}$ by trading partner changed over time.

Figure 1: Degree of vertical specialization by trading partner



In figure 1, in most years, China's degree is above 0 while those of other countries are below 0. When this index equals 0, it means that the rate of total imports generated by exports divided by total gross output induced by exports equals the rate of total imports to total gross output, as $\frac{o'A^m(I-A^d)^{-1}ex}{o'm} - \frac{o'(I-A^d)^{-1}ex}{o'x} = 0$ means $\frac{o'A^m(I-A^d)^{-1}ex}{o'(I-A^d)^{-1}ex} = \frac{o'm}{o'x}$. To export to China, Korea depends relatively more on the foreign sector than on the domestic production sector, as $\frac{o'A^m(I-A^d)^{-1}ex}{o'm} - \frac{o'(I-A^d)^{-1}ex}{o'x} > 0$ means $\frac{o'A^m(I-A^d)^{-1}ex}{o'(I-A^d)^{-1}ex} > \frac{o'm}{o'x}$.

To export to the US, EU and the Middle East, except for certain years such as 2009, Korea depends more on the domestic production base rather than the foreign sector as $\frac{o'A^m(I-A^d)^{-1}ex}{o'm} - \frac{o'(I-A^d)^{-1}ex}{o'x} < 0$ means $\frac{o'A^m(I-A^d)^{-1}ex}{o'(I-A^d)^{-1}ex} < \frac{o'm}{o'x}$. The extent of this is represented by the degree of deviation from zero. This extent is strong for China, even reaching 1.3% in 2006, though it has been decreasing in recent years. For the US, Europe, and the Middle East, the value ranged from approximately 0.4% to about -0.4%. In 2018, the degree of deviation from zero for China and Europe were similar, reaching 0.43% for China and -0.4% for Europe.

5.3. Determinants of the degree of vertical specialization

1) Decomposition of the formula

Exports to one country can be divided into exports by industry, and exports by each industry can be divided into the exports of one product. This decomposition reveals that each industry's degree of vertical specialization and the export volume of industry will determine value of vertical specialization.

(4) $$\left(\frac{o'A^m(I-A^d)^{-1}}{o'm} - \frac{o'(I-A^d)^{-1}}{o'x}\right) ex_a = \left(\frac{o'A^m(I-A^d)^{-1}}{o'm} - \frac{o'(I-A^d)^{-1}}{o'x}\right) \binom{1}{0} k_{a1}$$

$$+ \left(\frac{o'A^m(I-A^d)^{-1}}{o'm} - \frac{o'(I-A^d)^{-1}}{o'x}\right)\binom{0}{1}k_{a2}.$$

In equation (4), it is assumed that only two industries, 1 and 2 are exported to country 'a', with k referring to the export volume of each industry, which is multiplied by the relevant matrix element. k_{a1} is the export volume of industry 1 to country 'a' and k_{a2} is the export volume of industry 2 to country 'a'.

2) Each industry's degree of vertical specialization

In equation (4), the part $\left(\frac{o'A^m(I-A^d)^{-1}}{o'm} - \frac{o'(I-A^d)^{-1}}{o'x}\right)\binom{1}{0}$ determines the degree of vertical specialization for industry 1, while the part $\left(\frac{o'A^m(I-A^d)^{-1}}{o'm} - \frac{o'(I-A^d)^{-1}}{o'x}\right)\binom{0}{1}$ is used to determining the degree of vertical specialization for industry 2. If the export volume of industry 1 is one for a certain year, different outcomes from $\left(\frac{o'A^m(I-A^d)^{-1}}{o'm} - \frac{o'(I-A^d)^{-1}}{o'x}\right)\binom{1}{0}$ by years reflects the change among A^m, A^d, o'm and o'x. A^m and A^d are determined by the economy's input structure of industries. I selected the four industries of computers, electronic and optical product; motor vehicles and, trailer and semi-trailers; chemicals and chemical products; and machinery and equipment. This was done because these industries account for the largest proportion of Korean exports as of 2018 (KITA, n.d.). The computer industry includes semiconductors, which accounts for about 20% of Korea's total exports as of 2018 (KITA, n.d.)

Table 4: Major industries' level of vertical specialization

(Unit: 10^{-9})

	Computers	Motor vehicles	Chemicals	Machines
2000	-176	257	95	-173
2002	-40	-427	579	-14
2004	13	-275	468	-29
2006	55	-226	322	-17
2008	24	-243	172	-65
2010	-49	-242	126	-85
2012	-47	-214	68	-94
2014	-38	-185	45	-94
2016	16	-156	68	-105
2018	-37	-154	118	-109

