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**Article**

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# New Indicators of Global Integration Using Input-Output Analysis<sup>†</sup>

By DONGSEOK KIM\*

*The import content of export (ICE) has served as an indicator of global integration for several decades. It is defined as the share of imported products embodied in exports and can be interpreted as the relative degree of the utilization of global production network (GPN) over the domestic supply chain (DSC) in terms of 'value-added.' This paper proposes two new indicators of global integration. They are defined as the ratios of imports (foreign products) to gross output (domestic products) generated by exports and can be interpreted as the relative degrees of the utilization of GPN over DSC in terms of 'production.' Both indicators are easy to compute and can be compared between years, between countries, between industries, and between groups of industries. The paper applies the new indicators to the recent edition of the OECD's Input-Output Database. Finally, the paper shows that the recent slowdown in international trade is mostly due to the decrease in the international trade of intermediate goods, with significant implications regarding the future of global integration.*

Key Word: New Indicators of Global Integration,  
Import Content of Export, Input-Output Analysis,  
OECD's Input-Output Database (OECD IO-DB)  
JEL Code: F15, F14, D57

## I. Introduction and Motivation

The rapid growth of international trade would be the most noteworthy change in the global economy over the past century. Trade, whether domestic or international, enhances the welfare of the economic agents involved in it, and

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international trade has contributed to the world's economic development immensely, especially since World War II.

International trade, simply defined as the exchange of goods and services among countries, eventually leads to the economic and social integration of the countries that engage in it. Global integration is a complicated phenomenon, and many indicators have been developed to measure the degree of global integration.

One of the most elementary yet frequently used indicators would be the magnitude of international trade – specifically, exports or the sum of exports and imports – or its ratio relative to the size, e.g., as a percentage of GDP, of economic activity. Maddison (2001) estimated that world exports as a percentage of the world GDP amounted to only 5.5% in 1950. However, this rate subsequently skyrocketed, reaching 12.8% in 1970, 20.4% in 1980 and 31.0% in 2008,<sup>1</sup> as shown in Figure 1.

More rigorous and scientific investigations of global integration require the use of intermediate input data. Industries' input structures, expressed in terms of input coefficients, reflect the production functions. Specifically, domestic and imported input coefficients vividly describe the degrees and patterns with which industries make use of domestic supply chains (DSC) and the global production network (GPN). This is why input-output (IO) analyses are extensively used in studies of international trade and especially global integration in recent decades, as intermediate inputs are studied extensively and rigorously in studies of international trade and global integration.

Figure 2 depicts the share of imported intermediate inputs out of total imports into Korea since the beginning of the country's rapid economic growth in the 1970s.

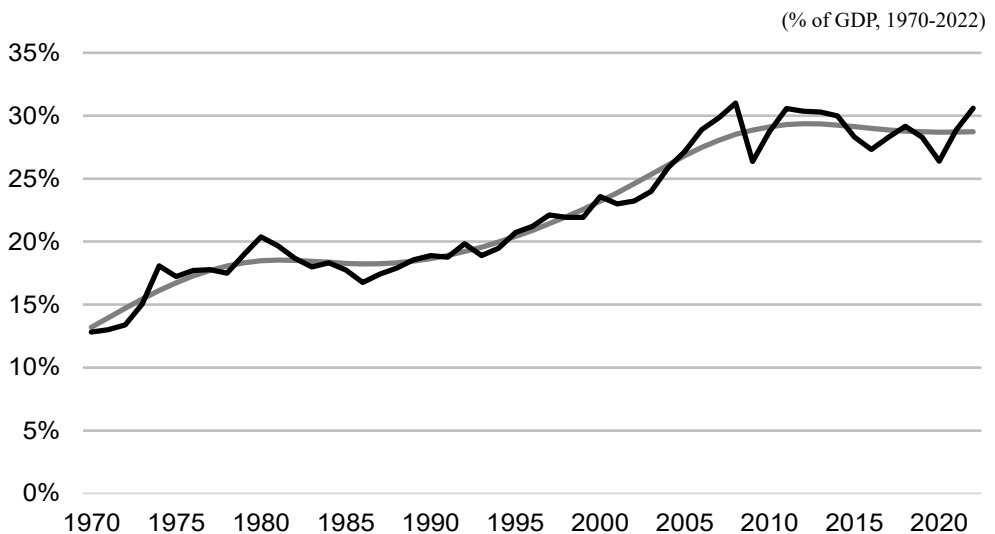


FIGURE 1. WORLD EXPORTS

Note: The smooth curve represents the values after Hodrick-Prescott filtering.

Source: World Bank.

<sup>1</sup>World Bank, "World Development Indicator."

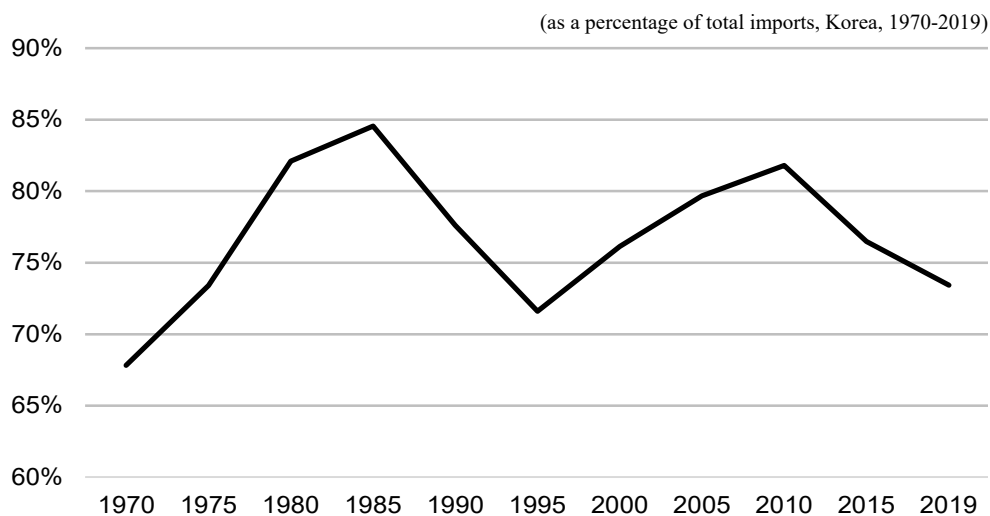


FIGURE 2. IMPORTED INTERMEDIATE INPUTS

Source: Bank of Korea, "Input-output tables of Korea."

Korea began its export-driven economic growth in the 1970s, but the economy was not equipped with sufficient capacity to produce intermediate inputs. Hence, the country had to depend heavily on imported intermediate inputs, which can be confirmed from the first increase in this share during the period of 1970-1985. This was followed by a decline during the period of 1985-1995, reflecting the country's efforts to alleviate the dependence on imported intermediate inputs through intensive R&D to enhance the competitiveness of domestic parts and components.

The second rise of this share (1995-2010) in Figure 2 is explained by Korea's active engagement in global integration in various forms, such as off-shoring, international out-sourcing, and other such means. The Korean government's trade policy toward general trade liberalization also contributed to the increase in imported intermediate inputs. While the second decline of the share since 2010 can be partially attributed to reshoring and onshoring, the enhanced comparative advantage of domestic parts and components, and the slowdown of international trade, among other factors, additional investigations and research are needed in this area.

The import content of export (ICE) metric has frequently been used as an indicator of global integration over the past several decades. ICE, defined as the increase in imports when exports increase by one unit, can be interpreted as the share of imported goods and services embodied in exported products. It can be said that the larger the ICE, the more the industry or the economy depends on the foreign sector, explaining why it has served as an indicator of global integration.

Unlike ICE, this paper proposes alternative indicators based on the relative degree of the utilization of GPN compared to the degree of the utilization of DSC. Understanding the motivation behind the use of these alternative indicators and how they differ from ICE requires knowledge about the special characteristics of imports in the circulation of a national economy. The basic equation for the determination of a country's national income in an open economy is  $V = C + I + (E - M)$ , where the

terms  $V$ ,  $C$ ,  $I$ ,  $E$  and  $M$  denote GDP or value-added (VA), consumption, investment, exports and imports, respectively.<sup>2</sup> The equation is alternatively referred to as the ‘definition of expenditure GDP.’

The above equation can be rewritten as  $V + M = C + I + E$ . When exports change by  $\Delta E$  while consumption and investment are fixed, therefore, we have  $\Delta V + \Delta M = \Delta E$ , where  $\Delta V$  and  $\Delta M$  denote the changes in VA and imports generated by  $\Delta E$ , respectively. In other words, an increase in exports increases VA and imports, and the sum of the increases equals the increase in exports. It should be noted that the increase in imports is the increase in exports for the exporting countries, i.e., of the trade partners, and hence, will lead to an increase in foreign VA of the same amount. Thus, an increase in exports will increase domestic and foreign VA, and the sum of these two equals the increase in exports.

If we divide both sides of  $\Delta V + \Delta M = \Delta E$  by  $\Delta E$ , the result is  $\Delta V/\Delta E + \Delta M/\Delta E = 1$ . The second term on the left-hand side is defined as ICE, while the first term could be called the ‘(domestic) value-added content of export (VCE).’ Note that ICE implies a competing relationship between domestic VA and foreign VA – even if it is not mentioned explicitly, while also defining the impact of a one-unit increase in exports on foreign VA as an indicator of global integration. In other words, ICE measures the degree of global integration according to the relative degree of the utilization of GPN compared to the degree of the utilization of DSC in terms of VA.

As mentioned previously, imports have a special characteristic in the circulation of a national economy. While imports are equivalent to VA in the foreign sector, imports are a significant component of the total supply in the domestic market. In other words, imports have dual competing relationships in the national economy: foreign VA (imports) vs. domestic VA (GDP), and foreign production (imports) vs. domestic production (gross output).

It is possible that in certain contexts, researchers or policymakers may become more interested in the extent to which an economy or an industry utilizes GPN and DSC in terms of production compared to those in VA. For example, production-based measures may be more informative than VA-based measures for those interested in the impacts on the market shares of imported and domestic products. This paper proposes two new indicators of global integration based on the relative degree of the utilization of GPN compared to the degree of the utilization of DSC in terms of ‘production.’ Specifically, the paper defines the increases in imports and gross output generated by exports as the degrees of the utilization of GPN and DSC, respectively, and proposes the ratios of these two as indicators of global integration. The first indicator uses the ‘amounts’ of imports and gross output generated by exports, while the second uses the ‘shares’ of these amounts in total exports and gross output, respectively.

The indicators proposed in this paper have an advantage in that their interpretation is straightforward because they are constructed as the ratios of the degrees of the utilization of GPN and DSC. When the values of the indicators of two countries are

<sup>2</sup>Government consumption and investment are classified as consumption ( $C$ ) and investment ( $I$ ), respectively.

0.2 and 0.1, for example, we can say that the relative utilization degree of GPN of the first country is twice that of the second country.

The indicators suggested in this paper enjoy the advantages of ICE. These indicators are derived from an elementary IO analysis, and the computing burden is negligible. Also, the indicators can be compared between countries, between years, between industries, and between groups of industries. The paper will apply the new indicators to the recently released 2021 edition of the OECD's Input-Output Database (OECD IO-DB). The 2021 edition, the latest of the OECD's IO-DB, contains the IO tables of 66 countries for 24 years (1995-2018).

The paper is organized as follows. Section II reviews the literature briefly, and the new indicators of global integration are explained in Section III. Section IV explains the data and the empirical results, and Section V concludes the paper.

## II. Literature

Integration of the world economy through international trade has been one of the most remarkable changes in the world economy, and enormous efforts have been made to devise indicators to measure various aspects of the global integration of countries and industries. The body of literature in this field is enormous, and this section is limited to studies of ICE and related topics.

It is interesting to observe that imports and the VA contents of exports have attracted attention in a seemingly remote context. Loschky and Ritter (2006) realized that the exports of Germany recorded unparalleled rapid growth in the 2000s but that it was accompanied by more rapid growth of imported intermediate inputs, discounting the contribution of exports to GDP. They computed, by means of an IO analysis, the amount of imported intermediate inputs caused by exports; they also computed its share in exports, referring to it as ICE, and reported that Germany's ICE soared from 31% in 1995 to 42% in 2005.

