Korea's Patterns of Trade

Jean Imbs and Laurent L. Pauwels

Imbs and Pauwels (2020) introduce a measure of openness based on indirect trade. This paper illustrates the differences in the Korean patterns of trade when openness is measured using conventional measures based on direct trade, and when it is measured using this measure of indirect trade, labeled Export Intensity (EI). According to EI, the Republic of Korea (Korea) has been following an upward trend in openness since 2000 and even after 2010. This stands in contrast with most other large trading countries, including China and Germany. We show this is a reflection of Korea's integration with a few partner economies, most notably China. Vertical integration is considerable between Korea and China, in manufacturing and in services alike. The extent of this integration would be invisible on the basis of conventional measures of openness.

Keywords: High Order Trade, Republic of Korea, Trade partners, Sectors

JEL Classification: E32, F44

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I. Introduction

Imbs and Pauwels (2020) introduce a measure of openness based on high order linkages. This paper applies this measure to characterize Korea's patterns of trade. For a given activity, the measure, labeled Export Intensity (EI) computes the fraction of the downstream uses of gross output that cross the border. It captures the exposure of a given activity to foreign shocks that travel via the global value chain.[1] This paper describes the patterns of Korean international trade as implied by EI over time, across sectors, and across trade partners. We document that Korea is a trade champion to an extent that is best captured by EI, rather than conventional measures. We show that Korea is exceptionally well integrated in global value chains. These value chains mostly involve China, unsurprisingly, but involve most of Korea's sectors. As expected, they are relevant to manufacturing sectors, but also to most services like wholesale, retail, and some business services.

Conventional measures of trade are typically focused on direct trade. For example, direct exports (or imports) are often normalized by economic activity to evaluate a country or a sector's openness.[2] Imbs and Pauwels (2020) introduce a measure of indirect trade building from the decomposition of gross output in each sector into its downstream uses. Because of global value chains, an increasing number of activities are not traded directly, but are still exposed to foreign developments via their downstream customers. A relevant measure of openness ought to account for the diffusion of shocks with a foreign origin via the value chain, rather than via direct trade. There are other measures of trade focused on indirect trade, most famously Trade in Value Added (TiVA).[3] A detailed discussion of the differences between EI and TiVA can be found in Imbs and Pauwels (2020). A key point is that TiVA decomposes exports, whereas EI decomposes gross output. TiVA still incorporates direct trade, which makes it unapplicable to sectors that trade very little or not at all, like services. TiVA can take infinite values for some

[1] See Imbs and Pauwels (2020) for a discussion of the differences between EI and Trade in Value Added (TiVA), the measure introduced by Johnson and Noguera (2012).

[2] See for instance Alcalá and Ciccone (2004) or Head and Mayer (2004)

[3] See for instance Johnson and Noguera (2012), Johnson (2014), Koopman, Wang, and Wei (2014), Bems and Kikkawa (2019), or Bems and Johnson (2017)

sectors in some countries, and this tends to happen precisely for those activities that trade very little directly. In short, TiVA was not designed to measure exposure to foreign shocks. EI fills this gap.

EI is computed on the basis of global input-output linkages as reported by the World Input-Output Tables.[4] By definition gross output in a sector must equal all of its intermediate and final uses downstream: For each sector gross output is either sold as an intermediate input at home or abroad, or sold as a final good at home or abroad. For a given sector, we separate all uses into purely domestic uses and all others. "All others" incorporates downstream uses that cross a border at one time or more, *i.e.* global value chains. We then compute the fraction of a given value chain that does cross the border at least once. This is done with a manipulation of the Leontief inverse of the world input-output matrix, which is described in detail in Imbs and Pauwels (2020), and summarized in Section II.

The rest of the paper is structured as follows. Section II summarizes briefly the computations involved in computing EI and its predecessors. Section III presents our results, in three steps. First we illustrate the differences between Korea's aggregate openness over time as implied by different measures. Second we discuss the sector breakdown of openness. Third we discuss the differences in the breakdown of Korea's main trade partners, and the relevant corresponding sectors. Section IV concludes.

II. Measuring Indirect Trade

A. Export Intensity

In this section we define three measures of high order trade, EI_i^r, EII_i^r, and EIF_i^r. The computations build from the identity that gross output in each sector must equal all of its downstream uses as intermediate or final goods:

$$Y_i^r = \sum_{s=1}^{S} \sum_{j=1}^{J} z_{ij}^{rs} + \sum_{j=1}^{J} F_{ij}^r \tag{1}$$

where Y_i^r is the value of gross output in sector $r = 1,...,R$ of country i =

[4] For details about WIOT, see (Dietzenbacher *et al.* 2013).

1,...,*I*, Z_{ij}^{rs} is the value of intermediate uses of this good in country *j* and sector *s*, and F_{ij}^{r} is the value of its final uses in country *j*. Throughout the paper, subscripts denote countries and superscripts denote sectors. Both indexes are ordered so that the first identifies the location of production, and the second identifies the location of use.

Imbs and Pauwels (2020) introduce a decomposition of the identity according to border crossings, isolating a component focused on domestic uses only:

$$Y_i^r = \left[\sum_{s=1}^{S} \sum_{j \neq 1}^{J} z_{ij}^{rs} + \sum_{j \neq 1}^{J} F_{ij}^{r} \right] + \left[\sum_{s=1}^{S} z_{ij}^{rs} + F_{ii}^{r} \right] \tag{2}$$

The second term focuses on domestic uses. Adapting this decomposition to the measure of Upstreamness introduced by Antràs and Chor (2013) and Antràs and Chor (2018) with $a_{ij}^{rs} = Z_{ij}^{rs} / Y_i^r$ and iterating:

$$\begin{aligned} U_i^r = & \left[F_{ii}^{r} + 2 \times \sum_{s=1}^{S} a_{ii}^{rs} F_{ii}^{s} + 3 \times \sum_{s=1}^{S} a_{ii}^{rs} a_{ii}^{ss} F_i^t + \cdots \right] \\ & + \left[\begin{array}{l} \sum_{j \neq i}^{J} F_{ij}^{r} + 2 \times \sum_{s=1}^{S} \sum_{j \neq i}^{J} (a_{ij}^{rs} F_j^s + a_{ii}^{rs} F_{ij}^s) \\ +3 \times \sum_{t=1}^{S} \sum_{s=1}^{S} \sum_{j \neq i}^{J} (a_{ij}^{rs} a_{jj}^{st} F_j^t + a_{ii}^{rs} a_{ij}^{st} F_j^t + a_{ij}^{rs} \sum_{k=1}^{J} a_{jk}^{st} F_k^t) + \cdots \end{array} \right] \end{aligned} \tag{3}$$

$$\mathrm{U}_i^r \equiv \mathrm{U}_i^{r\mathrm{DOM}} + \mathrm{U}_i^{rEI} \tag{4}$$

Imbs and Pauwels (2020) show that a measure of export intensity defined as $EI_i^r = \dfrac{U_i^{rEI}}{U_i^r}$ is the typical element of the Hadamard division

$$[(\mathbf{I} - \mathbf{A})^{-2}\,\mathbf{F} - (\mathbf{I} - \mathbf{A}^{\mathrm{DOM}})^{-2}\,\mathrm{F}^{\mathrm{DOM}}]\ \varnothing\ [(\mathbf{I} - \mathbf{A})^{-2}\,\mathbf{F}]$$

where a_{ij}^{rs} is the typical element of **A**, **F** is a vector of final demand, and the superscript "DOM" denotes a sub-sample focused on domestic linkages only.[5] Export Intensity EI_i^r measures the extent to which sector *r* of country *i* serve downstream sectors that are across a border, holding constant the length of the value chain for that country sector.