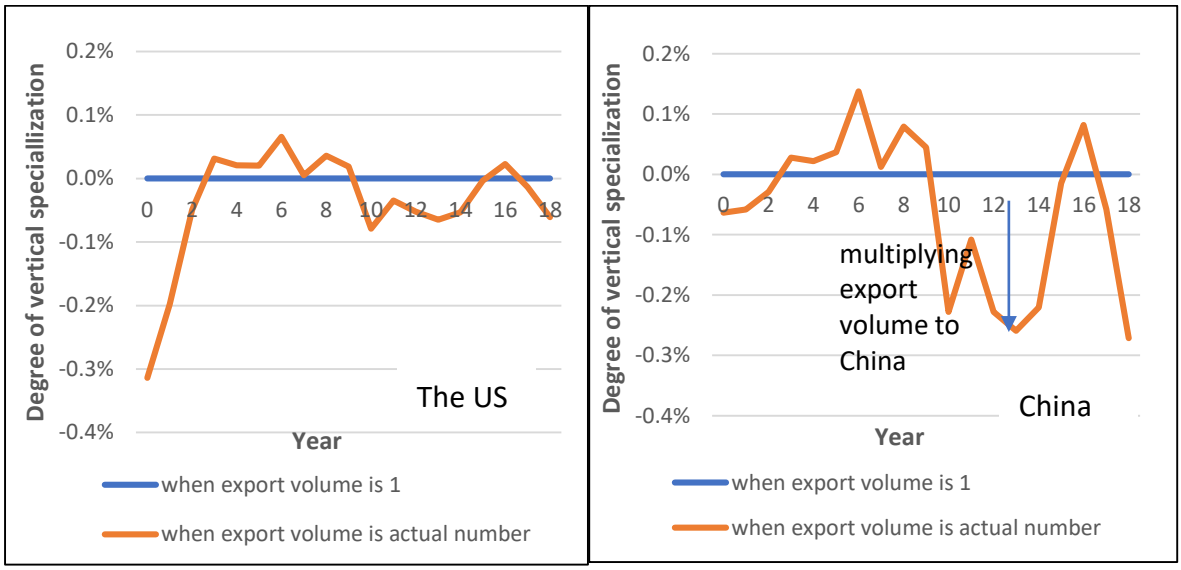
Table 4 reveals each industry's degree of vertical specialization between 2000 and 2018. This was derived by multiplying $\left(\frac{o'A^m(I-A^d)^{-1}}{o'm} - \frac{o'(I-A^d)^{-1}}{o'x}\right)$ by the vector in which the element of the industry equals 1, while the other elements equal 0. Numbers in red are negative, indicating that this industry depends more on the domestic production base rather than the foreign sector. The actual degree of vertical specialization for these industries is small such that they are multiplied to 10^9. This is necessary because denominator is a very large number, as the total amount of imports and gross output was used. This demonstrates that the relative dependence on the global production network is high for chemicals, as it reaches $118*10^{-9}$ in 2018, whereas it was low for the motor vehicle industry at $-154*10^{-9}$ in 2018. In terms of absolute values, though machines show stronger dependence on domestic production base, the extent of this is lower than motor vehicles.

3) Volume of exports by industry

In figure 2, the computer industry's degree of vertical specialization when exporting one computer is expressed by the blue horizontal line which is close to the axis as the number is miniscule. When exporting the total number of computers, the degree of vertical

specialization for computers is amplified by multiplying it by the actual export volume. This is expressed by the orange line. This orange line shows the degree of vertical specialization when exporting the total number of computer products to the US and China.

Figure 2: Degree of vertical specialization for computer industry when exporting to the US and China



In figure 2, the export volume of computer products to the US is five times that sent to China, as the value for the of US reaches -0.3% and that for China reaches -0.06% in 2000. However, from 2004 this was reversed in that the export volume of computers to China surpassed that to the US. In 2018, the export volume of computers to China was 4.4 times that to the US, as value for the US reached -0.06% while that for China reached -0.27%. Thus, the industry's level of vertical specialization and the export volume for each industry determine the degree of vertical specialization by trading partner.

The degree of vertical specialization for a country, as shown in figure 1, is the sum of the degree of vertical specialization of the total export volume for each industry to that

country. If Korea exports more products with a higher degree of vertical specialization to a specific country, the degree of vertical specialization when exporting to the country is higher.

5.4 Analysis of vertical specialization by trading partner

1) The US

Figure 3: Share of export by industry when exporting to the US

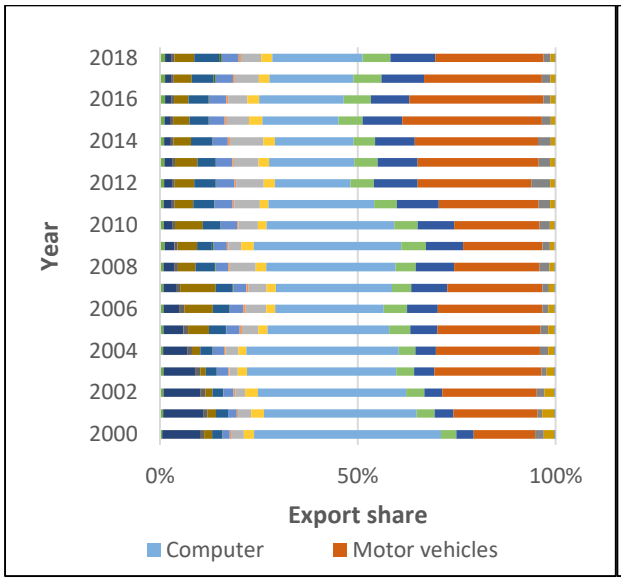


Figure 4: Degree of vertical specialization when exporting to the US

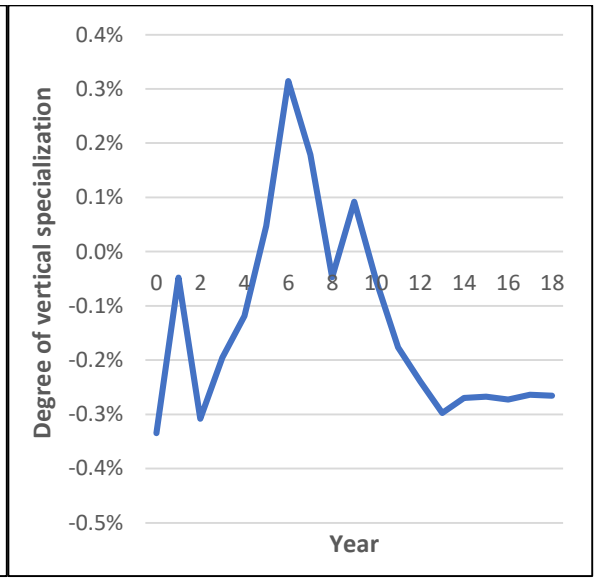


Figure 5: Degree of vertical specialization for computers when exporting to the US