Kim (2004) examined the widening gap between the growth rates of foreign demand (exports) and domestic demand (consumption and investment) in Korea. Korea's exports achieved remarkable growth in the early 2000s, but domestic demand showed an extremely sluggish trend. In 2003, for example, the growth rate of exports was 15.7% whereas consumption and investment recorded extremely low growth rates of -0.5% and 3.6%, respectively. The widening gap continued in early 2004, which resulted in a large current account surplus (GDP less domestic demand).

Previously, a gap between foreign and domestic demand was not usual in Korea. Generally, an increase in exports generates more income, resulting in an increase in domestic demand with a lag of several quarters. The widening gap, therefore, implies that the exports  $\rightarrow$  VA  $\rightarrow$  domestic demand channel has weakened. Kim (2004) called the share of VA generated by exports out of total exports the VA multiplier (VAM), referred to as 'VCE' here. According to Kim (2004), Korea's VAM increased from 0.629 in 1980 to 0.711 in 1993, at which point it began to decline, reaching 0.630 in 2000. He also showed that (i) the VAM of exports was lower than that of domestic demand, and (ii) while the VAMs of both exports and domestic demand have declined since 1993, the former declined far more rapidly.

While global integration can be defined in many ways, basically it refers to an increase in international trade accompanied by an increase in the share of imported intermediate inputs in exports. Global integration can take various forms and has been given various names depending on the specific context, such as the international fragmentation of production, global outsourcing, the integration of GPN, and offshoring, among others.

Hummels *et al.* (2001) paid attention to the strengthening ‘vertical linkages’ caused by the increase in ‘the use of imported (intermediate) inputs in producing goods that are exported,’ referring to this phenomenon as ‘vertical specialization.’ They used the IO tables of ten OECD member and nonmember countries from the OECD’s IO-DB, showing that vertical specialization explains 21% of the exports of these countries and that this rate increased by 30% over the period of 1970-90.

Breda *et al.* (2009) interpreted ICE ‘as a measure of internationalization,’ and they computed the ICEs at aggregate and industry levels in the 1990s using the IO tables of seven European countries. They found an increasing trend in most industries in most countries despite the fact that there were heterogeneous patterns of internationalization in some industries and in some countries to some extent.

Backer and Yamano (2008) defined ‘globalization’ as ‘the emergence of the global value chain’ and used ICE as an indicator of globalization. Considering that the classification of products into final and intermediate products is not possible using traditional trade statistics, they emphasized the use of IO tables to investigate new trend in international trade. They computed the ICEs of 38 countries during the period of 1970-2000 using the 1995, 2002 and 2006 editions of the OECD IO-DB, confirming the trend of global integration empirically.

Due to the increase in the use and the importance of ICE in examining international trade and global integration, the OECD has published ICE data in more recent editions of their IO-DBs.

Kim (2020) and Kim (2021) emphasized the need to consider the amounts of gross output, as well as imports, generated by exports simultaneously when measuring the degree of global integration. They computed (i) the share of imports generated by exports out of total imports and (ii) the share of gross output generated by exports out of total gross output, interpreting the two shares as the degree to which an economy or industry utilizes the GPN and DSC, respectively. Kim (2020) computed the two shares at the aggregate and industry levels for 64 countries during the period of 1995-2015 using the 2015 and 2018 editions of the OECD’s IO-DB. Kim (2021) computed the two shares for Korea for the period of 1970-2018. Kim (2020) and Kim (2021) examined the patterns of global integration empirically.

Although Kim (2020) and Kim (2021) considered the amounts of both gross output and imports generated by exports, they did not construct an indicator of global integration *per se*. They only used the two shares and built a scatter diagram to investigate the trend of global integration. However, the indicators of global integration suggested in this paper represent a direct development of the ideas in Kim (2020) and Kim (2021).

### III. New Indicators of Global Integration

The layout of the IO tables in the OECD IO-DB is depicted in Figure 3.<sup>3,4</sup> The rows and the columns of IO tables describe the market structures of products and the input structures of industries, respectively. Let  $n$  be the number of products/industries, and let  $i = 1, 2, \dots, n$  and  $j = 1, 2, \dots, n$  be the indices for products (rows) and industries (columns), respectively.

In Figure 3,  $\mathbf{Z} = [z_{ij}]$  is an  $n \times n$  matrix of the inter-industry trade of intermediate inputs. Specifically,  $z_{ij}$  is the amount of product  $i$  used as intermediate input in industry  $j$ .  $\mathbf{Z}^d = [z_{ij}^d]$  and  $\mathbf{Z}^m = [z_{ij}^m]$  are  $n \times n$  matrices of domestic and imported intermediate inputs, respectively, and  $\mathbf{Z} = \mathbf{Z}^d + \mathbf{Z}^m$ .

Intermediate inputs  $z_{ij}$  have dual meanings. In the market structure context,  $z_{ij}$  is the intermediate demand for product  $i$  by industry  $j$ , while in the input

TOTAL TABLE

|               |              |              |              |              |               |  |
|---------------|--------------|--------------|--------------|--------------|---------------|--|
| $\mathbf{Z}$  | $\mathbf{u}$ | $\mathbf{c}$ | $\mathbf{i}$ | $\mathbf{e}$ | $\mathbf{-m}$ |  |
| $\mathbf{w}$  |              |              |              |              |               |  |
| $\mathbf{v}$  |              |              |              |              |               |  |
| $\mathbf{x}'$ |              |              |              |              |               |  |

DOMESTIC AND IMPORTED TABLE

|                |                |                |                |              |              |              |
|----------------|----------------|----------------|----------------|--------------|--------------|--------------|
| $\mathbf{Z}^d$ | $\mathbf{u}^d$ | $\mathbf{c}^d$ | $\mathbf{i}^d$ | $\mathbf{e}$ | $\mathbf{0}$ | $\mathbf{x}$ |
| $\mathbf{w}^d$ |                |                |                |              |              |              |
| $\mathbf{Z}^m$ | $\mathbf{u}^m$ | $\mathbf{c}^m$ | $\mathbf{i}^m$ | $\mathbf{0}$ | $\mathbf{m}$ | $\mathbf{0}$ |
| $\mathbf{w}^m$ |                |                |                |              |              |              |
| $\mathbf{v}$   |                |                |                |              |              |              |
| $\mathbf{x}'$  |                |                |                |              |              |              |

FIGURE 3. LAYOUT OF INPUT-OUTPUT TABLES IN THE OECD IO-DB

<sup>3</sup>The layout in Figure 3 is a simplified version of the layout of the actual IO tables in the OECD IO-DB; (i) the consumption and investment columns are divided into multiple sub-categories in the OECD IO-DB, and (ii) net taxes and total consumption are omitted in Figure 3.

<sup>4</sup>We will follow the notations by Miller and Blair (2009) in this paper.



structure context,  $z_{ij}$  is the intermediate input of product  $i$  in industry  $j$ . Let  $\mathbf{o}$  be an  $n \times 1$  vector of 1s. Then,  $\mathbf{u} = \mathbf{Z}\mathbf{o}$  is the horizontal sum of  $\mathbf{Z}$  and is an  $n \times 1$  intermediate demand vector, and  $\mathbf{w} = \mathbf{o}'\mathbf{Z}$  is a  $1 \times n$  intermediate input vector. We can similarly define the domestic and imported intermediate demand and input vectors  $\mathbf{u}^d = \mathbf{Z}^d\mathbf{o}$ ,  $\mathbf{u}^m = \mathbf{Z}^m\mathbf{o}$ ,  $\mathbf{w}^d = \mathbf{o}'\mathbf{Z}^d$  and  $\mathbf{w}^m = \mathbf{o}'\mathbf{Z}^m$ . Subsequently, we have  $\mathbf{u} = \mathbf{u}^d + \mathbf{u}^m$  and  $\mathbf{w} = \mathbf{w}^d + \mathbf{w}^m$ .<sup>5</sup>

In Figure 3,  $\mathbf{c}$  and  $\mathbf{i}$  are the  $n \times 1$  vectors of consumption and investment, respectively, and are decomposed into corresponding domestic and imported components, i.e.,  $\mathbf{c} = \mathbf{c}^d + \mathbf{c}^m$  and  $\mathbf{i} = \mathbf{i}^d + \mathbf{i}^m$ . The  $n \times 1$  export vector contains domestic components only. Consumption, investment and exports constitute the final demand of the economy. We define the total, domestic and imported final demands as  $\mathbf{f} = \mathbf{c} + \mathbf{i} + \mathbf{e}$ ,  $\mathbf{f}^d = \mathbf{c}^d + \mathbf{i}^d + \mathbf{e}$  and  $\mathbf{f}^m = \mathbf{c}^m + \mathbf{i}^m$ , respectively.

The total supply of the economy consists of the total supply of domestic products ( $\mathbf{x}$ ) and the total supply of imported products ( $\mathbf{m}$ ), and the total demand consists of the total intermediate demand ( $\mathbf{u}$ ) and the total final demand ( $\mathbf{f}$ ). These are all  $n \times 1$  vectors. The market equilibrium of the total market is described by  $\mathbf{x} + \mathbf{m} = \mathbf{u} + \mathbf{f}$ , and those of the markets for imported and domestic products are described respectively by

$$\begin{aligned}\mathbf{x} &= \mathbf{u}^d + \mathbf{f}^d, \\ \mathbf{m} &= \mathbf{u}^m + \mathbf{f}^m.\end{aligned}$$

We now investigate the input structure. In Figure 3,  $\mathbf{v}$  and  $\mathbf{x}'$  are  $1 \times n$  vectors of VA and the total input, respectively.<sup>6</sup> Total input consists of the total intermediate input and VA; that is,

$$\mathbf{x}' = \mathbf{w} + \mathbf{v} = \mathbf{w}^d + \mathbf{w}^m + \mathbf{v}.$$

Input coefficients facilitate advanced and useful analyses. The  $n \times n$  domestic and imported input coefficient matrices are defined as  $\mathbf{A}^d = [a_{ij}^d] = [z_{ij}^d / x_j]$  and  $\mathbf{A}^m = [a_{ij}^m] = [z_{ij}^m / x_j]$ , respectively. Note that  $a_{ij}^d$  and  $a_{ij}^m$  are the shares of domestic and imported  $i$ th intermediate inputs in the total input of the  $j$ th industry, respectively.

According to the construction of  $\mathbf{A}^d$  and  $\mathbf{A}^m$ , we can show that  $\mathbf{u}^d = \mathbf{A}^d\mathbf{x}$  and  $\mathbf{u}^m = \mathbf{A}^m\mathbf{x}$ . The market equilibrium of domestic products can then be rewritten as  $\mathbf{x} = \mathbf{u}^d + \mathbf{f}^d = \mathbf{A}^d\mathbf{x} + \mathbf{f}^d$ , where the second equality follows from  $\mathbf{u}^d = \mathbf{A}^d\mathbf{x}$ . Solving this for  $\mathbf{x}$  results in  $\mathbf{x} = (\mathbf{I} - \mathbf{A}^d)^{-1}\mathbf{f}^d = \mathbf{R}^x\mathbf{f}^d$ , where  $\mathbf{R}^x = (\mathbf{I} - \mathbf{A}^d)^{-1}$ . The equation  $\mathbf{x} = \mathbf{R}^x\mathbf{f}^d$  describes the determination of gross output as a function of the domestic final demand. The  $(i, j)$ th element of  $\mathbf{R}^x = [r_{ij}^x]$  is the increase in the gross output of the  $i$ th product when the final demand for the  $j$ th domestic

<sup>5</sup>While the intermediate demand and input vectors are explicitly included in the IO tables of some countries, they are not included in the IO tables of the OECD IO-DB. These vectors are indicated in Figure 3 to clarify the layout.

<sup>6</sup>Total input and the transpose of gross output are identical in the IO tables.

product increases by one unit; i.e.,  $r_{ij}^x = \Delta x_i / \Delta f_j^d$ .