Export Intensity still embeds first order trade linkages in final or

[5] See Imbs and Pauwels (2020) for details.

intermediate goods, *i.e.*, F^r_{ij} for all $j \neq i$ and Z^{rs}_{ij} for all s and $j \neq i$. We introduce versions that abstract from final or intermediate direct trade, in order to focus on the consequences of high order linkages. Define

$$EII^r_i = \frac{U^{r\,EI}_i - \sum_{j \neq i} \sum_s Z^{rs}_{ij}}{U^r_i} \tag{5}$$

and

$$EIF^r_i = \frac{U^{r\,EI}_i - \sum_{j \neq i} F^r_{ij}}{U^r_i} \tag{6}$$

The two measures capture the foreign exposure of sector r in country i abstracting from direct exports arising from the sector itself.

B. Unilateral Export Intensity

Export intensity captures the foreign exposure of sector r in country i *vis à vis* the rest of the world. To obtain unilateral measures, the only ones able to describe the characteristics of a country's trade partners, we must specialize the measures to a unilateral context. To do so, we compute export intensity on the basis of the relevant matrices and vectors focused on a pair of countries ij.

We can easily define $EI^r_{ij} = \frac{U^{r\,EI}_{ij}}{U^r_{ij}}$, where $U^{r\,EI}_{ij}$ is the typical element in $(\mathbf{I} - \mathbf{A}_{ij})^{-2}\,\mathbf{F}_{ij} - (\mathbf{I} - \mathbf{A}^{\mathrm{DOM}}_{ij})^{-2}\,\mathbf{F}^{\mathrm{DOM}}_{ij}$, and U^r_{ij} is the typical element in $(\mathbf{I} - \mathbf{A}_{ij})^{-2}\,\mathbf{F}_{ij}$. All bilateral matrices are defined in Imbs and Pauwels (2020), and are straightforward specializations of the matrices **A** and **F** defined in the previous section. They simply focus on pairs of countries, *e.g.*, Korea and all of its trade partners. By definition, EI^r_{ij} captures the importance of country j as a foreign market for sector r in country i.

We introduce measures of unilateral export intensities that abstract from any direct trade:

$$EII^r_{ij} = \frac{U^{r\,EI}_{ij} - \sum_s Z^{rs}_{ij}}{U^r_{ij}}, \tag{7}$$

and

$$EIF^r_{ij} = \frac{U^{r\,EI}_{ij} - F^r_{ij}}{U^r_{ij}}, \tag{8}$$

C. Conventional measures of trade

The most widespread measures of openness are based on direct trade.[6] The value of exports (or imports) is often normalized by value added value converted in USD at PPP exchange rates, following Alcalá and Ciccone (2004). In our notation this can be rewritten as

$$XFIN_i^r = \frac{\sum_j -F_{ij}^r}{VA_i^r}$$

and

$$XINT_i^r = \frac{\sum_{j \neq i} \sum_s Z_{ij}^{rs}}{VA_i^r}$$

where the numerator sums the USD value of total exports from sector r in country i in final goods with $\sum_j F_{ij}^r$ and in intermediate goods with $\sum_{j \neq i} \sum_s Z_{ij}^{rs}$.

III. Korea's Patterns of Trade

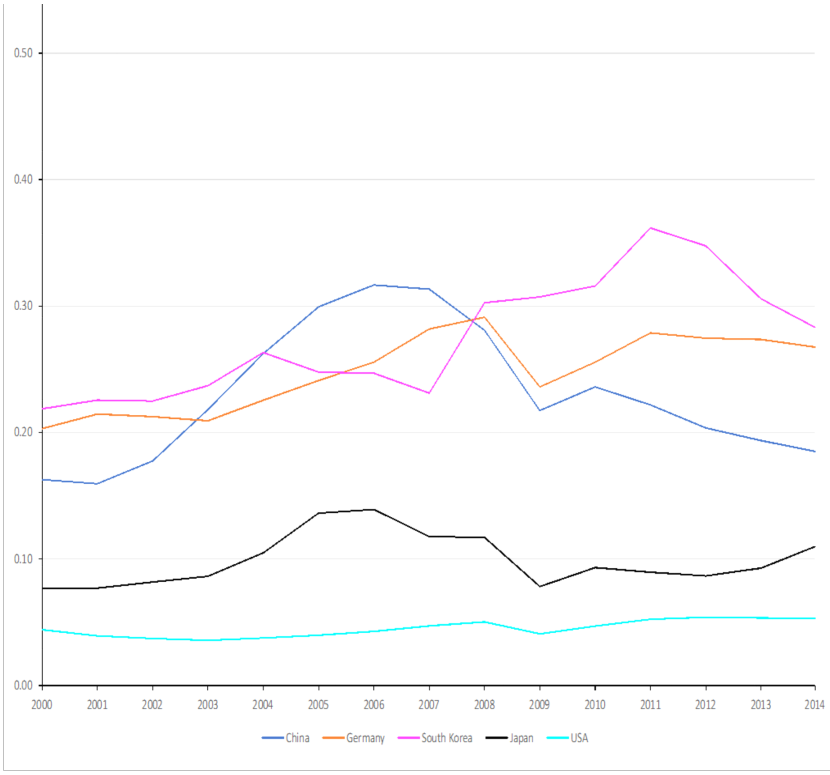
A. Korea's Openness

The world input-output matrix **W** has typical element Z_{ij}^{rs}. The World Input-Output Tables supplement input-output information with vectors of final demand F_{ij}^r. Final demand breaks down into a domestic and an international component by country j, but not by sector s. After accounting for inventories and scaling **W**, we obtain **A**, with typical element a_{ij}^{rs}. $\mathbf{A}^{\text{DOM}}$ is the block diagonal of **A** that contains the within country components of the direct requirement matrix. And $\mathbf{F}^{\text{DOM}}$ is defined by the domestic components of **F**. All matrices are measured using the 2016 release of the World Input-Output Tables, with data for 43 developed and developing countries from 2000 to 2014, or approximately 85 percent of world GDP.[7]

We first present aggregate numbers of Korea over time according to XFIN, EII, and EIF. We select three large, open economies including

[6] Inasmuch as TiVA isolates the value added component in direct gross exports it does build from direct trade measures, too.