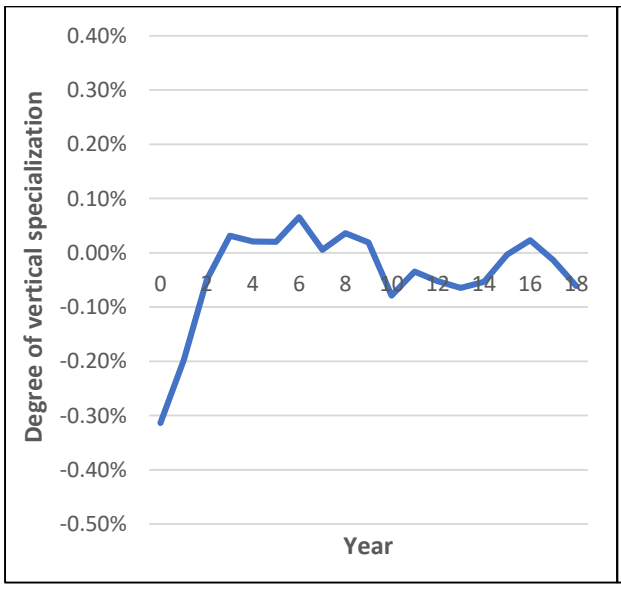
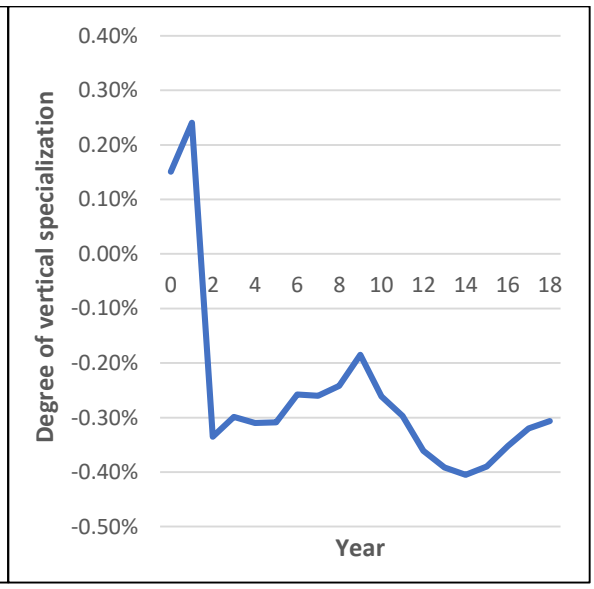


Figure 6: Degree of vertical specialization for motor vehicles when exporting to the US



In figure 3, both the computer and motor vehicle industries account for nearly 50% of total exports to the US as of 2018 (OECD, n.d.). Considering export volume's contribution to the degree of vertical specialization, analyzing the degree of vertical specialization when exporting to the US with two industries can be done. Figures 5 and 6 are derived by the multiplication of the industries' degrees of vertical specialization and their actual export volumes to the US. From 2010, as shown in figures 4 and 6, it appears that the vertical specialization graph when exporting to the US resembles that of motor vehicles. On the other hand, it also seems that the computer industry does not have much of an effect on the total vertical specialization to the US. Although Korea exports a great number of computers to the US, as shown in table 4, the absolute value of vertical specialization for computers is about four times less than that of motor vehicles in that the power of the computer industry is relatively small compared to the motor vehicle industry.

As shown in figure 6, the absolute value for motor vehicles is larger than that for computers. The motor vehicle industry is between 0.24% and - 0.4%, while for computers the value is between 0.1% and – 0.1%, except for the early 2000s. Although the export share of motor vehicles is decreasing in recent years, it appears that motor vehicles are crucial in determining the degree of vertical specialization when exporting to the US.

Both motor vehicles and computers cannot easily explain vertical specialization to the US before 2010. As shown in figures 4,5, and 6, the pattern of figure 5 is unlike those of both industries before 2010. The soaring figure between 2002 and 2006 and the sudden decrease between 2006 and 2008 are difficult to explain. Analyzing other industries' vertical specialization and export volume must be done to explain this.