The market equilibrium of the imported products can be expressed as

$$\mathbf{m} = \mathbf{u}^m + \mathbf{f}^m = \mathbf{A}^m \mathbf{x} + \mathbf{f}^m = \mathbf{A}^m (\mathbf{I} - \mathbf{A}^d)^{-1} \mathbf{f}^d + \mathbf{f}^m = \mathbf{R}^m \mathbf{f}^d + \mathbf{f}^m$$

with  $\mathbf{R}^m = \mathbf{A}^m (\mathbf{I} - \mathbf{A}^d)^{-1}$ ,

where the third equality follows from  $\mathbf{x} = (\mathbf{I} - \mathbf{A}^d)^{-1} \mathbf{f}^d$ . This equation describes the determination of imports as a function of the domestic and imported final demand levels. The  $(i, j)$  th element of  $\mathbf{R}^m = [r_{ij}^m]$  is the increase in the import of the  $i$  th product when the final demand for the  $j$  th domestic product increases by one unit; i.e.,  $r_{ij}^m = \Delta m_i / \Delta f_j^d$ .

Let  $\mathbf{A}^v = \text{diag}[a_i^v] = \text{diag}[v_i / x_i]$  be the  $n \times n$  VA coefficient diagonal matrix. This leads to  $\mathbf{v} = \mathbf{A}^v \mathbf{x} = \mathbf{A}^v (\mathbf{I} - \mathbf{A}^d)^{-1} \mathbf{f}^d = \mathbf{R}^v \mathbf{f}^d$  with  $\mathbf{R}^v = \mathbf{A}^v (\mathbf{I} - \mathbf{A}^d)^{-1}$ , where the second equality follows from  $\mathbf{x} = (\mathbf{I} - \mathbf{A}^d)^{-1} \mathbf{f}^d$ . The  $(i, j)$  th element of  $\mathbf{R}^v = [r_{ij}^v]$  is the increase in the VA in the  $i$  th industry when the final demand for the  $j$  th domestic product increases by one unit; i.e.,  $r_{ij}^v = \Delta v_i / \Delta f_j^d$ .

We rewrite the decomposition of  $\mathbf{x}$  and  $\mathbf{m}$  as follows, where the second equalities follow from  $\mathbf{f}^d = \mathbf{c}^d + \mathbf{i}^d + \mathbf{e}$  and  $\mathbf{f}^m = \mathbf{c}^m + \mathbf{i}^m$ , respectively.

$$\begin{aligned} \mathbf{x} &= \mathbf{R}^x \mathbf{f}^d &= \mathbf{R}^x \mathbf{c}^d + \mathbf{R}^x \mathbf{i}^d + \mathbf{R}^x \mathbf{e}, \\ \mathbf{m} &= \mathbf{R}^m \mathbf{f}^d + \mathbf{f}^m &= \mathbf{R}^m \mathbf{c}^d + \mathbf{R}^m \mathbf{i}^d + \mathbf{R}^m \mathbf{e} + \mathbf{c}^m + \mathbf{i}^m. \end{aligned}$$

These two equations decompose gross output and imports into the contributions of the individual final demand terms. We premultiply  $\mathbf{o}'$  to both sides to obtain

$$(1) \quad \begin{aligned} \mathbf{o}' \mathbf{x} &= \mathbf{o}' \mathbf{R}^x \mathbf{c}^d + \mathbf{o}' \mathbf{R}^x \mathbf{i}^d + \mathbf{o}' \mathbf{R}^x \mathbf{e}, \\ \mathbf{o}' \mathbf{m} &= \mathbf{o}' \mathbf{R}^m \mathbf{c}^d + \mathbf{o}' \mathbf{R}^m \mathbf{i}^d + \mathbf{o}' \mathbf{R}^m \mathbf{e} + \mathbf{o}' \mathbf{c}^m + \mathbf{o}' \mathbf{i}^m. \end{aligned}$$

The third terms on the right-hand sides are the amounts of gross output and imports generated by exports, respectively, and can be interpreted as the magnitudes of the country's utilization of GPN and DSC to facilitate exports, respectively. Hence, the ratio of the two amounts can be interpreted as the relative degree of the utilization of or dependence on GPN compared to DSC;

$$\text{MXR}^a = \frac{\mathbf{o}' \mathbf{R}^m \mathbf{e}}{\mathbf{o}' \mathbf{R}^x \mathbf{e}}.$$

$\text{MXR}^a$  can also be computed for individual industries as follows. Assume that the country in question exported only the  $i$  th product. Then, the numerator of  $\text{MXR}^a$  becomes  $[\mathbf{o}' \mathbf{R}^m]_i \cdot e_i$ , where  $[\mathbf{a}]_i$  denotes the  $i$  th element of vector  $\mathbf{a}$  and  $e_i$  is the export of the  $i$  th product. Similarly, the denominator of  $\text{MXR}^a$

becomes  $[\mathbf{o}'\mathbf{R}^x]_i \cdot e_i$ . The ratio of these two amounts can be rewritten as<sup>7</sup>

$$\text{MXR}_i^a = \frac{[\mathbf{o}'\mathbf{R}^m]_i \cdot e_i}{[\mathbf{o}'\mathbf{R}^x]_i \cdot e_i} = \frac{[\mathbf{o}'\mathbf{R}^m]_i}{[\mathbf{o}'\mathbf{R}^x]_i}$$

and is interpreted as the relative degree of the utilization of the GPN compared to the DSC of the  $i$  th industry.  $\text{MXR}^a$  is the first indicator of global integration proposed in this paper.

We divide both sides of (1) by  $\mathbf{o}'\mathbf{x}$  and  $\mathbf{o}'\mathbf{m}$ , respectively, which results in

$$1 = \frac{\mathbf{o}'\mathbf{R}^x \mathbf{c}^d}{\mathbf{o}'\mathbf{x}} + \frac{\mathbf{o}'\mathbf{R}^{x,d}}{\mathbf{o}'\mathbf{x}} + \frac{\mathbf{o}'\mathbf{R}^x \mathbf{e}}{\mathbf{o}'\mathbf{x}},$$

$$1 = \frac{\mathbf{o}'\mathbf{R}^m \mathbf{c}^d}{\mathbf{o}'\mathbf{m}} + \frac{\mathbf{o}'\mathbf{R}^{m,d}}{\mathbf{o}'\mathbf{m}} + \frac{\mathbf{o}'\mathbf{R}^m \mathbf{e}}{\mathbf{o}'\mathbf{m}} + \frac{\mathbf{o}'\mathbf{c}^m}{\mathbf{o}'\mathbf{m}} + \frac{\mathbf{o}'\mathbf{i}^m}{\mathbf{o}'\mathbf{m}}.$$

The third terms on the right-hand sides are the shares of gross output and imports generated by exports in the total gross output and imports, respectively, and can be interpreted as the degree to which the country depends on GPN and DSC expressed in shares, respectively. Hence, the ratio of the two shares

$$\text{MXR}^s = \frac{\mathbf{o}'\mathbf{R}^m \mathbf{e} / \mathbf{o}'\mathbf{m}}{\mathbf{o}'\mathbf{R}^x \mathbf{e} / \mathbf{o}'\mathbf{x}}$$

can also be interpreted as the relative degree of the utilization of or dependence on GPN compared to DSC. This ratio can also be computed for individual industries, as follows:

$$\text{MXR}_i^s = \frac{[\mathbf{R}^m \mathbf{e}]_i / m_i}{[\mathbf{R}^x \mathbf{e}]_i / x_i}.$$

$\text{MXR}^s$  is the second indicator of global integration proposed in this paper. Both indicators,  $\text{MXR}^a$  and  $\text{MXR}^s$ , are defined as the relative utilization of or dependence on GPN compared to DSC; the former uses ‘amounts’ and the latter uses ‘shares.’<sup>8</sup>

$\text{MXR}^s$  is the ratio of the shares of imports (foreign production) and gross output (domestic production) generated by exports out of total imports and gross output,

<sup>7</sup>In the actual computation, one can use element-by-element (EBE) division, which is supported by most computing software for matrix algebra. Let  $\mathbf{a} = [a_i]$  and  $\mathbf{b} = [b_i]$  be either  $n \times 1$  or  $1 \times n$  vectors. Then, the EBE division of  $\mathbf{a}$  by  $\mathbf{b}$  is defined as  $\mathbf{a} \odot \mathbf{b} = [a_i / b_i]$ , where  $\odot$  is the EBE division operator. For example, ‘./’ is the EBE division operator in the GAUSS software package. The vector of  $\text{MXR}_i^s$  for individual products can easily be obtained by  $\mathbf{o}'\mathbf{R}^m \cdot / \mathbf{o}'\mathbf{R}^x$ .

<sup>8</sup> $\text{MXR}$  is an abbreviation of the ‘imports (  $\mathbf{m}$  ) – gross output (  $\mathbf{x}$  ) ratio,’ while the superscripts ‘a’ and ‘s’ signify ‘amounts’ and ‘shares,’ respectively.

respectively. In other words,  $\text{MXR}^s$  explicitly uses ‘aggregate’ exports and gross output data, and we can say, therefore, that the ‘macroeconomic’ aspects of exports are taken into consideration in the  $\text{MXR}^s$  metric. On the other hand,  $\text{MXR}^a$  is the ratio of imports and gross output generated by exports, and macroeconomic or comprehensive perspectives are not taken into consideration. In consequence, it is conjectured that  $\text{MXR}^s$  can be more useful when the emphasis is placed on macroeconomic aspects, while  $\text{MXR}^a$  can be more useful when the comparison at the product level is afforded more attention. Active empirical studies using these indicators are anticipated in the future.

Both indicators can be compared between years, between countries, and between industries. They can also be computed for a group of industries; for instance, we can compute these indicators for the manufacturing sector, i.e., a group of industries in the manufacturing sector, and compare them between years or between countries.<sup>9</sup>

ICE is defined as the increase in imports when exports increase by one unit and is computed as the share of imports generated by exports out of total imports. ICE can also be computed for individual industries.

$$\text{ICE} = \frac{\mathbf{o}'\mathbf{R}^m\mathbf{e}}{\mathbf{o}'\mathbf{e}},$$

$$\text{ICE}_i = [\mathbf{o}'\mathbf{R}^m]_i.$$

We now investigate the relationships among the indicators discussed thus far. We define the production multiplier of exports (PME) as the increase in gross output when exports increase by one unit; that is,  $\text{PME} = \mathbf{o}'\mathbf{R}^x\mathbf{e} / \mathbf{o}'\mathbf{e}$ .  $\text{MXR}^a$  and  $\text{MXR}^s$  can then be expressed as

$$\text{MXR}^a = \frac{\mathbf{o}'\mathbf{R}^m\mathbf{e}}{\mathbf{o}'\mathbf{R}^x\mathbf{e}} = \frac{\mathbf{o}'\mathbf{R}^m\mathbf{e} / \mathbf{o}'\mathbf{e}}{\mathbf{o}'\mathbf{R}^x\mathbf{e} / \mathbf{o}'\mathbf{e}} = \frac{\text{ICE}}{\text{PME}},$$

$$\text{MXR}^s = \frac{\mathbf{o}'\mathbf{R}^m\mathbf{e} / \mathbf{o}'\mathbf{m}}{\mathbf{o}'\mathbf{R}^x\mathbf{e} / \mathbf{o}'\mathbf{x}} = \frac{\mathbf{o}'\mathbf{R}^m\mathbf{e}}{\mathbf{o}'\mathbf{R}^x\mathbf{e}} \frac{\mathbf{o}'\mathbf{x}}{\mathbf{o}'\mathbf{m}} = \text{MXR}^a \frac{\mathbf{o}'\mathbf{x}}{\mathbf{o}'\mathbf{m}} = \frac{\text{ICE}}{\text{PME}} \frac{\mathbf{o}'\mathbf{x}}{\mathbf{o}'\mathbf{m}}.$$

In summary,  $\text{MXR}^a$  is the ratio of the increase in imports to the increase in gross output when exports increase by one unit, and  $\text{MXR}^s$  is the same ratio adjusted by the ratio of gross output to imports.

Secondly, VCE is defined as the increase in VA when exports increase by one unit and is computed as the share of domestic VA out of total exports. VCE can also be computed for individual industries.