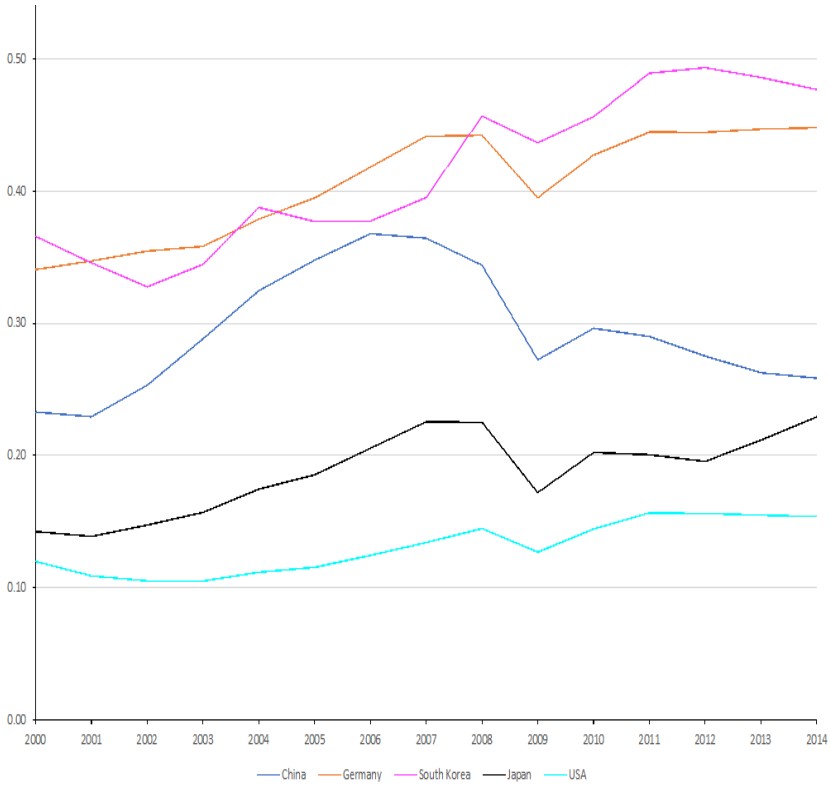
[7] See Imbs and Pauwels (2020) for details.



Note: XFIN is depicted over time for five countries. Country values are total final good exports relative to GDP in USD at PPP exchange rate.

FIGURE 1
EXPORTS OF FINAL GOODS AS A PERCENT OF GDP

China, Germany, Korea, along with Japan and the United States for comparison purposes. Figure 1 plots the very well known dynamics in XFIN, the ratio of exports in final goods relative to GDP between 2000 and 2014. The plots are unsurprising: The US and Japan are relatively closed in the sense that small percentages of their GDP are exported. Then come China, Germany, and Korea, in that order. The time patterns are also well known: The early 2000s saw China become the most open economy in the world (according to XFIN), which it reached just before the Global Financial Crisis of 2007. China subsequently retrenched onto its domestic market with exports falling back to 2000

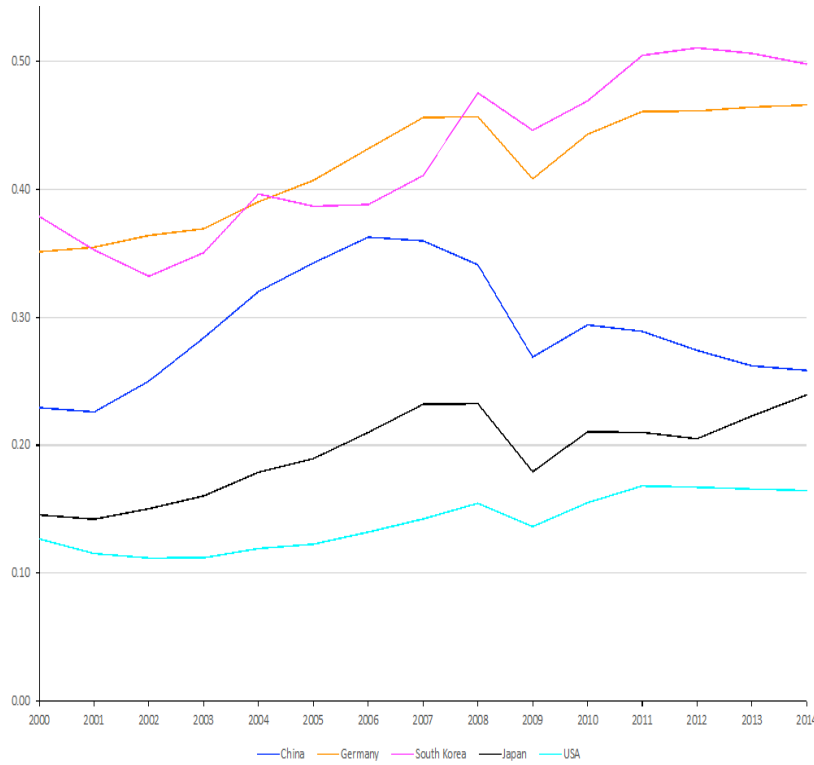


Note: The figure reports country-level averages of EII, using value added weights.

FIGURE 2
WEIGHTED AVERAGES OF EII

levels as a percentage of GDP. All countries experienced a retrenchment after 2007, except for Korea, whose ratio of trade to GDP continued to rise to become the highest in the world as early as 2009. It continues to be ranked first, in spite of a fall in 2012-2013-2014.

How do these dynamics change when openness is measured instead using EII or EIF? Figures 2 and 3 begin to answer that question. First, openness as measured by export intensity is higher on average: While the most open countries export about 30 percent of their GDP in Figure 1, export intensity reaches levels above 50 percent. This



Note: The figure reports country-level averages of EIF, using value added weights

