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Trade Linkages and International Business Cycle Comovement: Evidence from Korean Industry Data

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Trade Linkages and International Business Cycle Comovement: Evidence from Korean Industry Data[1]

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Abstract

Through the 2000s, Korea's export and import linkages to advanced and emerging markets increased significantly. At the same time, the correlation of output growth between Korea and these economies rose. This paper investigates the nature of the link between trade linkages and the comovement of international business cycles (BC) using Korean industry-level domestic and international input-output data. The results suggest that, at the industry-level, higher export linkages lead to a larger positive GDP growth comovement, while higher import linkages lead to higher negative employment growth comovement. Furthermore, the decomposition of aggregate BC comovement shows that the increase in trade with China has contributed the most to aggregate BC comovement, while the impact of trade linkages on BC comovement is propagated domestically via vertical linkages. These findings suggest that the Korean economy can be significantly affected by a few countries that are highly linked through trade to Korea and/or a few industries that are highly interconnected to other industries.

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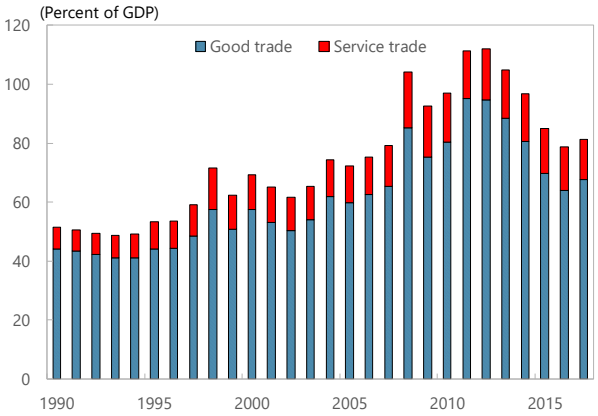
I. Introduction

Korea's participation in global trade increased dramatically during the 1990s and 2000s: that is, trade openness (i.e., the share of trade to GDP) almost doubled from 1990 to 2011 (the peak), mainly through the rise of goods trade, while it started to decline from 2012 (left panel of Figure 1). At the same time, the production structure became more vertical, as intermediate input accounts for an increasing share of total output. The share of intermediate input increased by about 10 percentage points from 2000 to 2012 (the peak), mainly through the rise of intermediate input trade (right panel of Figure 1).[2]

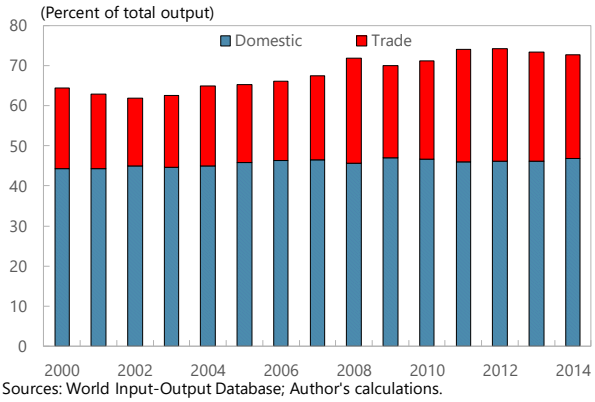
Figure 1. Trade and Vertical Linkage

<Trade openness>



Sources: World Development Indicators.

<Intermediate input share>



Sources: World Input-Output Database; Author's calculations.
Notes: Domestic and trade linkages denote domestic intermediate input purchase-to-total output ratio and intermediate input trade-to-total output ratio, respectively.

Over the 2000s, Korea's trade linkages showed a large increase, while in the same period, Korea's growth correlation with many advanced and emerging economies also increased. For instance, the comparison of export and import linkages between, before, and after the GFC documents that both export and trade linkages rose substantially in the manufacturing sector. However, vertical linkages, both upstream and downstream, remained stable at high levels over the 2000s. The highly connected network structure between firms (Gabaix 2010) or industries (Acemoglu et al. 2016a) within a country plays an important role in the transmission of microeconomic shocks to the whole economy. As trade linkages to other countries increase, the interdependence among economies becomes more important than in the past, which is expected to lead to the amplification of economic shocks and an increase of business cycle (BC) comovement.