<sup>9</sup>Let  $g$  be the group of industries, and let  $\mathbf{e}^g$ ,  $\mathbf{x}^g$  and  $\mathbf{m}^g$  be the exports, gross output and imports vectors, respectively, constructed in such a way that the amounts of the industries that do not belong to  $g$  are all zero. Then,  $\text{MXR}^a$  and  $\text{MXR}^s$  computed using  $\mathbf{e}^g$ ,  $\mathbf{x}^g$  and  $\mathbf{m}^g$  are indicators of the global integration of the group of industries  $g$ . In fact,  $\text{MXR}^a$  and  $\text{MXR}^s$  of the entire economy represent a special case.

$$\text{VCE} = \frac{\mathbf{o}'\mathbf{R}^v\mathbf{e}}{\mathbf{o}'\mathbf{e}},$$

$$\text{VCE}_i = [\mathbf{o}'\mathbf{R}^v]_i.$$

It can be easily proved that  $\text{ICE} + \text{VCE} = 1$  and  $\text{ICE}_i + \text{VCE}_i = 1$  for all  $i = 1, 2, \dots, n$ . (The proof is in the Appendix.) It can be said, therefore, that ICE and VCE have same amount of information, and VCE can also be used to measure the degree of global integration. The only difference is that the larger the VCE is, the *smaller* the degree of global integration also is.

Both  $\text{MXR}^a$  and  $\text{MXR}^s$  are proportionate to the relative degree of the utilization of GPN over DSC because they are defined as the ratios of foreign production (imports) and domestic production (gross output) generated by exports. It can be said, therefore, that the interpretation of these indicators is straightforward. If the values of  $\text{MXR}^a$  of two countries are 0.2 and 0.1, for example, we can say that the degree of global integration of the first country is twice that of the second country.

This does not hold for ICE because it is not defined as the ratio of ICE to VCE. The relative degree of the utilization of GPN over DSC in terms of VA is  $\frac{\text{ICE}}{\text{VCE}} = \frac{\text{ICE}}{1-\text{ICE}}$  because  $\text{ICE} + \text{VCE} = 1$ . Therefore, if the values of ICE of two countries are 0.2 and 0.1, for example, then the relative degrees of utilization of GPN over DSC in terms of VA are  $\frac{0.2}{0.8}$  and  $\frac{0.1}{0.9}$ , and we can say that the first country's degree of global integration is  $\frac{0.2}{0.8} / \frac{0.1}{0.9} = \frac{9}{4} = 2.25$  times that of the second country.

## IV. Data and Empirical Results<sup>10</sup>

### A. Data

The 2021 edition of the OECD's IO-DB was used in the empirical analysis in this paper. This edition was released in 2021 and 2022 and is the latest edition of the OECD IO-DB. It contains the IO tables of 66 OECD member and non-member countries for 24 years (1995-2018). These countries account for over 90% of the world's GDP and international trade and over 70% of the world's population as of 2018.

All IO tables in the OECD IO-DB are harmonized; they are arranged in accordance with common industry classification and common currency unit. There are two IO tables for a country: the 'TTL' (total) table and the 'DOMIMP' (domestic and imported) table, as depicted in Figure 3. The industry classification of the OECD IO-DB is based on the International Standard Industrial Classification (ISIC), Revision 4, and categorizes the entire economy into 45 industries. The currency unit of the OECD IO-DB is million US dollars.

<sup>10</sup>Tables and figures in this section were constructed based on the author's computations using IO tables from the 2021 edition of the OECD IO-DB.

It was determined that the classification system with 45 industries is excessively finely classified considering the goals of this paper, and the tables were rearranged according to a 25-industry classification. A concordance table between the industry classification systems of the OECD IO-DB and this paper is given here as Table 1.

Although most terms and indicators were computed for all 66 countries in the empirical study, the results for the top eight countries in terms of total exports in 2018 are reported in this paper. These countries are China, the United States, Germany, Japan, France, Korea, United Kingdom, and Italy.<sup>11</sup> The United States was the top exporting country until 2011 but was surpassed by China in 2012. Total exports of the eight countries are depicted in Figure 4. These eight countries accounted for 50.0% of the total exports of the 66 countries in 2018. It is readily observed from Figures 1 and 4 that the financial crisis of 2018 caused enormous damage to international trade.

TABLE 1—CONCORDANCE TABLE AMONG THE THREE INDUSTRY CLASSIFICATIONS

| 25-Sector Classification |  | OECD IO-DB | ISIC                |
|--------------------------|--|------------|---------------------|
| Sector                   | Name                                   | Sector     | Revision 4          |
| 1                        | Agricultural, forest and fishery goods | 1~2        | 01~03               |
| 2                        | Mined and quarried goods               | 3~5        | 05~09               |
| 3                        | Food, beverage and tobacco products    | 6          | 10~12               |
| 4                        | Textile and leather products           | 7          | 13~15               |
| 5                        | Wood and paper products                | 8~9        | 16~18               |
| 6                        | Coal and petroleum products            | 10         | 19                  |
| 7                        | Chemical products                      | 11~13      | 20~22               |
| 8                        | Non-metallic mineral products          | 14         | 23                  |
| 9                        | Basic metal products                   | 15         | 24                  |
| 10                       | Fabricated metal products              | 16         | 25                  |
| 11                       | Electric and electronic equipment      | 17~18      | 26~27               |
| 12                       | Machinery and equipment                | 19         | 28                  |
| 13                       | Motor vehicles and trailers            | 20         | 29                  |
| 14                       | Other transport equipment              | 21         | 30                  |
| 15                       | Other manufactured products            | 22         | 31~33               |
| 16                       | Electricity, gas and water supply      | 23~24      | 35~39               |
| 17                       | Construction                           | 25         | 41~43               |
| 18                       | Wholesale and retail                   | 26         | 45~47               |
| 19                       | Transportation and warehousing         | 27~30      | 49~52               |
| 20                       | Communication services                 | 31, 33~34  | 53, 58~61           |
| 21                       | Accommodation and food services        | 32         | 55~56               |
| 22                       | Business services                      | 35~39      | 62~82 <sup>1)</sup> |
| 23                       | Public administration and defense      | 40         | 84                  |
| 24                       | Education, healthcare and social work  | 41~42      | 85~88               |
| 25                       | Other services                         | 43~45      | 90~98               |

Note: 1) Less 67 and 76.

<sup>11</sup>We use the following country codes in the tables and figures in this paper: CHN (China), USA (United States), DEU (Germany), JPN (Japan), FRA (France), KOR (Korea), GBR (United Kingdom), and ITA (Italy). These are identical to the codes in the OECD IO-DB.

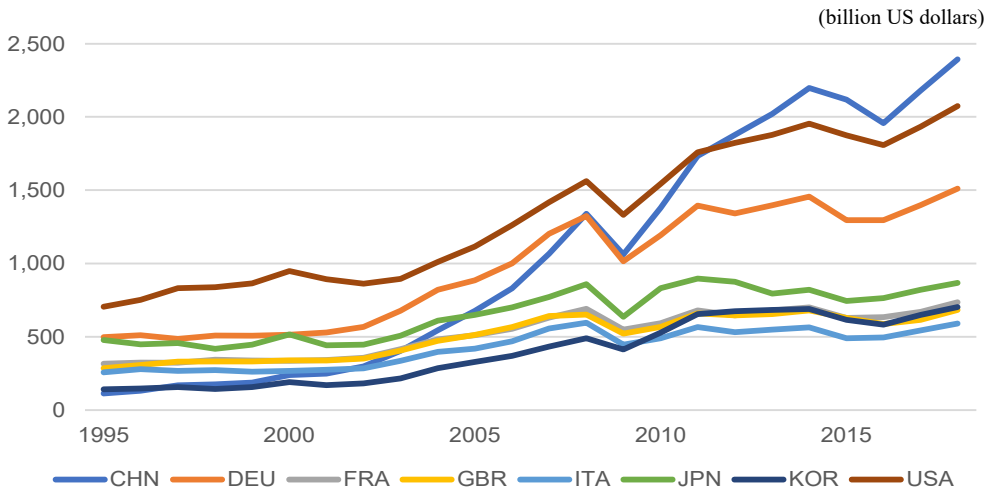


FIGURE 4. TOTAL EXPORTS OF EIGHT SELECTED COUNTRIES

*B. Indicators of Global Integration at the Country Level*

The ICEs of the eight countries during the period of 1995-2018 are given in Figure 5. The ICE of Korea was highest during the entire period, and those of Japan and United States were lowest. France, Germany and Italy showed a highly similar pattern during the period, possibly reflecting their similar patterns of exports and imports of both final and intermediate products, while those of China and United Kingdom were similar to each other.

We observe from Figure 5 that the ICEs of the eight countries in general increased until the late 2000s, after which they began to decrease. Although some countries did not show a clear declining trend, the slopes are diminishing in such cases. To clarify the patterns, Hodrick-Prescott filtering was applied; these results are given in Figure 6, where these conjectures are confirmed. Figure 7 presents the average ICE

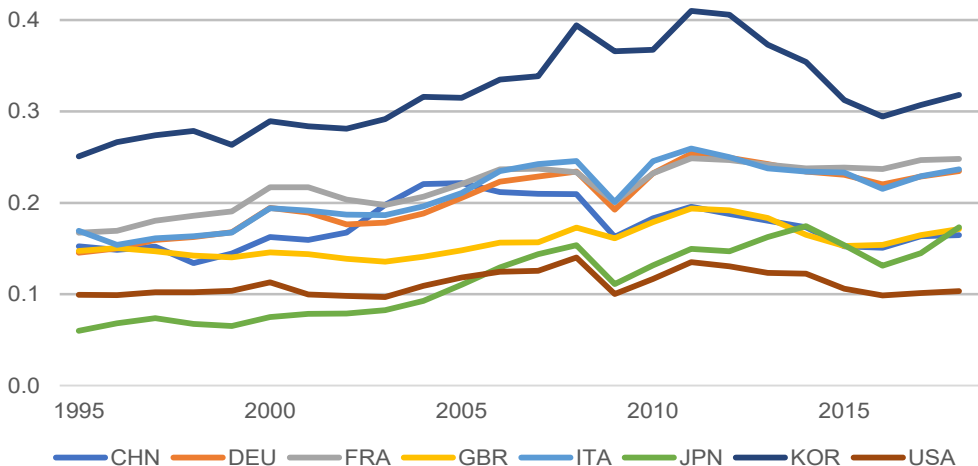


FIGURE 5. ICES OF EIGHT SELECTED COUNTRIES

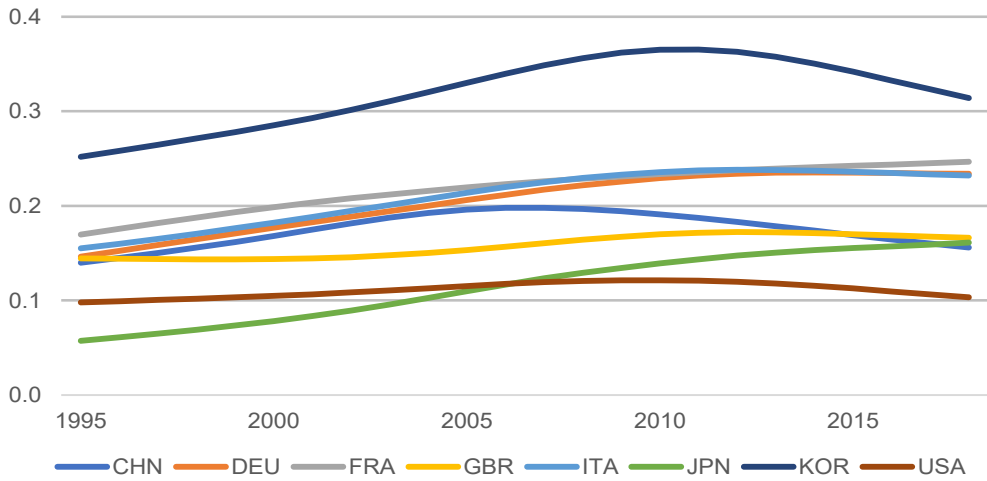


FIGURE 6. ICES OF EIGHT SELECTED COUNTRIES (HP FILTERED)

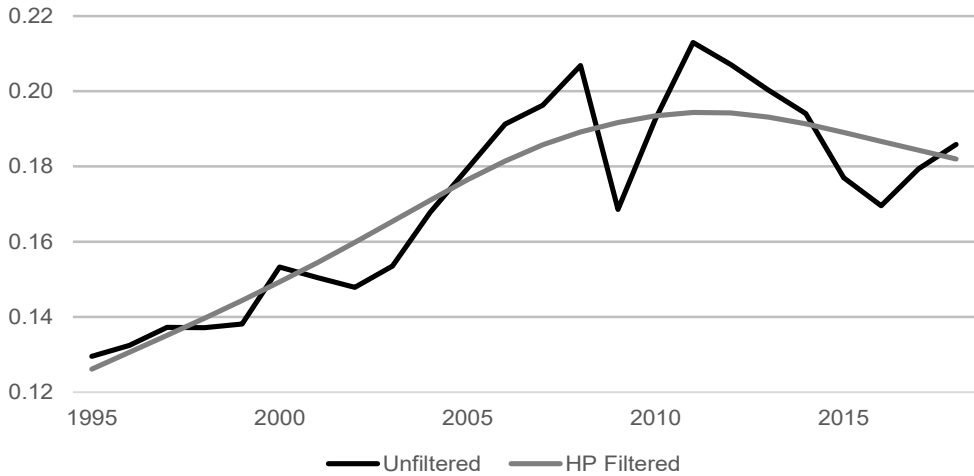


FIGURE 7. AVERAGE ICE VALUES OF EIGHT SELECTED COUNTRIES

of the eight countries.<sup>12</sup> This value was approximately 0.129 in 1995, but it increased rapidly to 0.213 in 2011, then dropped to 0.170 in 2016, and recovered to 0.186 in 2018. It appears that the time-series fluctuation became stronger in recent years, suggesting an important research topic.