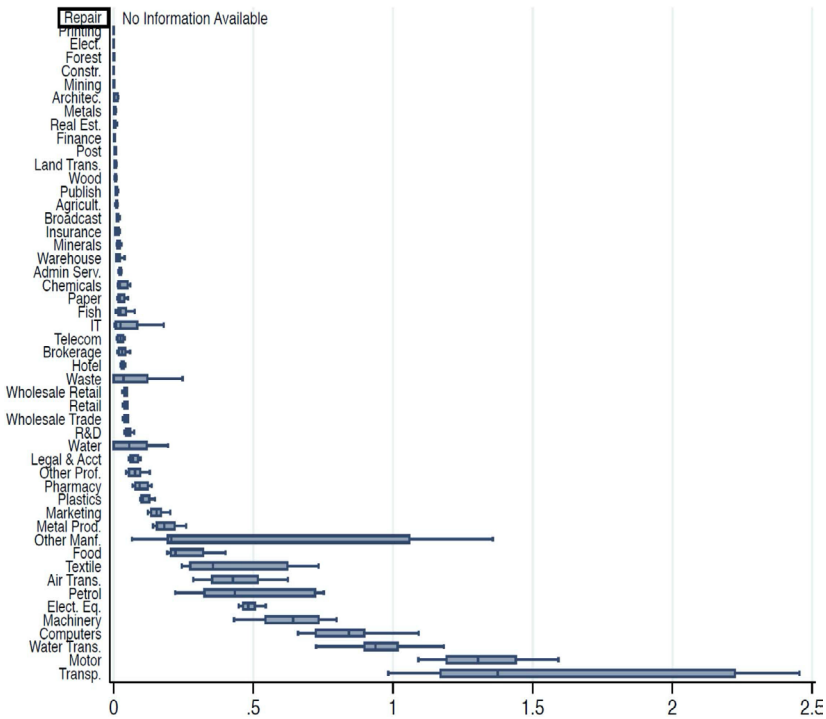
FIGURE 3
WEIGHTED AVERAGES OF EIF

means that in the most open countries more than half of the average sector's output (indirectly) serves customers outside of the national borders. The ranking between countries remains identical to Figure 1, with Korea and Germany the most open countries. Interestingly, Korea and Japan experience a much more marked upward trend over the period considered, and unlike Figure 1 do not retrench after 2010. The contrast between the two results suggest that (i) Germany and Korea have integrated massively in the global value chain since 2000, and (ii) the trend has accelerated since 2010, unlike in other prominent exporting countries like China. Integration in Korea has been on an upward trend since 2000, most of it because of vertical integration.

B. Open Sectors in Korea

We now illustrate the dispersion in openness across sectors, as implied by measures of direct trade vs. export intensity. We do this in the form of boxplots for each sector, representing the variation in each measure over time. Each boxplot contains mean, interquartile range, and extreme values. Figure 4 reports the sector distribution of XFIN, and Figure 5 that of XINT.

Figure 4 illustrates the fact that exports as a fraction of value added are very small for the vast majority of sectors except a handful. Somewhat counter-intuitively, this continues to be true in very open

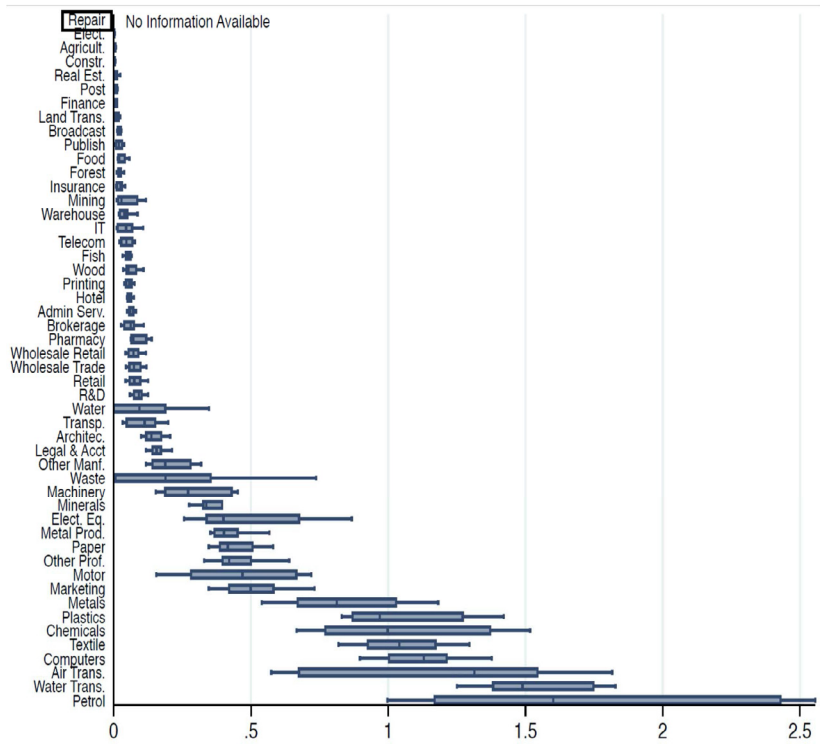


Note: Boxplots of sector values of XFIN over time. Each plot reports means, interquartile ranges, and extrema.

FIGURE 4
XFIN IN SOUTH KOREA (OVER 2000-2014)

countries, and in particular in Korea, the most open country in the world as measured by the fraction of value added that is (directly) exported. Out of the 50 sectors reported in WIOT, only 5 export directly more than 50 percent of value added. They are the usual suspects, including most heavy manufacturing activities. Other activities like Other Manufacturing and Textiles display large volatility over time. But the vast majority of sectors are in fact "closed" in the sense that their direct exports are virtually zero, and they remain so over the full period. Of course, this includes all service sectors.

Figure 5 confirms the same skewness exists for direct exports in intermediate goods, as a fraction of value added. Average values of XINT are slightly higher than in Figure 4, but most sectors continue to export

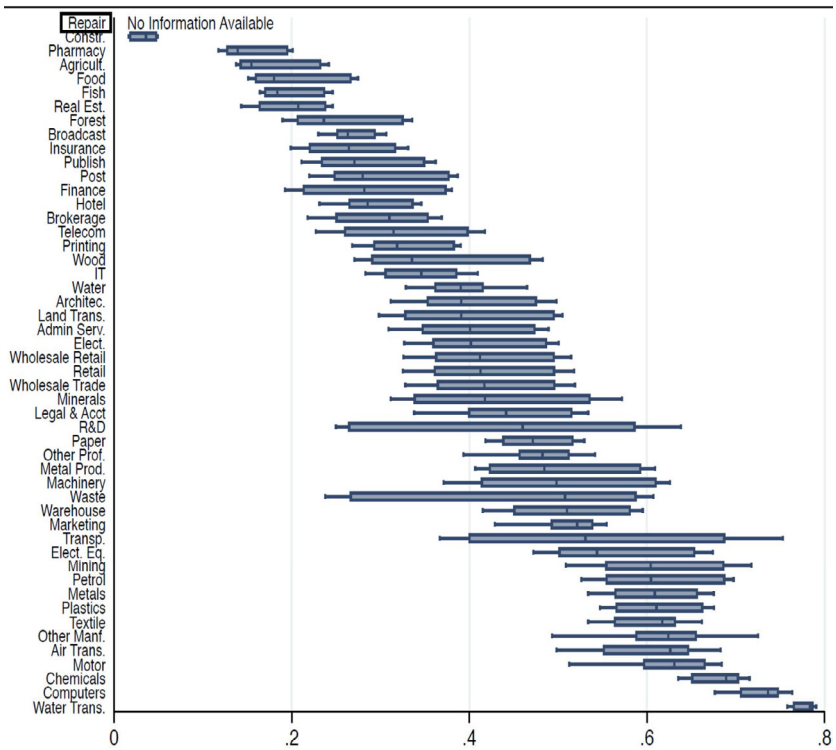


Note: Boxplots of sector values of XINT over time. Each plot reports means, interquartile ranges, and extrema.