2) China

Figure 7: Share of export by industry when exporting to China

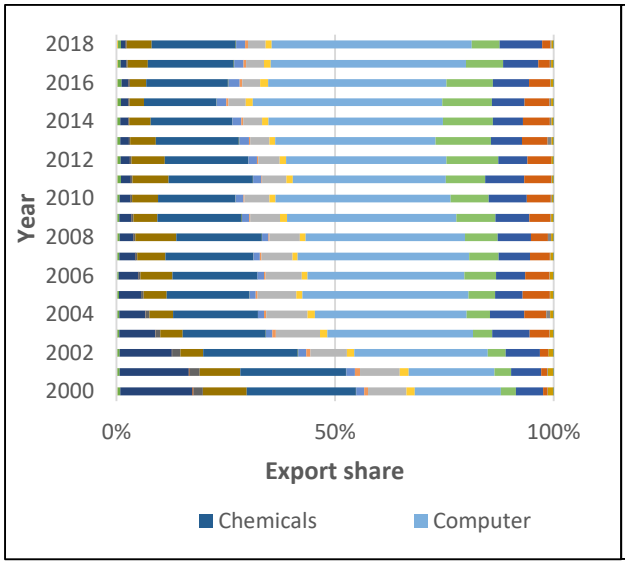


Figure 8: Degree of vertical specialization when exporting to China

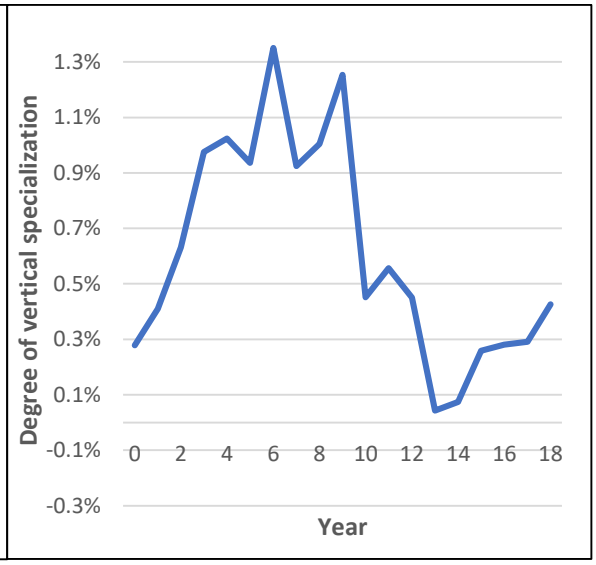


Figure 9: Degree of vertical specialization for computers when exporting to China

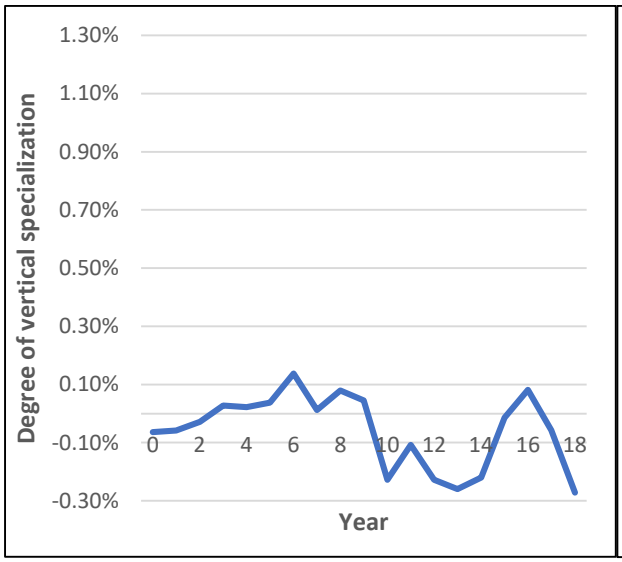
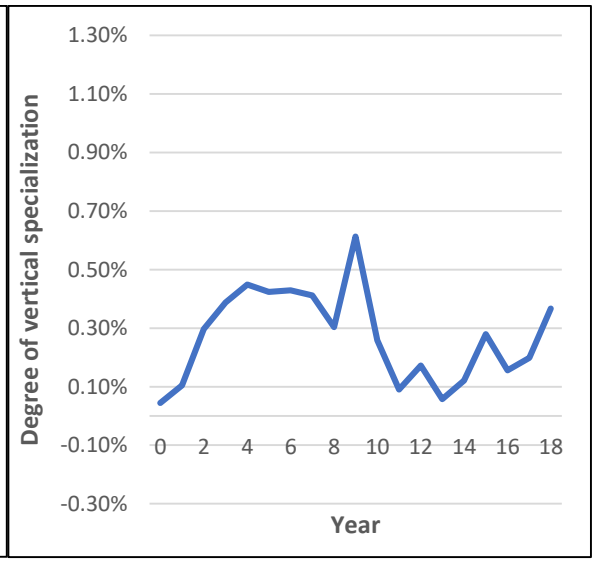


Figure 10: Degree of vertical specialization for chemicals when exporting to China



For China, as of 2018, the proportion for both the computer industry and the chemical industry exceeds 60% (OECD, n.d.). In figure 7, it is clear that the computer industry increases rapidly. Figure 9 reflects that the fluctuation of vertical specialization for computers

when exporting to China is much greater than that for the US. However, it appears that chemical industry affects more to overall vertical specialization than computer industry. This occurs due to the difference in the individual level of vertical specialization between the two industries. Table 4 shows that the absolute value of vertical specialization for chemicals is at least three times that for computers most of the time.

As a result, the degree of vertical specialization for the computer industry to China reaches 0.14% and -0.27%, while that for chemicals and chemical products ranges from 0.04% to 0.6%, though its share is much smaller than that of computers. It seems that chemical products have significant effect in determining the degree of vertical specialization when exporting to China.

As shown in figures 8,9, and 10, the degree of vertical specialization to China before 2006 is difficult to explain when considering the computer and chemical industries, as their patterns are quite different. This requires a comprehensive analysis involving other products.