The  $MRX^a$  values of the eight countries and the average of these values during the period of 1995-2018 are given in Figure 8 and Figure 9, respectively. While the patterns of individual countries'  $MRX^a$  values are similar to those of the ICE values, we also observe significant differences at the same time. For instance, France,

<sup>12</sup>This is the weighted average of the ICES of the eight countries which was computed from the aggregated IO tables of the eight countries. It is evident that the ICE began declining around early 2010s. A sharp decline of ICE in 2009 was the result of the freezing of international trade following the financial crisis in 2008 and must not be interpreted as a sharp retreat of 'global integration' itself.



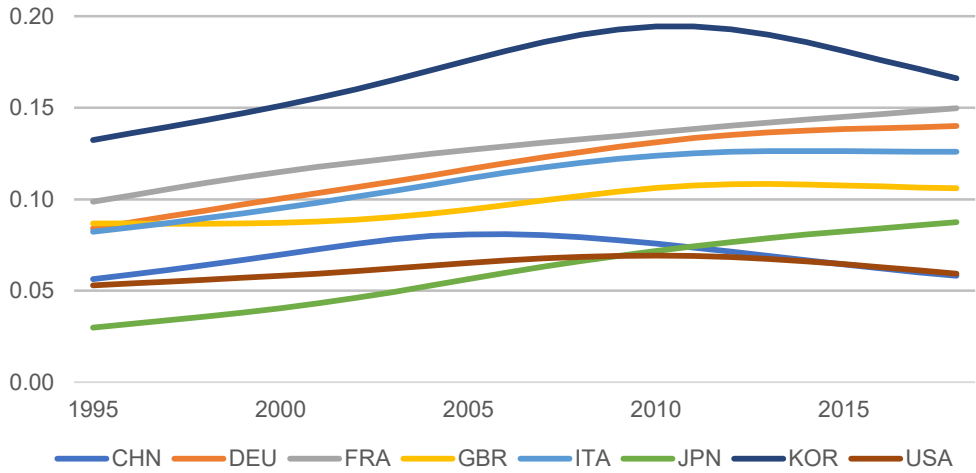


FIGURE 8. MRX<sup>a</sup> VALUES OF EIGHT SELECTED COUNTRIES (HP FILTERED)

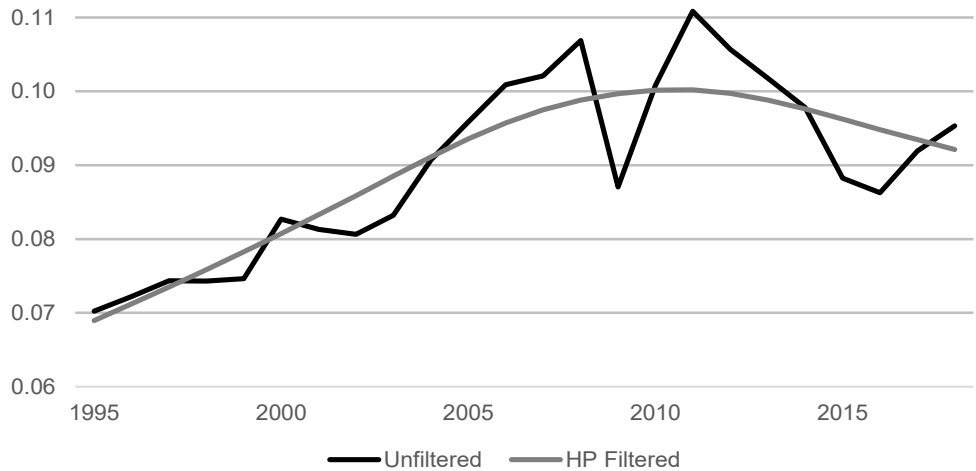


FIGURE 9. AVERAGE MRX<sup>a</sup> VALUES OF EIGHT SELECTED COUNTRIES

Italy and Germany showed very similar patterns for ICE, whereas their MRX<sup>a</sup> s were significantly dissimilar.

In addition, China’s ICE and MRX<sup>a</sup> trends imply highly distinct patterns of global integration according to both time-series and cross-country assessments. Specifically, China’s ICE time series implies that the relative degree of global integration was higher than that of Italy, though the two have become similar in recent years. The MRX<sup>a</sup> trend, however, implies that China’s degree of global integration was lower than Italy’s during the entire period. Clearly, this arose because these two indicators are constructed differently.

Comparing Figure 9 with Figure 7, we learn that the average ICE and MRX<sup>a</sup> outcomes for the eight countries are highly similar in terms of the corresponding time-series patterns, though the ranges of the values are different. In fact, it is expected that the ICE value is close to the share of foreign VA (imports) in total VA

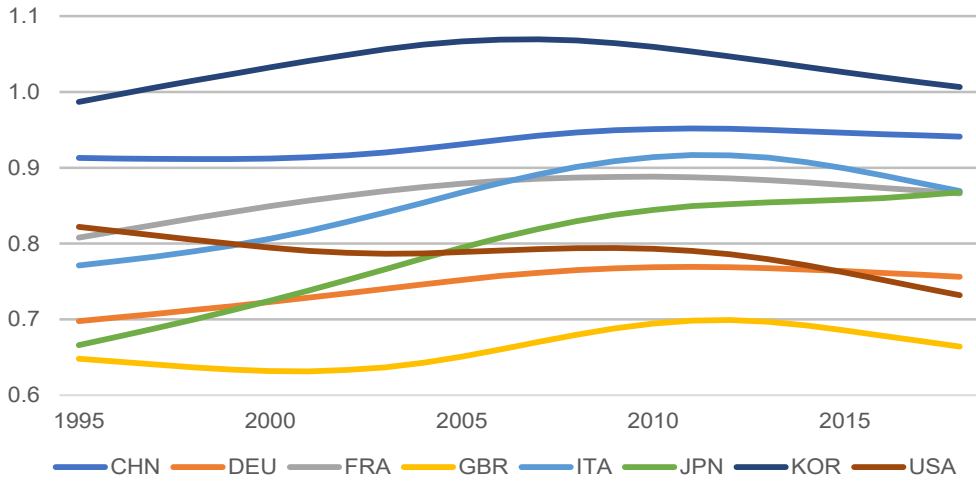


FIGURE 10. MRX<sup>s</sup> VALUES OF EIGHT SELECTED COUNTRIES (HP FILTERED)

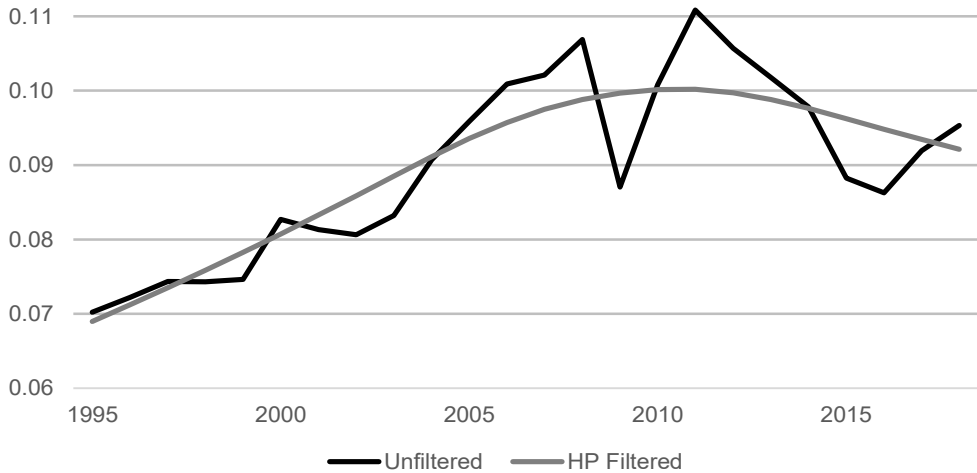


FIGURE 11. AVERAGE MRX<sup>s</sup> VALUES OF EIGHT SELECTED COUNTRIES

(GDP + imports). However, ICE can be slightly larger than the latter because the share of foreign VA (imports) embodied in exports is usually greater than that in domestic final demand. In 2018, for example, the average ICE for the eight countries was 0.186, while the share of foreign VA was 0.168. Similarly, it is expected that the value of  $MRX^a$  is close to the ratio of the supply of imported products (imports) relative to that of domestic products (gross output). In 2018, the average  $MRX^a$  for the eight countries was 0.095, while the ratio of imports to gross output was 0.099. This conjecture can also be confirmed at both country and industry levels.

The  $MRX^s$ s of the eight countries and the average of these values during the period of 1995-2018 are given in Figure 10 and Figure 11, respectively, where we can observe that the patterns of  $MRX^s$  are considerably different from those of  $MRX^a$  and ICE. First, while Korea's  $MRX^s$  level is higher than those of other countries' for all years and the pattern of  $MRX^s$  is similar to that of  $MRX^a$ , the

turning point appears earlier. Second, France, Germany and Italy reveal similar patterns in that their  $MRX^a$  s show an increasing pattern while their  $MRX^s$  s have a rising and then declining pattern. Third, Germany's positions in terms of  $MRX^a$  and  $MRX^s$  are substantially different, and fourth, the United States maintained a declining degree of global integration as expressed in  $MRX^s$  during the entire period. Above all,  $MRX^s$  is based on shares, not on amounts, which very likely caused these differences.

In the figures above, we observed that ICE and  $MRX^a$  display similar patterns for individual countries, with the corresponding averages also similar, while  $MRX^s$  showed somewhat different patterns. This can be directly confirmed by the correlation coefficients. The pairwise correlation coefficients among the three indicators were computed for each of the eight countries and for their averages, as shown in Table 2. The correlation coefficients between ICE and  $MRX^a$  exceed 0.95 for all countries and for the average. However, the correlation coefficients between  $MRX^s$  and the other two indicators are significantly smaller, on average, and reveal a major variation among the countries.

Such differences in the formulae and the resulting differences in the behaviors frequently cause discrepancies in the relative degrees, i.e., the rankings, of global integration among countries. The estimates of the three indicators of China, Germany and Italy in 2018 are given in the first panel of Table 3, while the second panel gives their rankings. Interestingly, Italy ranked first in terms of ICE, China ranked first in terms of  $MRX^a$ , and Germany ranked first in terms of  $MRX^s$ .

These types of reversals or discrepancies among the indicators can also arise in a time-series context; in fact, there are many years in which the three indicators imply different directions of change in the degree of global integration. The values of the three indicators for China, for instance, and the yearly change rates are computed in Table 4. We observe that (i) in 2001, ICE decreased by 1.8% while  $MRX^a$  and  $MRX^s$  increased by 1.9% and 2.5%, respectively; (ii) in 2003,  $MRX^s$  decreased by 1.5% while ICE and  $MRX^a$  increased by 18.2% and 16.0%, respectively; and (iii) in 2005,  $MRX^a$  decreased by 2.8% while ICE and  $MRX^s$  increased correspondingly by 0.5% and 1.5%. These types of reversals occurred in many years in many countries.