FIGURE 5
XINT IN SOUTH KOREA (OVER 2000-2014)

very little directly, and only the same five heavy manufacturing sectors export consistently more than 50 percent of their value added. Most sectors are "closed" when it comes to capturing how much of their value added is exported directly.

Figure 6 plots the same information for the same sectors, reporting the values of export intensity instead. The contrast is striking: The cross-sector distribution of openness is much less skewed with export intensity than it was with any measure of direct trade. Very few sectors are consistently "closed", in the sense of very low values for export intensity. Construction is the only sector in Korea that displays a value for EII that is consistently below 10 percent. To reiterate, this means that for all other sectors, 10 percent or more of their gross output is in



Note: Boxplots of sector values of EII over time. Each plot reports means, interquartile ranges, and extrema.

Figure 6
EII in South Korea (over 2000-2014)

fact indirectly sold to foreign customers. Most services, like Wholesale Trade or business services have average values above 40 percent over the period. The ranking at the very top of the distribution is similar to what measures of direct trade imply: Heavy manufactures are the most open. But the difference between the top 5 or 10 sectors and the rest of them is much less marked. For example, Motors, Chemicals, or Computers have values of EII above 60 percent. But Marketing, Transportation, or Waste have values around 50 percent: The difference is minimal, much smaller than what was implied by Figures 4 and 5. Korea continues to be a very open economy, but this comes from the fact that *most* of its sectors are open. This illustrates the large integration of the Korean economy in global supply chains: Korean services, for example, are very open by international standards, because their downstream customers are often located across the border.

C. Korea's Trade Partners

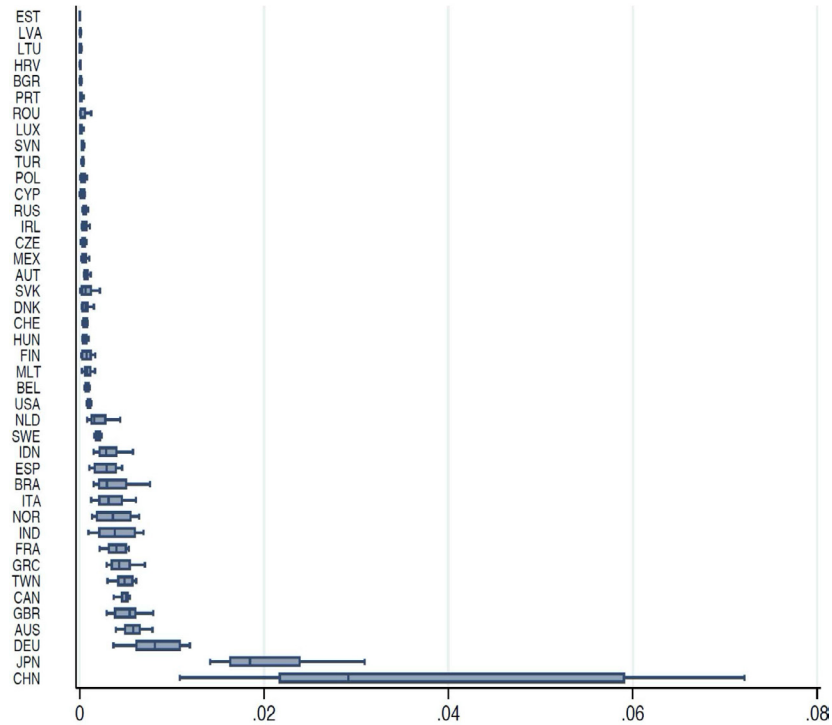
This section introduces the unilateral versions of export intensity measures, with the purpose of describing the cross-section of Korea's trade partners. As before, we compare the distribution of trade partners on the basis of export intensity with what conventional direct trade measures would imply.

Figure 7 ranks Korea's trade partners according to $XFIN_{ij}$, defined as the aggregate of $XFIN_{ij}^{r}$:

$$XFIN_{tj} = \frac{\sum_r F_{ij}^r}{\sum_r VA_i^r}$$

The figure illustrates the well known rise of China as the main export market for Korea over the 2000s. The next trade partners in the list are also unsurprising: Japan is a far second after China, followed by Germany, Australia, and a group of Western European rich countries.

Figure 8 now ranks Korea's trade partners according to EII_{ij}, defined as gross output weighted averages of EII_{ij}^{r}. The country ranking is similar at the top, with China once again the overwhelmingly dominant trade partner of Korea. But the next countries in the list are actually quite different: Taiwan and Japan come second, followed by Russia, Norway, and Germany. This illustrates the predominance of vertical, indirect trade between Korea and Taiwan in particular, and also with energy-exporting Russia and Norway. It is also notable that EII takes



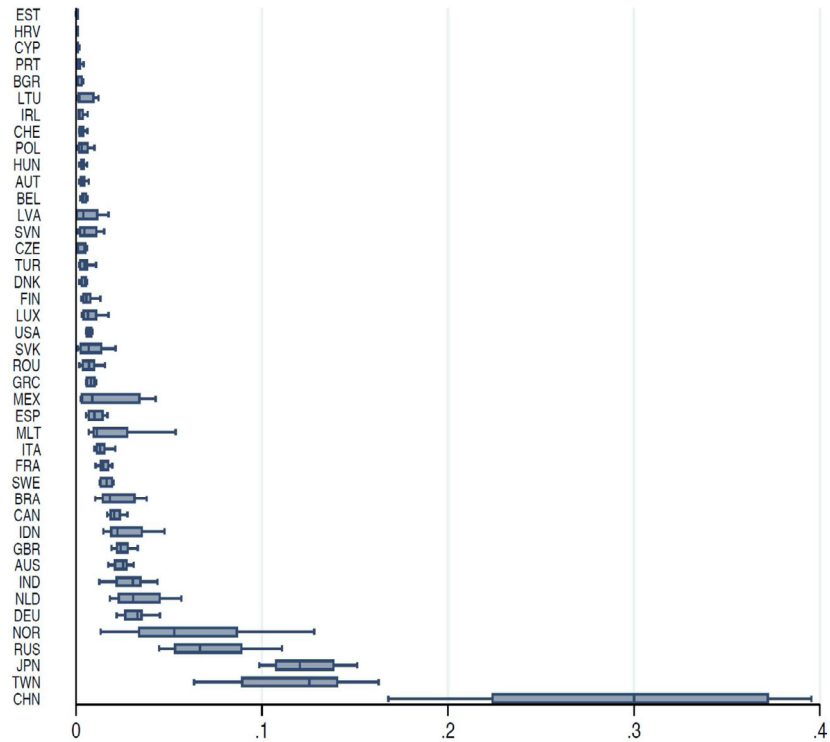
Note: Boxplots of aggregate values of $XFIN_{ij}$ across j. Each plot reports means, interquartile ranges, and extreme values over time.

FIGURE 7

KOREA'S TRADE PARTNERS ON THE BASIS OF *XFIN* (2000-2014)

larger values for more countries than direct trade: Figure 7 suggests that Korea has basically three main partners. Figure 8 suggests there are perhaps seven or eight countries that have tight links with Korea, once indirect trade is allowed. Korea is much more integrated in the world economy than what is suggested by its direct exports, a reflection of its integration in global value chains.