3) Europe

Figure 11: Share of export by industry when exporting to Europe

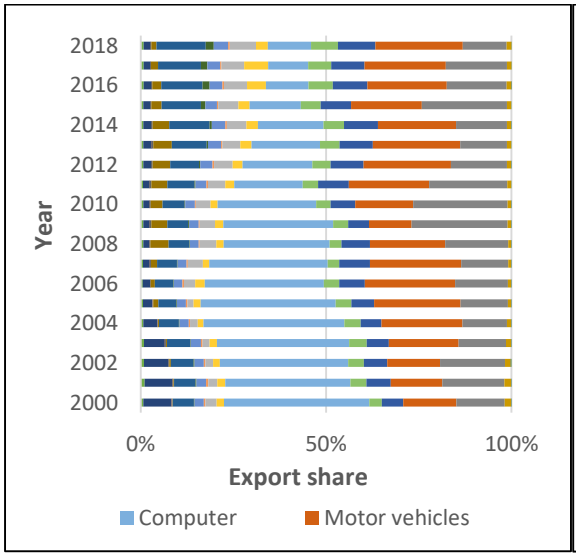


Figure 12: Degree of vertical specialization when exporting to Europe

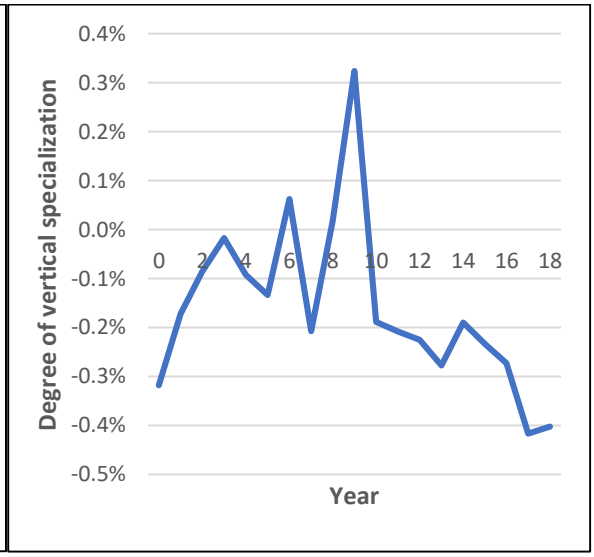


Figure 13: Degree of vertical specialization for computers when exporting to Europe

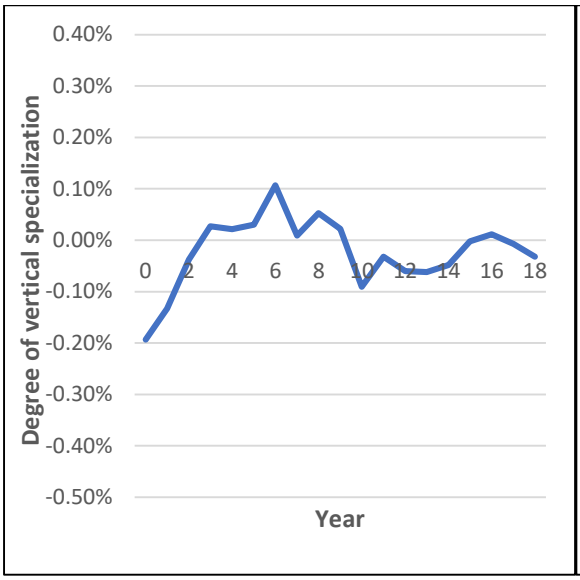
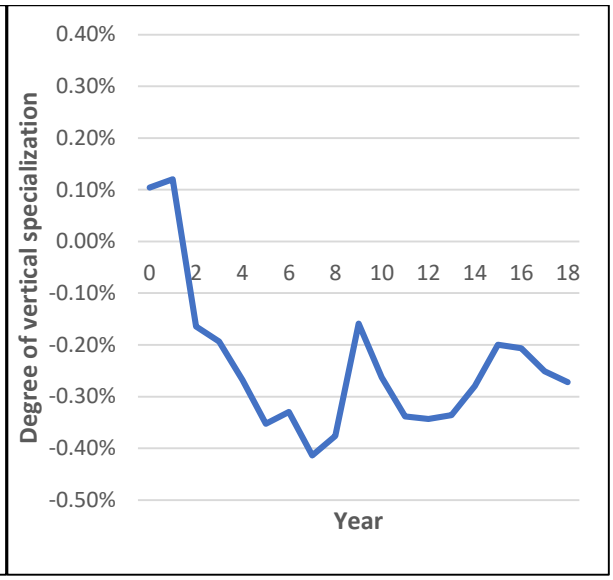


Figure 14: Degree of vertical specialization for motor vehicles when exporting to Europe



As in figure 11, computer and motor vehicles have been the two industries exporting most except for recent years. From 2010, the similar patterns in the graphs between figure 12 and figure 14 show that motor vehicles have a strong effect on the degree of vertical specialization to Europe. As shown in table 4 and figure 14, absolute value of vertical specialization for motor vehicles is high that it ranges from 0.12% to – 0.41%, as shown in figure 13.

Computer industry appears to strongly affect vertical specialization to Europe in early 2000s as it reaches -0.2% as shown in figure 13. However, combined effect of decreasing volume and low absolute value of its vertical specialization resulted in less contribution to overall vertical specialization to Europe. As shown in figure 13, the degree is between 0.11% and -0.1% except for early 2000s, while the value of motor vehicles industry is between 0.12% and – 0.41%. It is difficult to explain the period before 2008 with these two industries. There are major fluctuations and other industries affect these fluctuations.