TABLE 2—CORRELATION COEFFICIENTS AMONG THE THREE INDICATORS

| Country        | Correlation Coefficients Between |               |                   |
|----------------|----------------------------------|---------------|-------------------|
|                | ICE – $MRX^a$                    | ICE – $MRX^s$ | $MRX^a$ – $MRX^s$ |
| China          | 0.961                            | 0.366         | 0.180             |
| Germany        | 0.993                            | 0.945         | 0.913             |
| France         | 0.992                            | 0.871         | 0.811             |
| United Kingdom | 0.995                            | 0.952         | 0.923             |
| Italy          | 0.996                            | 0.938         | 0.923             |
| Japan          | 0.997                            | 0.931         | 0.925             |
| Korea          | 0.998                            | 0.509         | 0.513             |
| United States  | 0.986                            | 0.532         | 0.410             |
| Average        | 0.990                            | 0.915         | 0.888             |

TABLE 3—THREE INDICATORS FOR CHINA, GERMANY AND ITALY IN 2018

| Country | Estimates |                  |                  | Rankings |                  |                  |
|---------|-----------|------------------|------------------|----------|------------------|------------------|
|         | ICE       | MRX <sup>a</sup> | MRX <sup>s</sup> | ICE      | MRX <sup>a</sup> | MRX <sup>s</sup> |
| China   | 0.165     | 0.948            | 0.063            | 3        | 1                | 3                |
| Germany | 0.235     | 0.761            | 0.141            | 2        | 3                | 1                |
| Italy   | 0.237     | 0.854            | 0.129            | 1        | 2                | 2                |

TABLE 4—THREE INDICATORS OF GLOBAL INTEGRATION OF CHINA

| Year | Estimates |                  |                  | Change Rates (%) <sup>1)</sup> |                  |                  |
|------|-----------|------------------|------------------|--------------------------------|------------------|------------------|
|      | ICE       | MRX <sup>a</sup> | MRX <sup>s</sup> | ICE                            | MRX <sup>a</sup> | MRX <sup>s</sup> |
| 1995 | 0.152     | 0.061            | 0.913            |                                |                  |                  |
| 1996 | 0.149     | 0.060            | 0.917            | -2.5                           | -2.0             | 0.4              |
| 1997 | 0.152     | 0.062            | 0.940            | 2.4                            | 3.3              | 2.5              |
| 1998 | 0.134     | 0.052            | 0.908            | -11.9                          | -15.7            | -3.4             |
| 1999 | 0.144     | 0.057            | 0.909            | 7.8                            | 8.1              | 0.1              |
| 2000 | 0.162     | 0.066            | 0.896            | 12.4                           | 16.0             | -1.5             |
| 2001 | 0.159     | 0.067            | 0.918            | -1.8                           | 1.9              | 2.5              |
| 2002 | 0.167     | 0.074            | 0.897            | 5.1                            | 10.8             | -2.3             |
| 2003 | 0.198     | 0.086            | 0.883            | 18.2                           | 16.0             | -1.5             |
| 2004 | 0.220     | 0.095            | 0.906            | 11.4                           | 10.6             | 2.5              |
| 2005 | 0.222     | 0.093            | 0.920            | 0.5                            | -2.8             | 1.5              |
| 2006 | 0.212     | 0.085            | 0.946            | -4.4                           | -8.6             | 2.9              |
| 2007 | 0.210     | 0.082            | 0.989            | -1.0                           | -3.5             | 4.5              |
| 2008 | 0.209     | 0.084            | 0.980            | -0.2                           | 2.4              | -0.9             |
| 2009 | 0.163     | 0.062            | 0.933            | -22.3                          | -26.2            | -4.8             |
| 2010 | 0.183     | 0.074            | 0.942            | 12.4                           | 19.5             | 1.0              |
| 2011 | 0.196     | 0.080            | 0.972            | 7.0                            | 7.9              | 3.1              |
| 2012 | 0.188     | 0.073            | 0.975            | -4.2                           | -8.9             | 0.3              |
| 2013 | 0.180     | 0.069            | 0.969            | -3.8                           | -4.5             | -0.6             |
| 2014 | 0.173     | 0.065            | 0.926            | -4.1                           | -5.9             | -4.4             |
| 2015 | 0.152     | 0.055            | 0.908            | -12.1                          | -16.0            | -2.0             |
| 2016 | 0.151     | 0.056            | 0.927            | -1.0                           | 2.7              | 2.2              |
| 2017 | 0.163     | 0.063            | 0.956            | 8.4                            | 11.7             | 3.1              |
| 2018 | 0.165     | 0.063            | 0.948            | 0.7                            | 0.8              | -0.9             |

Note: 1) The years in which the signs of the three indicators' change rates are not identical are shaded in gray.

We investigate the reversals of ICE and MRX<sup>a</sup> in China during the period of 2000-2001 more deeply. Table 5 summarizes the ICE and MRX<sup>a</sup> values and their components in 2000 and 2001, along with the respective change rates in 2001. Recall

$$\text{ICE} = \frac{\mathbf{o}'\mathbf{R}^m\mathbf{e}}{\mathbf{o}'\mathbf{e}} \quad \text{and} \quad \text{MRX}^a = \frac{\mathbf{o}'\mathbf{R}^m\mathbf{e}}{\mathbf{o}'\mathbf{R}^x\mathbf{e}}.$$

Total exports ( $\mathbf{o}'\mathbf{e}$ ) of China increased by 4.2% during the period of 2000-01.

TABLE 5—CHANGE RATES OF ICE AND  $MXR^a$  FOR CHINA IN THE 2001  $o'R^x e$ 

(Unit: Million US Dollars)

| Year         | $o'e$   | $o'R^m e$ | $o'R^x e$ | ICE   | $MXR^a$ |
|--------------|---------|-----------|-----------|-------|---------|
| 2000         | 237,426 | 38,542    | 585,406   | 0.162 | 0.066   |
| 2001         | 247,380 | 39,422    | 587,729   | 0.159 | 0.067   |
| Change Rates | 4.2%    | 2.3%      | 0.4%      | -1.8% | 1.9%    |

This increased total imports ( $o'R^m e$ ) only by 2.3%; consequently, ICE decreased by 1.8%. However, the change rate of the gross output caused by the increase in exports ( $o'R^x e$ ) was even smaller at only 0.4%. In other words, the relative utilization of GPN compared to DSC in terms of ‘production’ increased, and  $MXR^a$  rose by 1.9%. In conclusion, ICE implies that China’s degree of global integration weakened while  $MXR^a$  implies that it strengthened.

### C. Indicators of Global Integration at the Product/Industry Level

The three indicators of global integration above can be computed at the industry level. While the three indicators for all 25 industries were computed, those of six selected industries are reported here: agricultural, forest and fishery goods; textile and leather products; chemical products; electric and electronic equipment; motor vehicles and trailers; and business services.<sup>13</sup>

The exports of the six selected products by the eight countries in 2018 are given in Table 6, as are two new indicators,  $MXR^a$  and  $MXR^s$ , in Figures 12 and 13, respectively. The charts in Figure 12 show that the industry-level indicators comply with the country-level trends to some extent, while we observe considerable

TABLE 6—EXPORTS OF SIX SELECTED PRODUCTS IN 2018

(Unit: Billion US Dollars)

| Country             | AGRI  | TEXT  | CHEM    | ELEC    | AUTO    | BUSI    |
|---------------------|-------|-------|---------|---------|---------|---------|
| China               | 16.5  | 275.1 | 219.9   | 729.2   | 45.7    | 104.4   |
| Germany             | 7.9   | 12.9  | 189.3   | 139.8   | 249.9   | 145.5   |
| France              | 16.3  | 9.5   | 88.0    | 45.4    | 51.2    | 114.1   |
| United Kingdom      | 3.4   | 3.8   | 41.6    | 12.3    | 48.1    | 260.6   |
| Italy               | 6.2   | 42.4  | 56.6    | 35.0    | 43.4    | 35.4    |
| Japan               | 1.1   | 4.8   | 78.1    | 137.3   | 156.8   | 72.0    |
| Korea               | 0.9   | 10.3  | 86.7    | 231.6   | 65.3    | 30.3    |
| United States       | 51.8  | 10.0  | 177.1   | 138.5   | 104.6   | 410.7   |
| Total <sup>1)</sup> | 369.0 | 616.0 | 1,805.0 | 2,316.9 | 1,365.7 | 2,379.2 |

Note: 1) Sum of all 66 countries.

<sup>13</sup>We use the following industry codes in the tables and figures in this paper: agricultural, forest and fishery goods (AGRI, Industry 1); textile and leather products (TEXT, 4); chemical products (CHEM, 7); electric and electronic equipment (ELEC, 11); motor vehicles and trailers (AUTO, 13); and business services (BUSI, 22). The numbers in parentheses are the corresponding industry numbers in the 25-industry classification.

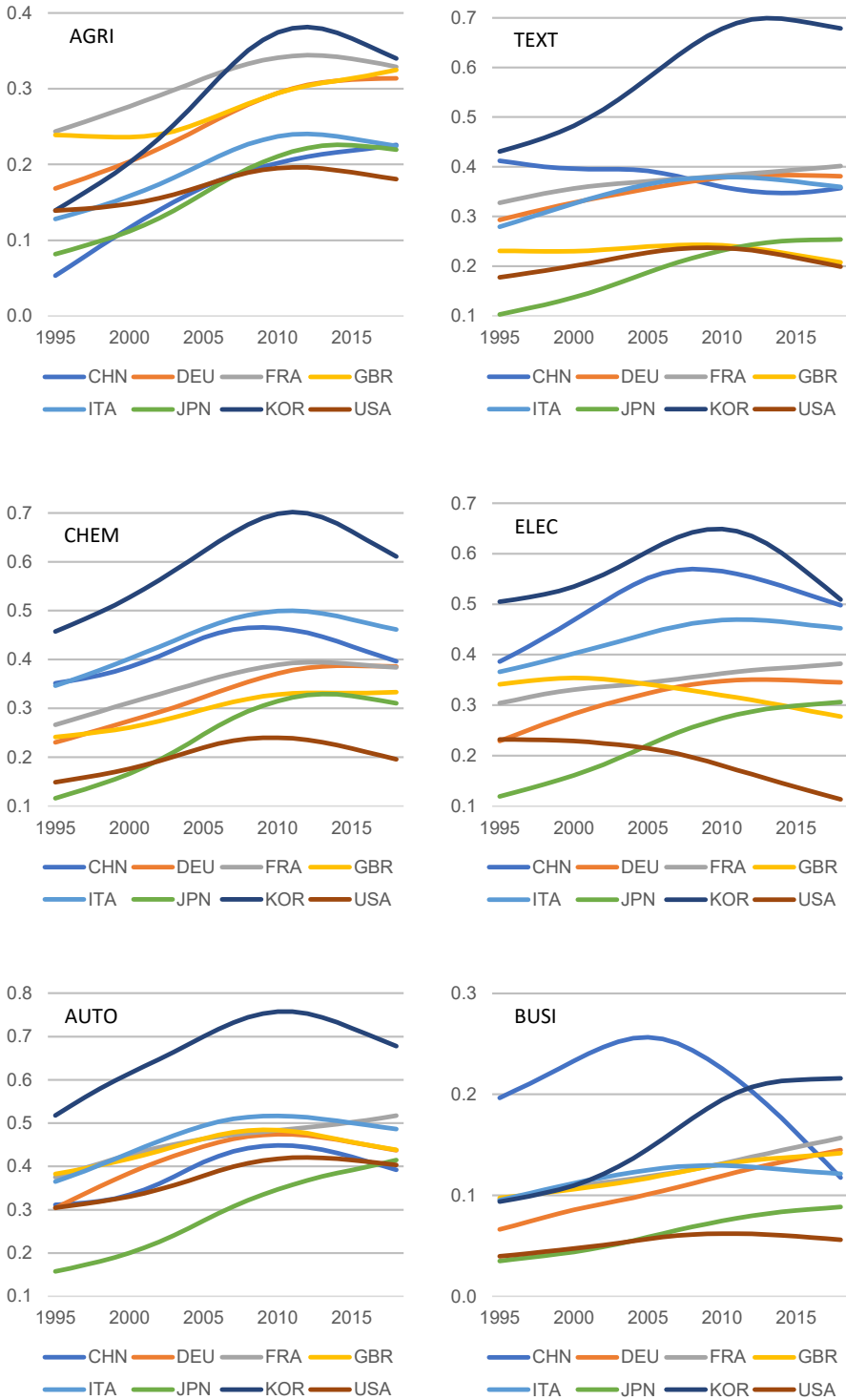


FIGURE 12.  $MXR^a$  VALUES OF SIX SELECTED INDUSTRIES (HP FILTERED)