Figures 7 and 8 do not give information on time changes in the distribution of Korea's trade partners. In Figures 9 and 10 we select the top seven trade partners as implied by EII_{ij}, and track the values of $XFIN_{ij}$ and EII_{ij} since 2000. Both figures illustrate the rise of China as Korea's main trade partner. What is interesting is the reversal in the trend for China that is apparent for XFIN and not for EII. In other

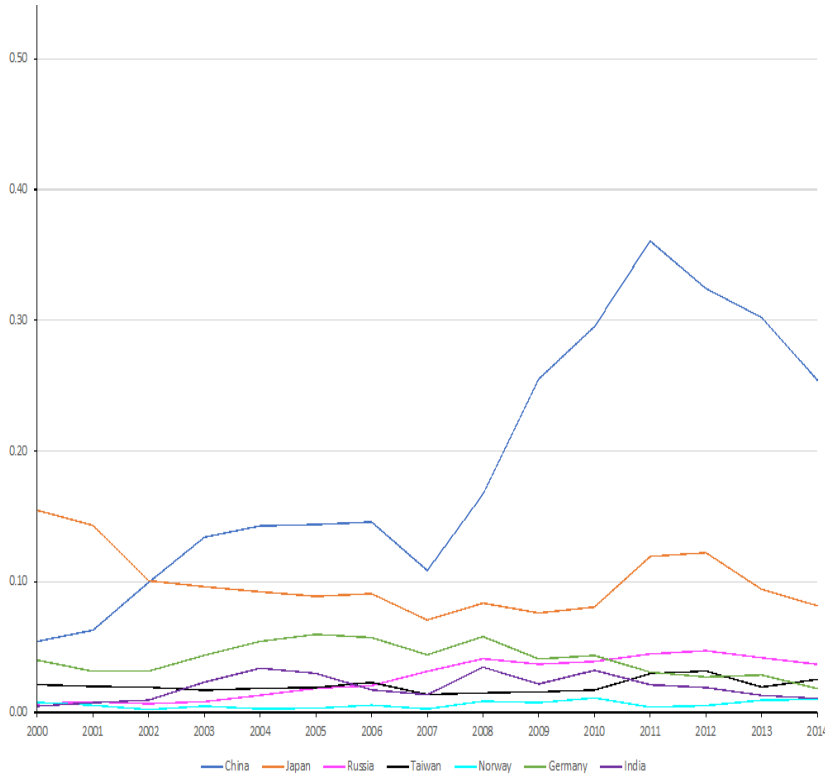


Note: Boxplots of aggregate values of EII_{ij} across j. Each plot reports means, interquartile ranges, and extreme values over time.

FIGURE 8
KOREA'S TRADE PARTNERS ON THE BASIS OF *EII* (2000-2014)

words, China's predominance in Korea's trade started receding from 2011 according to direct trade, but not according to export intensity: Figure 10 shows an uninterrupted upward trend from 2000 to 2014. Both figures also illustrate the vast predominance of China for Korea's trade, far above Japan. In direct trade, this predominance started rising in earnest from 2007, perhaps as direct exports from Korea to China intensified after the Great Financial Crisis. At the time, China started retrenching on its domestic market, and therefore imported more. But in indirect trade, it prevails throughout the period. In other word, while direct trade between Korea and China fluctuates, indirect trade is unambiguously on the rise over the period.

A similar upward trend in EII is visible between Korean and Taiwan.

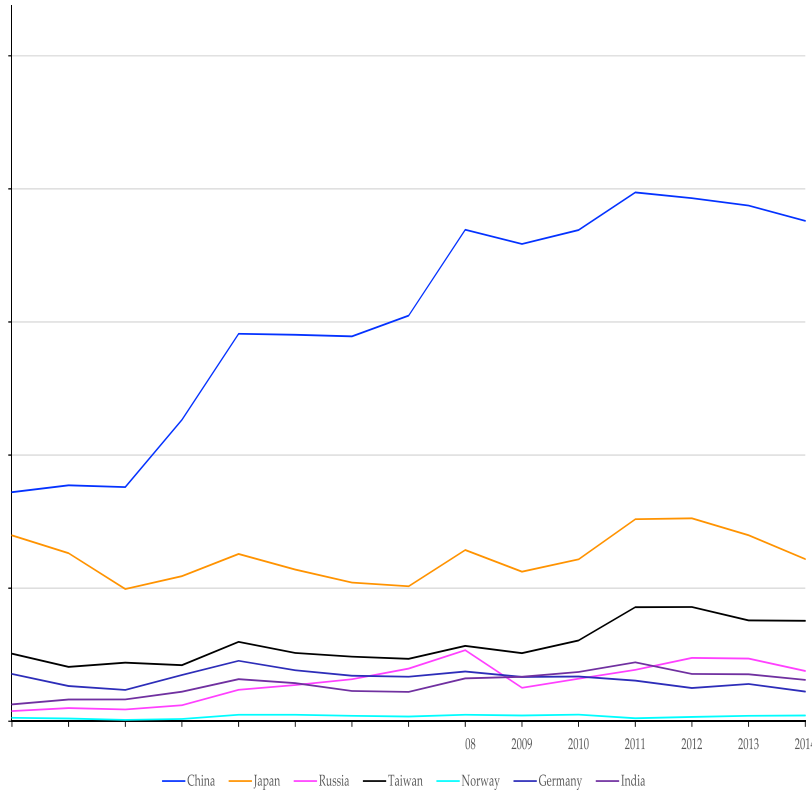


Note: *XFIN* over time for Korea's main trade partners.

FIGURE 9
XFIN OVER TIME, BY TRADE PARTNER

Even though levels are substantially smaller than for China and Japan, Korean indirect trade with Taiwan displays a marked upward trend. In contrast, direct exports to Taiwan are negligible according to XFIN, and they remain so throughout the period. These figures show that the ranking and the evolution of Korea's trade partners both depend crucially on allowances for indirect trade. On the basis of export intensity, China and Taiwan have been increasingly important for Korea since 2000. Not on the basis of conventional measures of direct trade.