The present paper explores the role of trade and vertical linkages in Korea's BC comovement with its trading partners. Trade and vertical linkages are expected to affect BC comovement at the industry-level, which in turn impacts the aggregate comovement. We use industry-level data on input, output, and trade from the World Input-Output Database (WIOD) for the period 2000-2014. As pointed out by di Giovanni and Levchenko (2010), examining cross-border BC comovement at the industry-level has advantages relative to looking directly at GDP growth correlations. First, the inclusion of a rich set of fixed effects (country and industry fixed effects) to control for many possible unobservable country- and industry-specific characteristics can help

[2] The trend of global value chains (GVCs) in Korea is broadly consistent with that of global economy over the 2000s: that is, (i) acceleration before the Global Financial Crisis (GFC); (ii) a significant decline during the GFC (2008-2009); (iii) a short recovery during 2010-2011; and (iv) a mild reversal afterwards (e.g., Degain et al. 2017).

reduce the concerns of omitted variables and simultaneity in estimation. Second, using industry-level input-output linkages, we can further investigate the role of vertical production linkages across industries in international BC comovement.

Economic growth can be affected by foreign countries' economies and thus tends to comove with its trading partners' GDP growth in two different channels: (i) a direct channel via direct export/import linkages to a particular country, and (ii) an indirect channel via upstream/downstream linkages to other industries that are trading with a foreign country. These channels can play a crucial role in the transmission of economic shocks from a trading partner to a domestic industry, which in turn leads to BC comovement between Korea and its trading partners.

The main results of this paper are summarized as follows. The international BC comovement is observed at the industry-level in Korea: (i) industry that is highly export-linked to a country (either directly or indirectly) exhibits stronger comovement with the country's GDP growth; (ii) industry that is highly import-linked to a country exhibits stronger negative comovement with that country's employment growth; and (iii) the results are robust across country coverages (42 countries or 10 largest trading partners), but they show differentiation across industry sectors (manufacturing or services). Having established these results, we quantify the relative importance of the various channels for aggregate BC comovement: (i) the increase in trade with China contributed the most to aggregate BC comovement; and (ii) the impact of trade linkages on BC comovement was propagated domestically via vertical linkages, especially through upstream linkages. The findings imply that the Korean economy can be significantly affected by a few countries that are highly trade-linked and/or a few industries (being also dominated by a few large firms) that are highly linked to other industries and account for a large share of international trade.

The structure of this paper is as follows. The next section reviews related literature and discusses contributions of this paper. Section III presents data and some stylized facts on trade and vertical linkages of the Korean economy and BC comovement with a global economy. Section IV estimates the role of trade and vertical linkages in determining BC comovement and quantifies the relative importance of various channels for aggregate BC comovement. Section V concludes and provides a discussion of policy implications.

II. Related Literature

The rise of trade openness and intermediate input share may have important macroeconomic implications, in terms of economic growth and stability. The macroeconomic impacts of the rise of economic linkages have attracted increasing attention recently. In the domestic context, one class of literature studied how shocks to firms or sectors can spread to other firms or sectors through a network of input-output linkages, which will lead to larger macroeconomic impacts. Network-based theoretical research finds that macroeconomic fluctuations are primarily the result of many microeconomic shocks at the industry- or firm-level (e.g., Carvalho 2010; Gabaix 2011; Acemoglu et al. 2012).