4) The Middle East

Figure 15: Share of export by industry when exporting to the Middle East

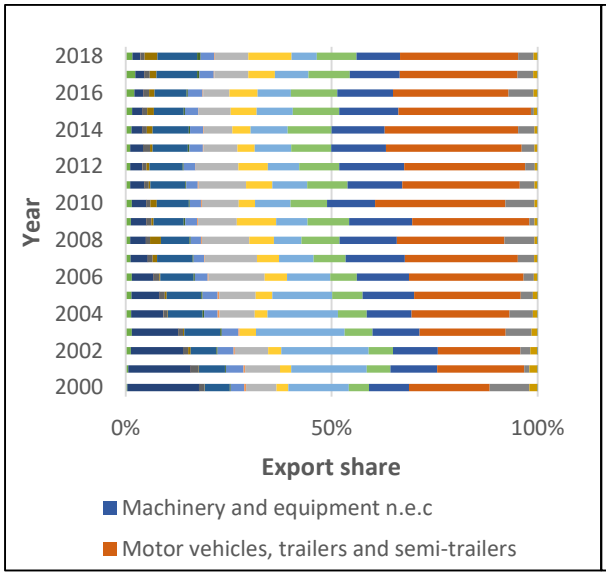


Figure 16: Degree of vertical specialization when exporting to the Middle East

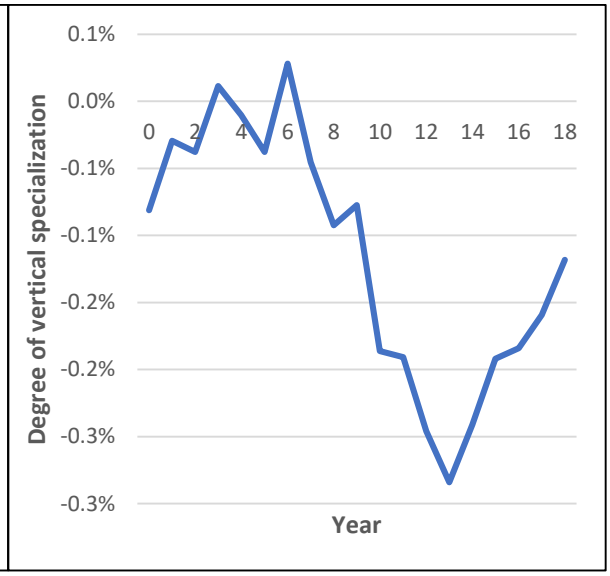


Figure 17: Degree of vertical specialization for motor vehicles when exporting to the Middle East

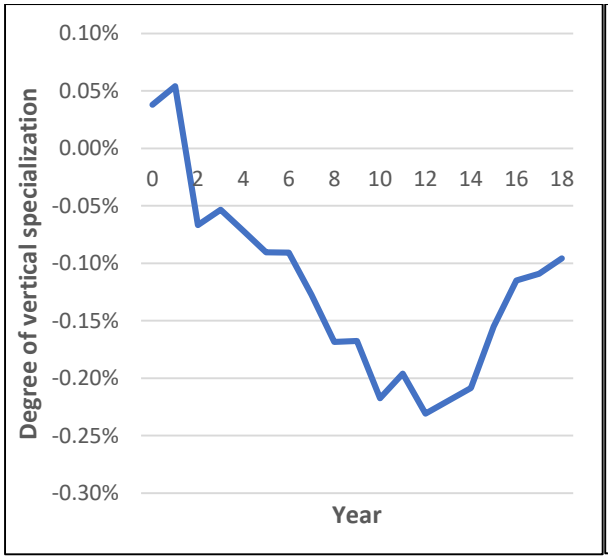
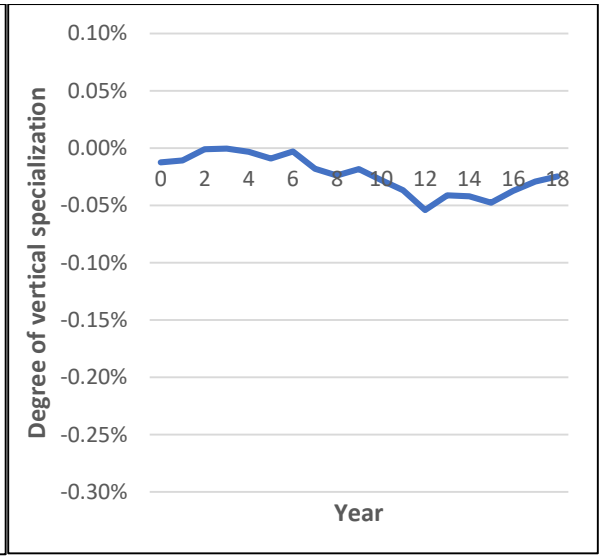


Figure 18: Degree of vertical specialization for machinery when exporting to the Middle East



In 2018, motor vehicles and machinery industries represented the two largest exporters to the Middle East (OECD, n.d.). The graph of the Middle East shows a unique pattern compared to others. It appears that this occurs due to the motor vehicle industry. As

shown in figures 16 and 17, the patterns of the two graphs are similar, especially from 2010. As table 4 indicates, the absolute value of vertical specialization for the motor vehicle industry is high, and the combined effect of the large volume of export and the high absolute value of vertical specialization are powerful. As shown in figure 17, vertical specialization for motor vehicles to the Middle East ranges from 0.05% to -0.23%.

Also, vertical specialization for machinery appears to affect vertical specialization to the Middle East, though at a smaller degree compared to motor vehicles. This occurs because their absolute value of vertical specialization is low compared to that of motor vehicles, as shown in table 4, and corresponding export volume is less than half that of motor vehicles most of the time. It appears that other industries, including textiles, also affected the degree of vertical specialization when exporting to the Middle East before 2010.

6. Conclusion

In the current globalized era, relocation of production stages, as is represented by vertical specialization and outsourcing, is prevalent. To explain vertical specialization, indicators were developed, and that one of the most renowned is ICE. Since ICE was developed by Hummels et al. (2001), it has been used by many scholars and organizations, including the OECD. Alternatively, Kim (2021) devised a more accurate and comprehensive way to measure the degree by decomposing imports and gross output. It is differentiated from ICE that it includes the domestic production base in addition to the foreign sector.

Based on his findings, this thesis attempts to analyze Korea’s degree of integration into the global production network when exporting to each trading partner. Kim (2021) explained the degree using the country and the product level. This thesis is focuses on the trade partner level, which is explained by the product level. This thesis aims to derive a more

accurate degree of dependence on the global production network when exporting to specific countries via an industry analysis.