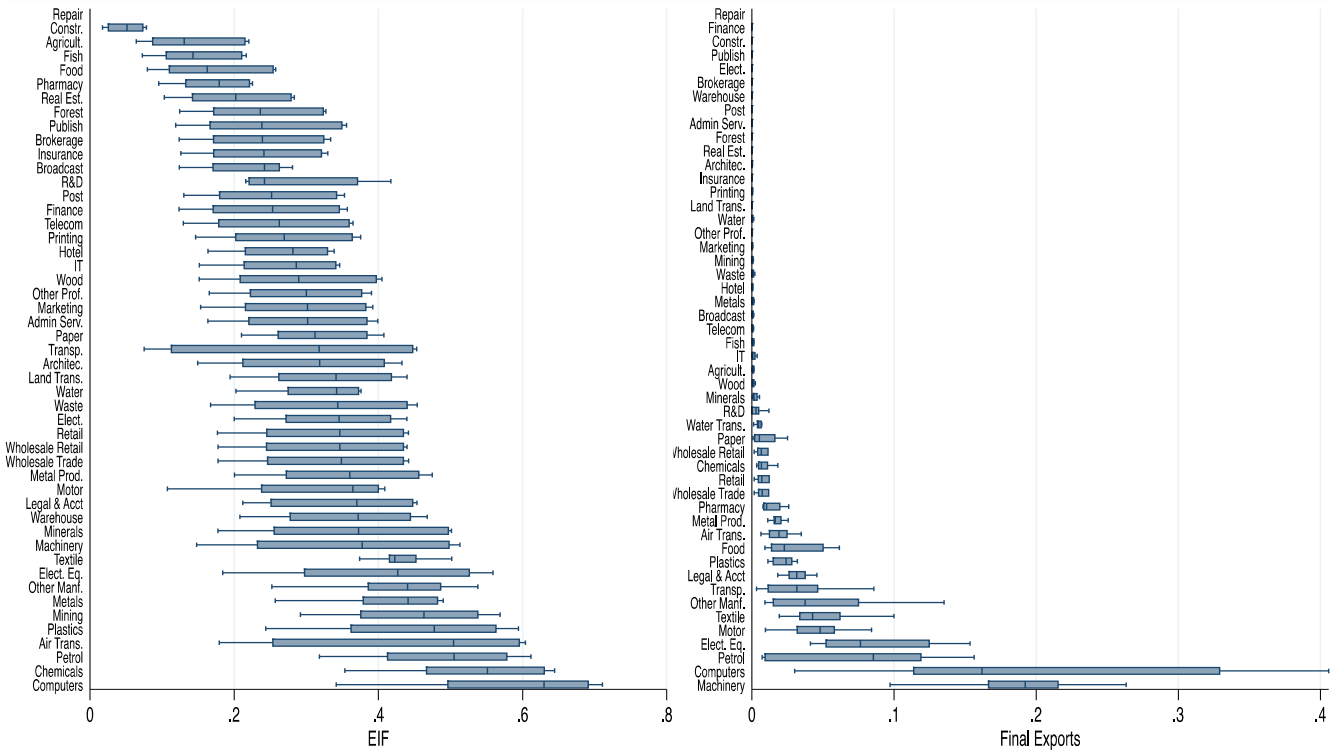
We now focus on Korea's three large trade partners, and combine the unilateral approach with a sectoral breakdown. We report the sector-level distribution of exports according to EII (EII^{r}_{ij} for all r) and XFIN



Note: *EII* over time for Korea's main trade partners.

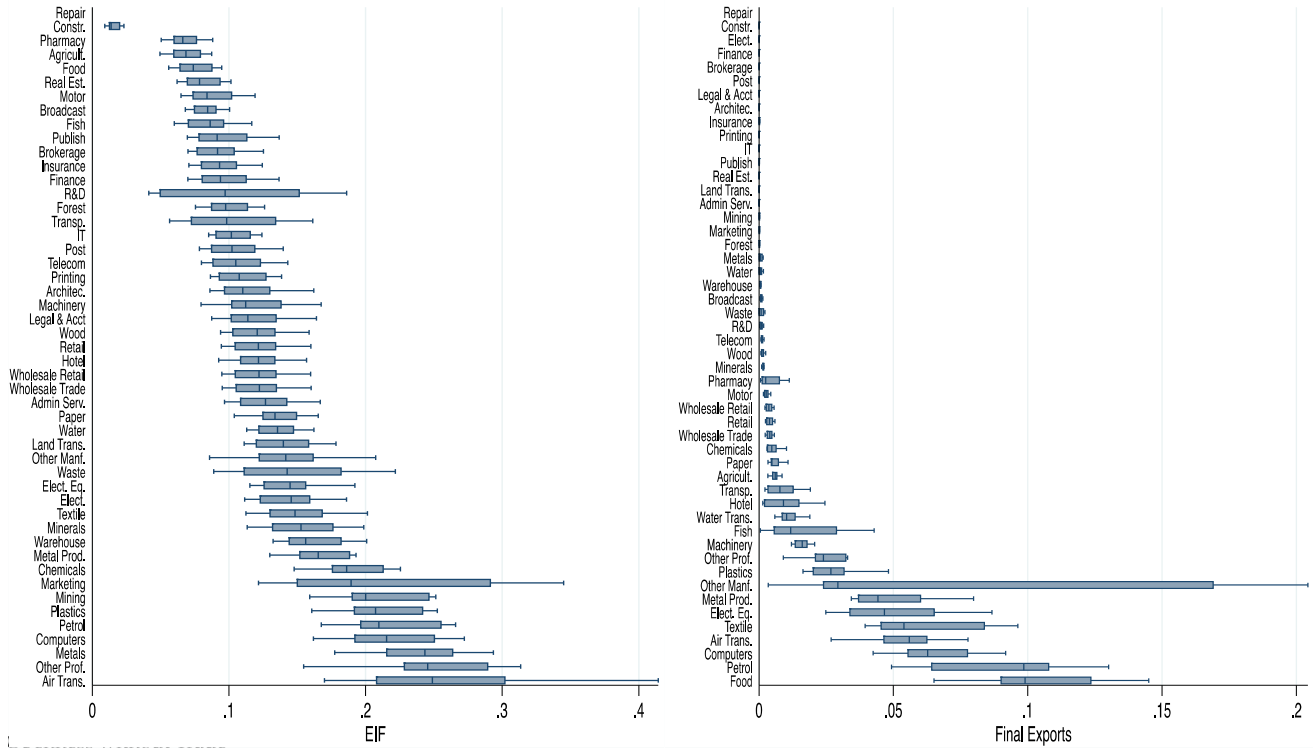
FIGURE 10
EII OVER TIME, BY TRADE PARTNER

($XFIN^r_{ij}$ for all r) for j = China, Japan, and Germany. The corresponding results are reported in Figures 11, 12, and 13. The comparison between the three figures shows the striking extent of bilateral integration between Korea and China, for two reasons. First, EII is systematically much higher for most sectors between Korea and China. All sectors but perhaps the five least open have average values of EII^r_{ij} above 30 percent when j = China, and these values have increased drastically over the period. This is dramatically different from what direct export measures imply, *i.e.*, that only a few manufacturing sectors trade with China. Figure 11 illustrates how the Korean economy is deeply intertwined with the Chinese economy, across all sectors, including a lot of services.



Note: Sector breakdown of EII^{r}_{ij} and $XFIN^{r}_{ij}$ between Korea and China.

FIGURE 11
KOREA AND CHINA (2000-2014)



Note: Sector breakdown of EII^{r}_{ij} and $XFIN^{r}_{ij}$ between Korea and Japan.