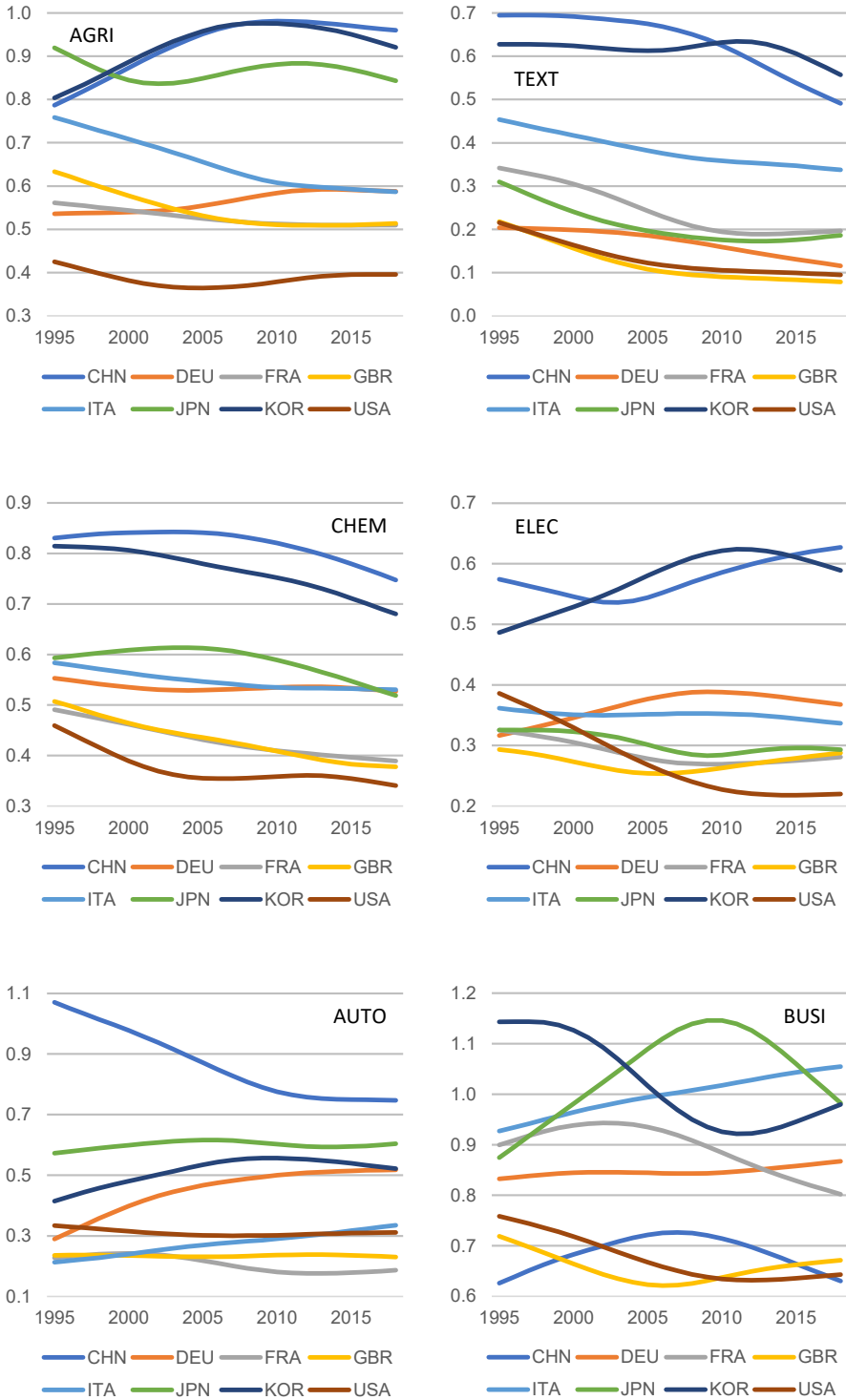


FIGURE 13. MXR<sup>3</sup> VALUES OF SIX SELECTED INDUSTRIES (HP FILTERED)

variations among industries at the same time. For example, the picture of the world business service market appears substantially different from that of the electronics market. We can also realize, from Figures 12 and 13, that the patterns of the two indicators,  $MXR^a$  and  $MXR^s$ , are considerably distinct. Again, this occurs because the two indicators are based on two different measures – amounts and shares, respectively – and that  $MXR^s$  is considered to take into consideration the other final demand terms implicitly.

The inter-country, inter-industry comparisons of the industry-level indicators provide a clearer perspective as to the characteristics of individual countries' industries in the world market because they contrast the dynamics of global integration among industries vividly. The estimates of  $MXR^a$  and  $MXR^s$  of the six selected industries of the eight countries are given in Figures 14 and 15, respectively. It is interesting to observe that the two indicators appear to provide considerably different implications regarding individual industries' degrees of global integration. For example, the degree of global integration for business services has remained lower compared to all other selected industries in all eight countries in terms of  $MXR^a$ . However, the values of  $MXR^s$  offer contrasting implications due to the difference in the emphasis of the indicators.



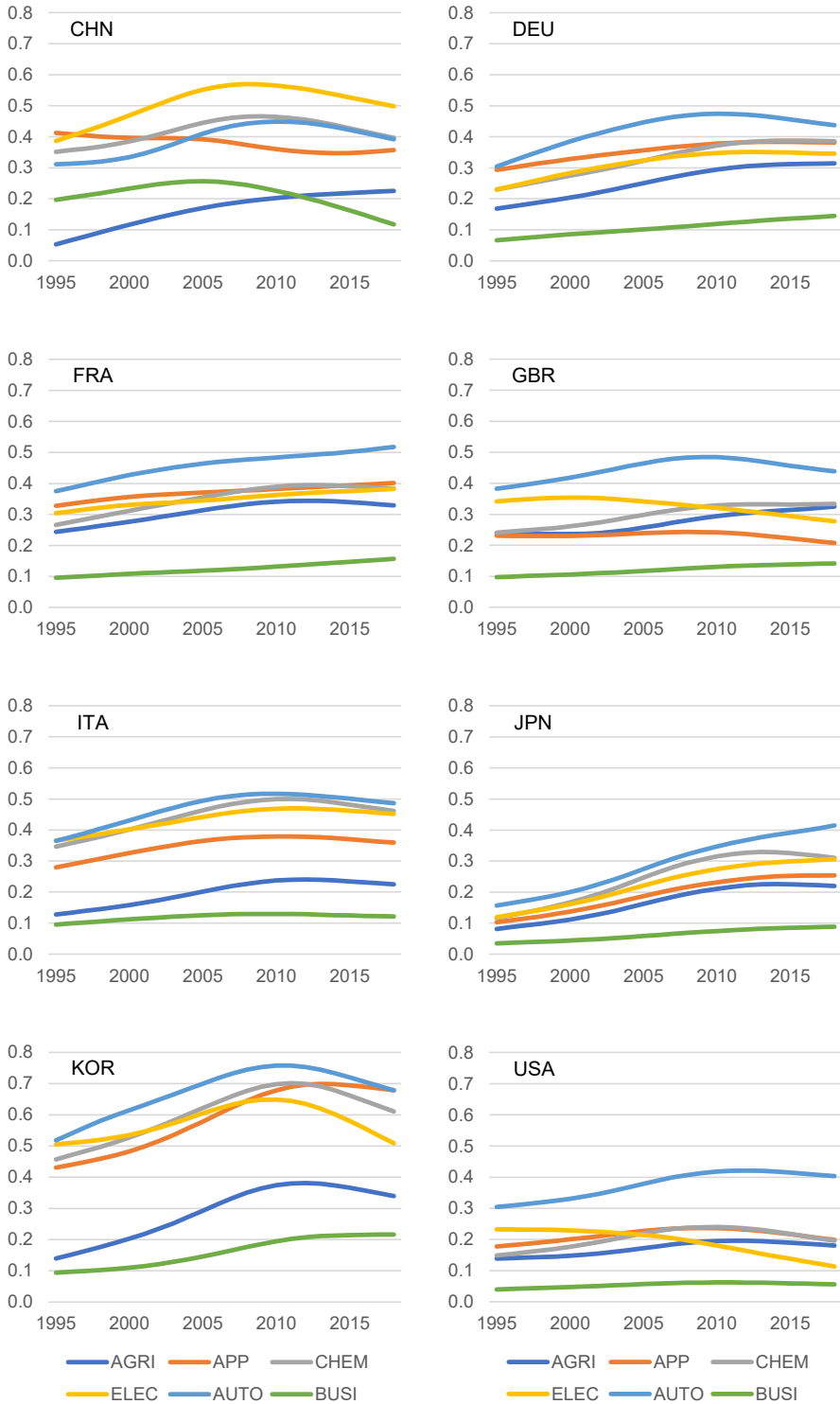


FIGURE 14.  $MXR^a$  VALUES OF EIGHT SELECTED COUNTRIES (HP FILTERED)

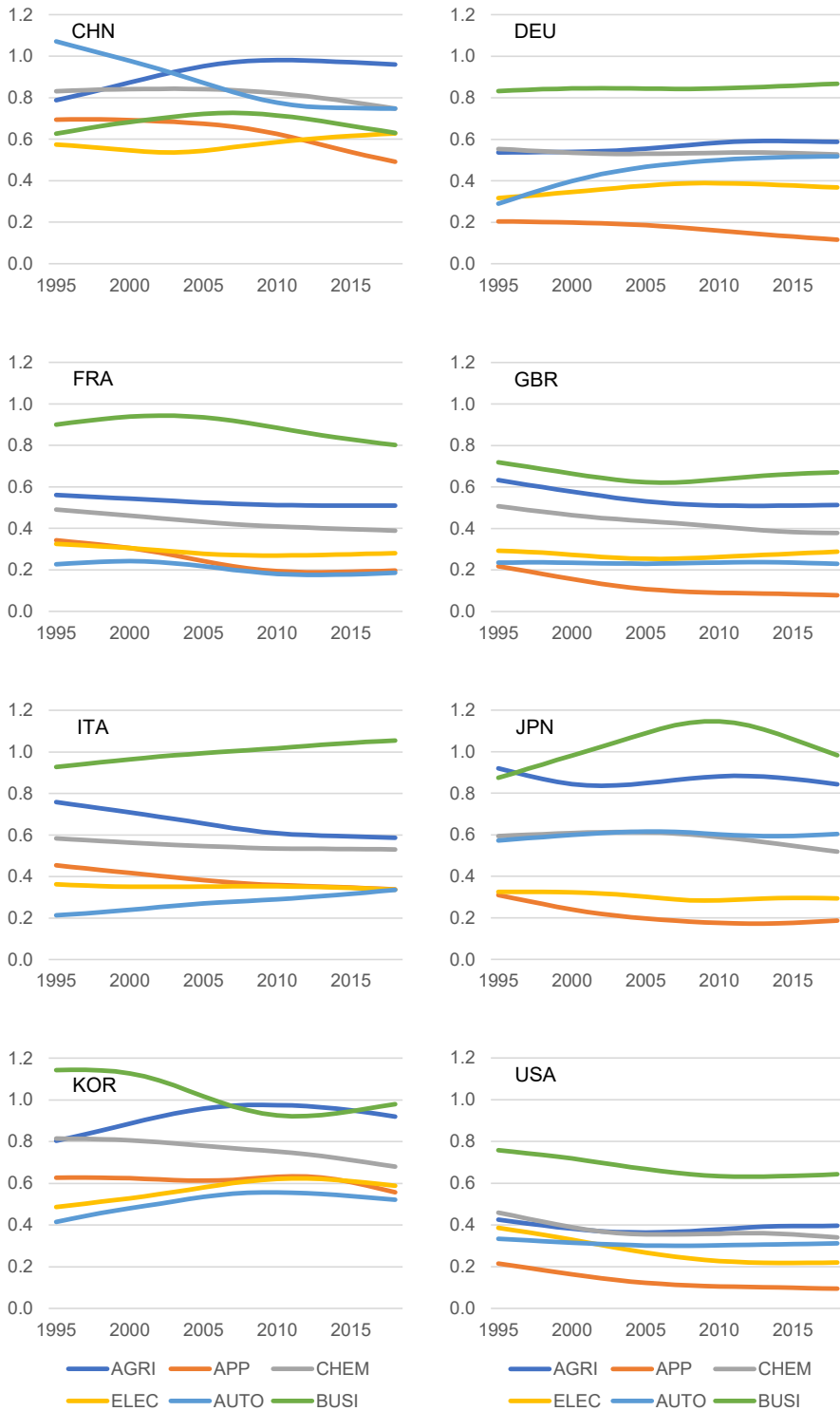


FIGURE 15.  $MXR^S$  VALUES OF EIGHT SELECTED COUNTRIES (HP FILTERED)

### D. Recent Trends in International Trade through the Lens of Global Integration

The global exports/imports market experienced severe turbulence over the past 15 years. World trade experienced a decrease of around 19% in 2009 due to the financial crisis of 2008, and the slow world economy and COVID-19 caused 11% and 9% decreases in 2015 and 2020, respectively. Despite the fact that heightened fluctuations in world trade makes it a challenging task to forecast the future of international trade, it seems reasonable to expect that the intensity of international trade compared to the economic activity of the globe will not strengthen very soon.