Moreover, recent research has attempted to examine empirical evidence on the transmission of industry-level shocks (e.g., Chinese import penetration) to the US economy through input-output linkages, using the US industry-level data (Acemoglu et al. 2016a, 2016b). They find that the increased Chinese import penetration into the US economy has negative impacts on valued added and employment in US industry, and the negative impact is larger for the industries of

high upstream exposure to Chinese imports. By explicitly considering downstream and upstream effects of imports from China and using exporter-specific information to allocate Chinese imports to the downstream sectors in the U.S., Wang et al. (2018) find that contrary to Acemoglu et al. (2016b), the employment effects from trading with China is found to be positive. The most important factor is employment stimulation through the downstream channels in non-manufacturing sectors. Ahn and Duval (2016) also study the impact of export and import with China on its trading partners and document the positive impacts of Chinese trade on productivity and the adverse impacts of Chinese imports on employment. Meanwhile, complementary to this paper, Lee (2019) studies the role of vertical and trade linkages in propagating domestic and external growth shocks, using Korean industry-level input-output data. The paper finds that domestic industry shocks are transmitted mainly through downstream linkages while external export shocks are propagated through direct export linkages.

Other studies in the literature on the effects of economic interlinkages focus on BC comovement through trade and vertical linkages, which is more closely related to this paper. Network interlinkage may lead to domestic and international comovement in business cycles. Domestic comovement in a sectoral business cycle may be found to be due to either common shocks or to vertical linkages that propagate shocks across sectors. Shea (2002) documents that input-output linkages, not common shocks, played an important role in sectoral comovement in the U.S.

On the international comovement in business cycles, Frankel and Rose's (1998) seminal paper uncovers a well-known empirical regularity: that is, countries that trade more with each other exhibit higher business cycle correlation. However, Imbs (2004) criticizes that Frankel and Rose's (1998) result may be driven by common shocks that happen to be stronger for country pairs that trade more with each other. In addition, some quantitative literature has difficulty capturing the trade-comovement relationship, known as the "trade-comovement puzzle" (Kose and Yi 2006; Johnson 2014). This puzzle has been addressed by recent empirical analyses to examine the micro origins of international BC comovement using industry-level data (di Giovanni and Levchenko 2010) and firm-level data (di Giovanni et al. 2018). The results, when controlling for common shocks by a rich set of fixed effects, still reveal clear evidence of positive international trade comovement relationships driven by a transmission of shocks at the industry- or firm-level through trade and vertical linkages.

This paper contributes to the literature by applying the analyses of international BC comovement to the Korean economy. It modifies the empirical model of di Giovanni and Levchenko (2010) and di Giovanni et al. (2018) to explore the impacts of the rise in trade linkages on BC comovement in Korea, which is highly dependent on international trade and is exposed to drastic changes in GVCs, especially with its top three trading partners, China, the U.S., and Japan. The industrial analysis of the Korean economy's international BC comovement is expected to shed light on the potential transmission channels of external economic shocks to the Korean economy. Nevertheless, identification of the important channels for global shock propagations would provide some feasible policy responses to attenuate the adverse effects from external shocks. In addition, this paper is unique in analyzing the role of changes in trade linkages in determining international BC comovement, while previous literature focused on the role of the different levels of trade linkages at the industry- or firm-level. The paper also contributes to the literature

by separately identifying: (i) export and import channels; and (ii) differentiated roles of trade and vertical linkages in BC comovement for GDP and employment.[3]

III. Data and Descriptive Statistics

A. Data

The industry-level data on input, output, value added, and international trade are taken from the WIOD (2016 release), which contains the World Input-Output Tables (WIOT) and the Socio-Economic Accounts (SEA) (see Table A.1 in Appendix A for data descriptions and sources). The WIOT is an extension of a national input-output table made by combining national supply and use tables and various trade databases. It covers 56 industries for each of the 43 countries over 15 years (2000-2014).[4] This paper focuses on the comovement of economic activities between Korea and its trading partners, with a special focus on the largest three trading partners, China, the U.S., and Japan. For this purpose, we combine or drop some industries, based on the availability of reliable data, which leads to 38 industry classifications (see Table A.2 in Appendix A for detailed industry classifications used in this paper).[5] The data cover the time period of 2000-2014 with classification of two subperiods by the GFC for the empirical analysis—that is, pre-GFC (2000-07) and post-GFC (2009-14).[6]