FIGURE 12
KOREA AND JAPAN (2000-2014)

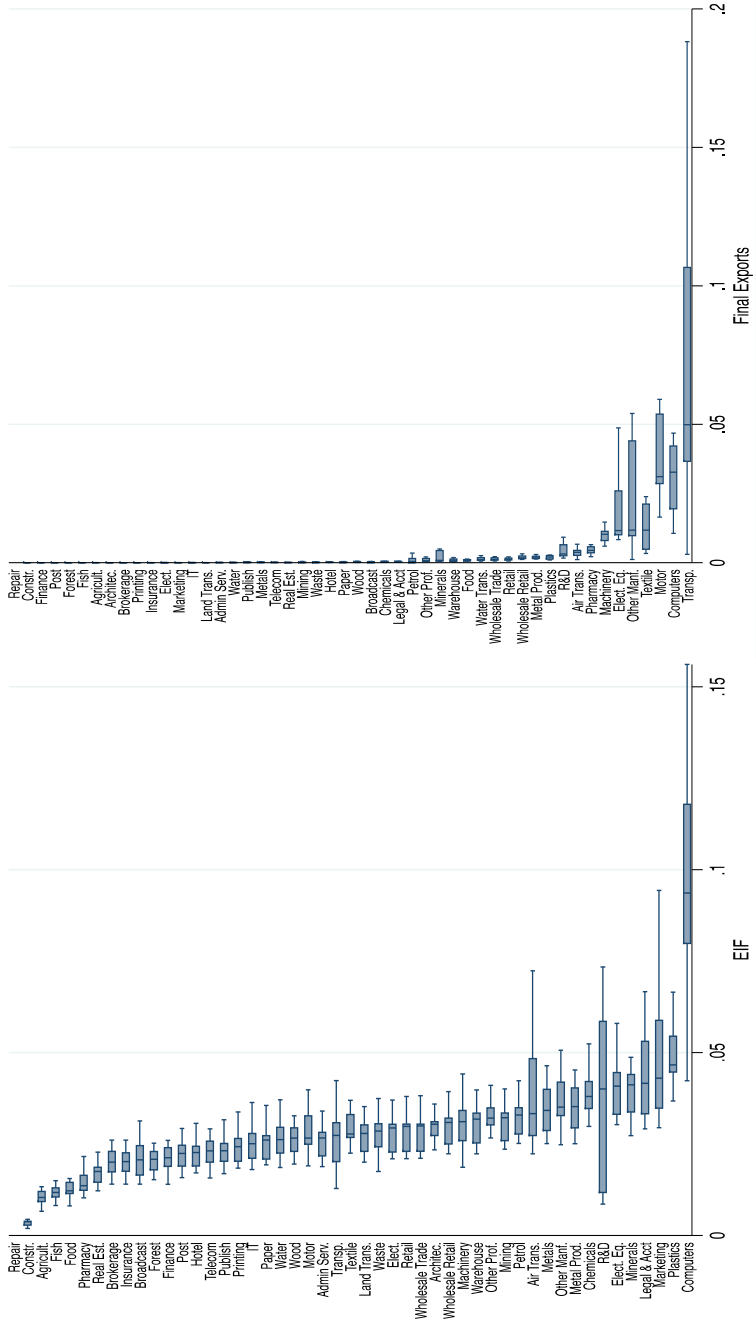


FIGURE 13

KOREA AND GERMANY (2000-2014)

Note: Sector breakdown of EII^{r}_{ij} and $XFIN^{r}_{ij}$ between Korea and Germany.

Second, Figure 12 and 13, focused on Japan and Germany, present sector-level breakdowns that are drastically different from Figure 11. In particular, export intensity is unanimously lower, across all sectors, between Korea and Japan (or Germany) than they are with China. This is focusing on indirect trade: Even with Japan, there are only six (heavy manufacturing) sectors for which EII^{r}_{ij} exceeds 20 percent. And with Germany, all sectors are below 10 percent. The Korean economy is deeply integrated with China, across virtually all of its sectors. This integration exceeds by far that with Korea's second trade partner, Japan. And it has been deepening uninterruptedly since 2000. As the right panels of Figures 11, 12, and 13 show, these facts are simply not apparent when using conventional measures of integration, based on direct trade.

IV. Conclusion

We apply to Korea the measure of openness based on high order trade, labeled Export Intensity (EI), introduced in Imbs and Pauwels (2020). We examine Korea's patterns of trade when measured by EI, vs. when it is measured by more conventional direct trade. We show that Korea's openness has increased uninterruptedly since 2000 when measured with EI, but not when measured by direct trade. This increase is disproportionately caused by China, whose direct imports from Korea have fallen since 2011, but whose indirect imports have risen monotonously since 2000. The extent of Korea's integration with China is vastly greater than with Korea's second trade partner, Japan: It covers most sectors in Korea's economy, including services. At sector level, export intensity takes values two to three times greater between Korea and China than between Korea and Japan or Germany. This is not surprising given the size and proximity of the Chinese economy. But it would not be detectable using standard measures of openness, based on direct trade.

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References

Alcalá, Francisco, and Antonio Ciccone. "Trade and Productivity." *The*

Quarterly Journal of Economics 119 (No. 2 2004): 613–46.

Antràs, P., and D. Chor. "On the Measurement of Upstreamness and Downstreamness in Global Value Chains." In *World Trade Evolution: Growth, Productivity and Employment*, edited by Lili Yan Ing and Miaojie Yu. Routledge (2018).

Antràs, Pol, and Davin Chor. "Organizing the Global Value Chain." *Econometrica* 81 (No. 6 2013): 2127–2204.

Bems, Rudolfs, and Robert C. Johnson. "Demand for Value Added and Value-Added Exchange Rates." *American Economic Journal: Macroeconomics* 9 (No. 4 2017): 45–90.

Bems, Rudolfs, and Ayumu Ken Kikkawa. "Measuring trade in value added with Firm-Level Data." Working Paper Research 378. National Bank of Belgium (2019).

Dietzenbacher, E., B. Los, R. Stehrer, M. P. Timmer, and G. J. de Vries. "The Construction of World Input-Output Tables in the WIOD Project." *Economic Systems Research* 25 (2013): 71–98.

Head, K., and T. Mayer. "The Empirics of Agglomeration and Trade." In *Handbook of Regional and Urban Economics*. North-Holland (2004).

Imbs, Jean, and Laurent Pauwels. "High Order Openness." (2020).

Johnson, Robert C. "Trade in Intermediate Inputs and Business Cycle Comovement." *American Economic Journal: Macroeconomics* 6 (No. 4 2014).

Johnson, Robert C., and Guillermo Noguera. "Accounting for Intermediates: Production Sharing and Trade in Value Added." *Journal of International Economics* 86 (No. 2 2012): 224–36.

Koopman, Robert, Zhi Wang, and Shang-Jin Wei. "Tracing Value-Added and Double Counting in Gross Exports." *American Economic Review* 104 (No. 2 2014): 459–94.