As mentioned earlier, world exports as a percentage of the world GDP amounted to only 5.5% in 1950 but exploded to 31.0% in the late 2000s. However, the recent trend gives the impression that the ratio has entered a steady level, or a ‘saturation level’, at about 30% and that it is not reasonable to expect a sizeable increase. This can also be confirmed by the statistics from the OECD IO-DB; total exports as a percentage of GDP rose to 26.5% in 2008 and has stayed in the 24~26% band since then.

The OECD IO-DB presents an important hint as to the relationship between international trade and global integration which cannot be easily obtained without the help of IO tables. Figure 16 shows the share of imported intermediate goods out of total imports by all 66 countries in the OECD IO-DB. The share was 55.6% in 1995 but increased to 62.3% in 2011. It then continually decreased, reaching 58.6% in 2016. Hodrick-Prescott filtering implies a declining trend since the early 2010s. The time-series pattern of the share is strikingly similar to that of the world export/GDP share, and other shares such as the share of total imported intermediate inputs out of total input or out of total intermediate input also reveal very similar patterns. The shares of imported intermediate goods out of total imports by the aforementioned eight countries are given in Figure 17, where we observe declining trends over the past few decades in most countries.

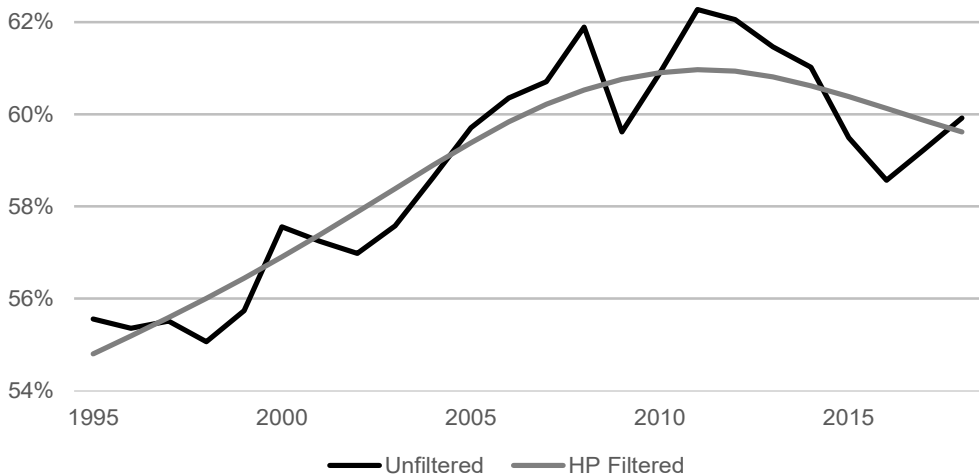


FIGURE 16. IMPORTED INTERMEDIATE DEMAND AS A PERCENTAGE OF TOTAL IMPORTS IN THE OECD IO-DB 2021 EDITION

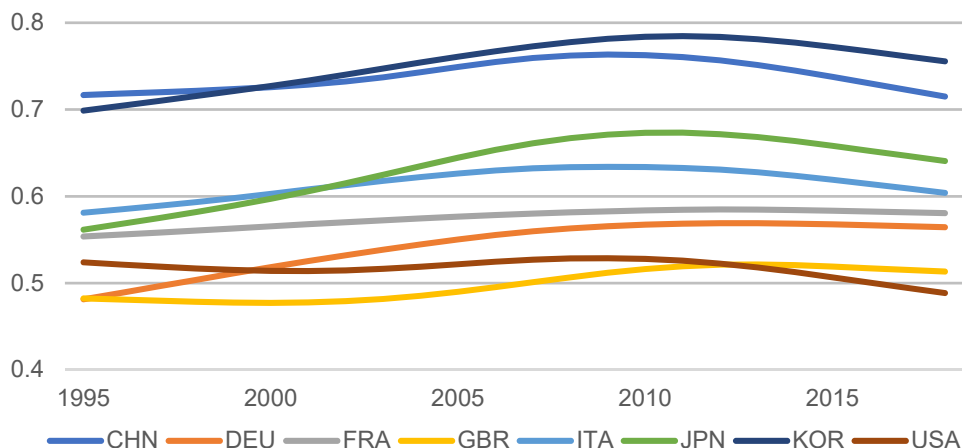


FIGURE 17. IMPORTED INTERMEDIATE DEMAND OUT OF THE TOTAL IMPORTS OF EIGHT COUNTRIES (HP FILTERED)

This implies that the decrease in the trade of intermediate inputs has been the main cause of the recent slowdown in international trade. For example, total imports by the 66 countries in the IO-DB decreased from 18,165 to 16,642 billion US\$. The decrement was 1,523 billion US\$. On the other hand, total imports of intermediate goods decreased from 11,312 to 9,747 billion US\$, and the decrement was 1,566 billion US dollars. During the same period, total imports of final goods – consumption and capital goods – increased by 42 billion US\$. In consequence, the decrease in total imports was entirely due to the decrease in the imports of intermediate goods, and the imports of final goods even increased, though not by much.<sup>14</sup>

Here, we learned about the role of imported intermediate goods in this study of global integration. In fact, imports of intermediate goods remain at the center of global integration and constitute the gist of the definition of global integration. In this regard, more attention should be directed toward the decline in the share of imported intermediate goods out of total imports rather than toward the slowdown in world trade itself. Also, there is a possibility that the recent decline in the share of imported intermediate goods out of total imports may insinuate a slowdown or even the saturation of global integration. Obviously, it can be too early to reach a conclusion, and further research is thus warranted.

## V. Conclusion

ICE is a useful indicator and has considerable advantages. It measures the amount of imported intermediate goods embodied in exported products and thus reflects the degree to which a country or an industry utilizes the GPN measure. However, there are contexts in which measures of global integration based on ‘production’ are more

<sup>14</sup>This was also mentioned in Kim (2023).

strongly needed. In this paper, we proposed two new indicators of global integration as alternatives to ICE. Both indicators, termed  $MXR^a$  and  $MXR^s$ , are designed to measure the relative degree of the utilization of GPN over DSC and are defined as the ratios of imports (foreign production) to gross output (domestic production) generated by exports. The former uses amounts while the latter uses shares. Both indicators can easily be computed and can be compared between years, between countries, between industries, and between groups of industries. Also, the interpretation of these indicators is straightforward. We applied the two new indicators to the actual IO tables of 66 countries in the 2021 edition of the OECD IO-DB and investigated the trends during the period of 1995-2018 using the indicators computed at country and industry levels.

Three recommendations follow. First, global integration is a complex phenomenon that cannot be easily uncovered and defined by only a few indicators. We can find many years in which different indicators indicate different directions of change, and we can find many countries for which different indicators imply different rankings. For this reason, it is necessary to base research in this area on as many indicators, with much in-depth analysis, as possible.

Second, the global export market has showed considerable fluctuations, especially since the financial crisis of 2008. Hence, the indicators of global integration also reveal strong fluctuations because international trade data is the primary ingredient. For this reason, capturing the mid- and long-term trends of global integration has become increasingly difficult, and it is necessary to adopt a desirable quantitative method to ‘smooth out’ the time series and find the trend.

Third, global integration is a complex phenomenon, and in order to enhance our understanding of it, active empirical studies of the determinants of the degree of global integration would be useful, using as broad a range of indicators as possible. The determinants of the degree of global integration could be categorized into two groups. The first is the group of ‘global’ factors that have a similar impact on most industries in most countries, such as global economic trends, transportation technology, ICT, and the level of piracy, among others. We witnessed that the financial crisis of 2008 presented an enormous shock to almost every indicator in every industry and in every country, and it would be a typical determinant in the first group. The second is the group of country-specific and/or industry-specific factors. The competitiveness of domestic intermediate inputs would be the most important factor in the second group.

Finally, we observed that the slowdown in international trade in recent years was mostly due to the decrease in the international trade of intermediate goods. This has significant implications for the future pattern of global integration, as the international trade of intermediate goods plays a crucial role in this process. Thus, comprehensive research and investigations can be expected in this field.

## APPENDIX

**Proof of**  $ICE + VCE = 1$  and  $ICE_i + VCE_i = 1$  for all  $i = 1, 2, \dots, n$ .

We have  $ICE_i = [\mathbf{o}'\mathbf{R}^m]_i$  and  $VCE_i = [\mathbf{o}'\mathbf{R}^v]_i$  where  $[\mathbf{a}]_i$  is the  $i$ th element of a vector  $\mathbf{a}$ . Thus it suffices to show  $\mathbf{o}'\mathbf{R}^m + \mathbf{o}'\mathbf{R}^v = \mathbf{o}'$  to prove  $ICE_i + VCE_i = 1$  for all  $i = 1, 2, \dots, n$ . Note that  $ICE + VCE = 1$  follows from  $ICE_i + VCE_i = 1$ .

Considering that total input consists of domestic intermediate input, imported intermediate input, and value-added, we have  $\mathbf{o}'\mathbf{A}^d + \mathbf{o}'\mathbf{A}^m + \mathbf{o}'\mathbf{A}^v = \mathbf{o}'\mathbf{I}$ .<sup>15</sup> Then,  $\mathbf{o}'\mathbf{R}^m + \mathbf{o}'\mathbf{R}^v$  becomes

$$\begin{aligned}
 \mathbf{o}'\mathbf{R}^m + \mathbf{o}'\mathbf{R}^v &= \mathbf{o}'\mathbf{A}^m(\mathbf{I} - \mathbf{A}^d)^{-1} + \mathbf{o}'\mathbf{A}^v(\mathbf{I} - \mathbf{A}^d)^{-1} \\
 &= (\mathbf{o}'\mathbf{A}^m + \mathbf{o}'\mathbf{A}^v)(\mathbf{I} - \mathbf{A}^d)^{-1} \\
 &= (\mathbf{o}'\mathbf{I} - \mathbf{o}'\mathbf{A}^d)(\mathbf{I} - \mathbf{A}^d)^{-1} && \because \mathbf{o}'\mathbf{A}^d + \mathbf{o}'\mathbf{A}^m + \mathbf{o}'\mathbf{A}^v = \mathbf{o}'\mathbf{I} \\
 &= \mathbf{o}'(\mathbf{I} - \mathbf{A}^d)(\mathbf{I} - \mathbf{A}^d)^{-1} \\
 &= \mathbf{o}'. && \square
 \end{aligned}$$

<sup>15</sup>This does not imply that  $\mathbf{A}^d + \mathbf{A}^m + \mathbf{A}^v = \mathbf{I}$ .

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