This thesis measured the degree of vertical specialization according to four trading partners and four major industries. It also explained the degree of vertical specialization by trading partner based on four industries. This thesis concludes that both industries' levels of vertical specialization and the export volume of the industries affect the degree of vertical specialization when exporting to partner countries. The findings show that products such as motor vehicles depend more on the domestic production base to a great extent and that products such as chemicals depend more on the global production network to a great extent.

If a country attempts to increase its degree of vertical specialization when exporting to a specific country, it is recommended to increase the export volume of products with higher vertical specialization levels or to increase the degree of vertical specialization in industries which exports considerable amounts of products. Identifying each industry's level of vertical specialization and the export volume and discerning a combined effect would be the key to raising or lowering the degree of vertical specialization to a specific country.

This thesis has a limitation in that as shown in the country analysis, during some periods, vertical specialization when exporting to countries was not explained by major industries although their export volumes were high. This requires a comprehensive analysis of other industries, as levels of vertical specialization contribute strongly to the overall degree. The contribution rate of each industry's level of vertical specialization and the export volume to changes in the vertical specialization to a specific country would be a viable subject for further study.

In addition, as Koopman et al. (2010) pointed out, this research has a limitation in that it regards domestic items and export items as identical products despite the fact that the corresponding rate of intermediate input can differ. As a result, the degree of integration into

the global production network could be overestimated or underestimated, as A^m represents the average rate of intermediate input to gross output. In addition, as noted in work by Kim (2004), an input-output analysis itself has some limitations in that it assumes a demand-driven model that does not consider dynamic adjustments. Despite these shortcomings, it is worthwhile to complement the traditional method with a more balanced approach, and the present work attempts to broaden the applicability of the alternative method.

References

Amador, J., & Cabral, S. (2008). Vertical specialization in Portuguese international trade. *Economic Bulletin*, 91-107. https://core.ac.uk/download/pdf/6567404.pdf

ARAUJO, S. (2009). *Vertical specialization and global value chains*. United Nations. https://c11.kr/16nfe

Bridgman, B. (2012). The rise of vertical specialization trade. *Journal of International Economics*, *86*(1), 133–140. https://doi.org/10.1016/j.jinteco.2011.08.016

Chen, H. Y., & Chang, Y. M. (2006). Trade verticality and structural change in industries: Th e cases of Taiwan and South Korea. *Open Economies Review*, *17*(3), 321–340. https://doi.org/10.1007/s11079-006-9052-y

Constantinescu, C., Mattoo, A., & Ruta, M. (2019). Does vertical specialisation increase productivity? *The World Economy*, *42*(8), 2385–2402. https://doi.org/10.1111/twec.12801

Dean, J., Fung, K. C., & Wang, Z. (2007). *Measuring the Vertical Specialization in Chinese Trade*. United States International Trade Commission. https://www.usitc.gov/publications/332/ec200701a.pdf

Domingues, T., Amaral, J. F. D., & Lopes, J. C. (2021, January). *Global value chains, value-added generation and structural change in EU core and periphery economies: An Input- Output approach*. Lisbon school of Economics and Management. https://rem.rc.iseg.ulisboa.pt/wps/pdf/REM_WP_0157_2021.pdf

Escaith, H., & Gonguet, F. (2011). International Trade and Real Transmission Channels of Financial Shocks in Global Production Networks: An Asian–USA Perspective. In Satishi, I., *Asia Beyond the Global Economic Crisis: The Transmission Mechanism of Financial Shocks (pp. 73-105).* Edward Elgar Publishing.

Feenstra, R. C. (1998). Integration of trade and disintegration of production in the global economy. *Journal of economic Perspectives*, *12*(4), 31-50. https://pubs.aeaweb.org/doi/10.1257/jep.12.4.31

Gündoğdu, C. (2015). *Domestic content of exports and the vertical specialization: an analysis for Turkish export, 1995-2011* [Master's thesis, Middle East Technical University]. OpenMETU. http://etd.lib.metu.edu.tr/upload/12619392/index.pdf

Hummels, D. L., Ishii, J., & Yi, K. M. (2001). The nature and growth of vertical specialization in world trade. *Journal of International Economics*, *54*(1), 75–96. https://doi.org/10.1016/S0022-1996(00)00093-3

Hummels, D. L., Rapoport, D., & Yi, K. M. (1998). Vertical specialization and the changing nature of world trade. *Economic Policy Review*, *4*(2), 79–99. https://core.ac.uk/download/pdf/6792678.pdf

Kim, D. S. (2004). 산업연관표를 이용한 수출의 부가가치 유발효과 분석 [Impact of Exports on GDP: Analysis using Input-Output Tables]. *KDI Economy Outlook*, 21(2), 112~121.

Kim, D. S. (2020). Measuring the degree of integration into the global production network by the decomposition of gross output and imports: A cross-country study, 1995-2015 1. *Journal of Economic Research (JER)*, 25(3), 223-248. https://c11.kr/16nfy

Kim, D. S. (2021). *Input-Output Analysis; Chapter 6 impact analysis* [Class handout]. KDI School of Public Policy and Management

Kim, D. S. (2021). Measuring the Degree of Integration into the Global Production Network by the Decomposition of Gross Output and Imports: Korea 1970-2018. *KDI Journal of Economic Policy*, *43*(3), 33–53. https://doi.org/10.23895/kdijep.2021.43.3.33

Kim, D. S. (2021). Measuring the Impact of a Trade Dispute with a Supply-side Shock Using a Supply-driven Input-Output Analysis: Korea-Japan Dispute Case. *KDI Journal of Economic Policy*, *43*(1), 29–52. https://doi.org/10.23895/kdijep.2021.43.1.29

Kim, S. E., & Choi, Y. J. (2013). Vertical Specialization and Industrial GDP Growth in Korea. *Journal of International Trade & Commerce*, *9*(2), 221–247. https://doi.org/10.16980/jitc.9.2.201305.221

Koopman, R., Powers, W., Wang, Z., & Wei, S. J. (2010). *Give credit where credit is due: Tracing value added in global production chains.* National Bureau of Economic Research. https://www.nber.org/papers/w16426

Korea International Trade Association. (n.d.). *Trade statistics*. Retrieved October 1, 2022 from https://stat.kita.net

Krugman, P., Cooper, R. N., & Srinivasan, T. N. (1995). Growing World Trade: Causes and Consequences. *Brookings Papers on Economic Activity*, *1995*(1), 327-377. https://doi.org/10.2307/2534577

Lee, S. W., & Kim, S. J. (2022). How Large is the Impact of Exports on Economic Growth? Korea from the 1960s through the 2010s. *Journal of Economic Research (JER)*, 27(1), 69-84. https://c11.kr/16nfk

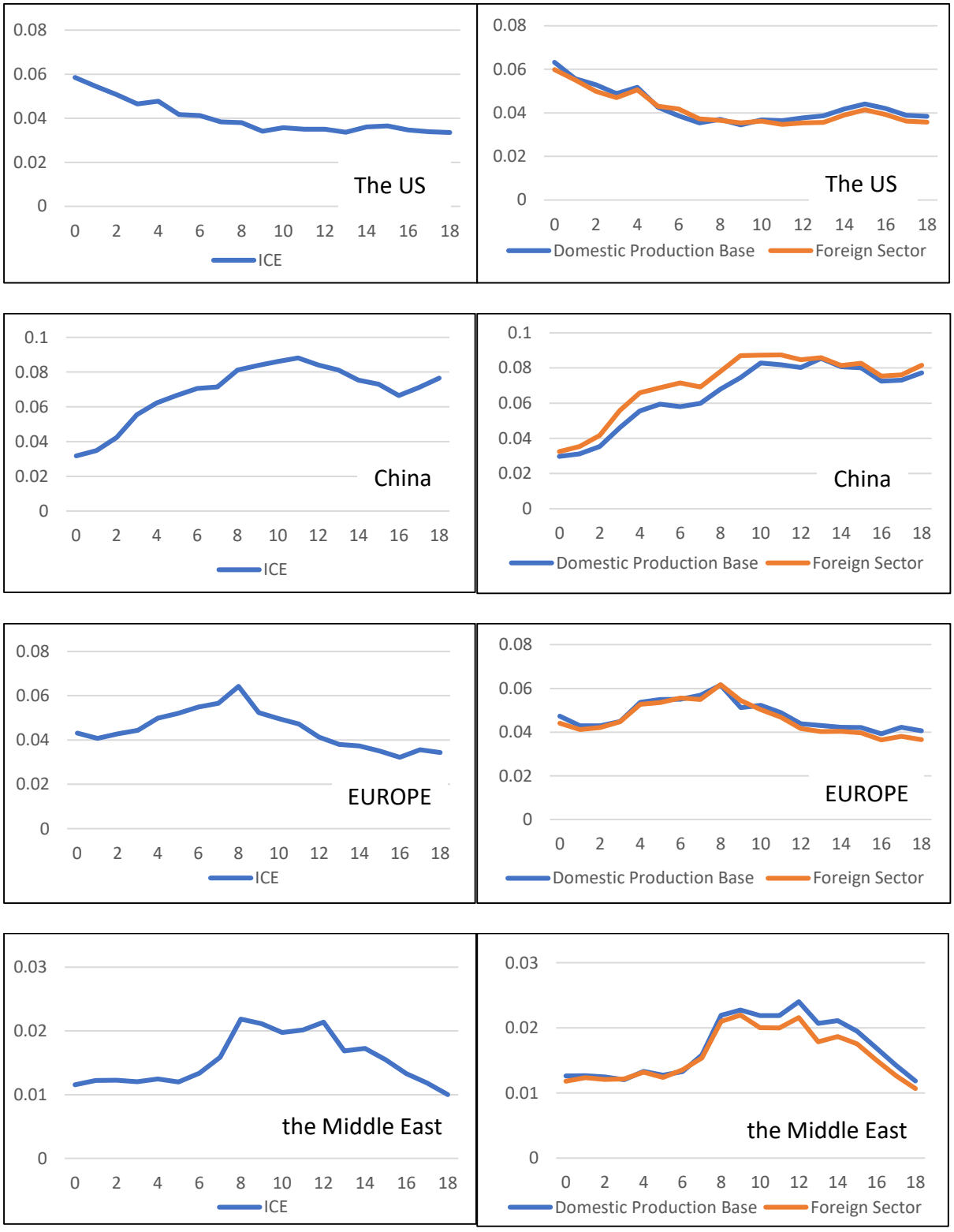
Nordas, K. H. (2003). *Determinants of vertical specialization*. International input-output association. http://www.iioa.org/conferences/intermediate-2004/pdf/543.pdf

OECD. (n.d.). *Bilateral Trade in Goods by Industry and End-use (BTDIxE)*. Retrieved October 1, 2022 from https://stats.oecd.org/Index.aspx?DataSetCode=BTDIXE_I4

OECD. (n.d.). *Input-Output Tables (IOTs) 2021 ed*. Retrieved October 1, 2022 from https://stats.oecd.org/Index.aspx?DataSetCode=IOTS_2021

Appendix

Figure A1: Comparison between ICE and alternative method by trading partner



Note: horizontal axis represents year and vertical axis represents values in table 3