B. Trade and Vertical Linkages

This subsection presents descriptive statistics on trade and vertical linkages, focusing on changes in these variables between, before, and after the GFC. For expositional purposes, we focus on Korea's largest three trading partners and four broad classifications of industry sectors, including agriculture (agriculture, forestry, and fishing), manufacturing, non-manufacturing (mining/quarrying, electricity/gas, water supply, and construction), and services.

Key variables of interest are the determinants of Korea's BC comovement with the global economy, such as trade (export and import) linkages and vertical (upstream and downstream) linkages, with a focus on changes in these variables and the implications for BC comovement. Export (import) linkages are measured as the share of intermediate input export (import) to gross

[3] An earlier study at the industry-level analyzes the role of overall trade linkages in determining BC comovement (di Giovanni and Levchenko 2012). However, a more recent firm-level study analyzes the role of export and import linkages separately (di Giovanni et al. 2018).

[4] For construction method and source databases, see Timmer et al. (2016). The countries included in this database are Australia, Austria, Belgium, Brazil, Bulgaria, Canada, China, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Malta, Mexico, Netherlands, Norway, Poland, Portugal, Romania, Russia Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Taiwan, Turkey, U.K., and U.S.

[5] It should be noted that several industries, for which data are available but the growth rate of industry value added are found to be identical, are combined. For these industries, it is suggested that originally separate industry-level value added data are unavailable but extrapolation with a growth rate may have been used to produce separate data for value added levels.

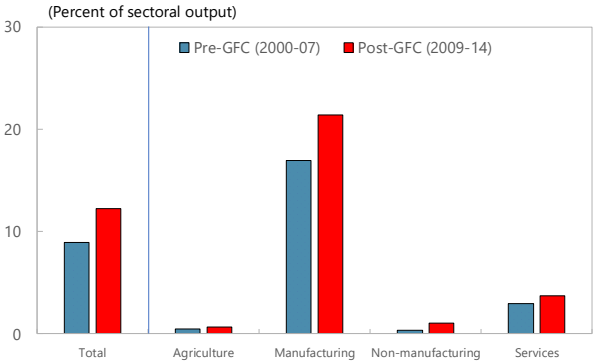
[6] We exclude the year 2008 in classification of two subperiods to mitigate large disturbances in data owing to the GFC.

(continued…)

output.[7] Figure 2 illustrates that Korea's overall export and import linkages to the global economy reflected an increase, after the GFC, in all four sectors (agriculture, manufacturing, non-manufacturing, and services). The rise of export linkage is particularly prominent in manufacturing, while that of import linkage shows a relatively pronounced rise in both manufacturing and non-manufacturing sectors. Nevertheless, it should also be noted that the level of export linkage is particularly high in manufacturing and that of import linkage is substantially higher in manufacturing and non-manufacturing sectors than in the other sectors.

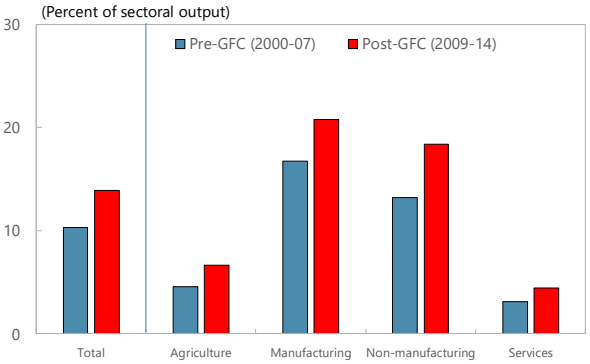
Figure 2. Trade Linkage: Sectoral

<Export linkage>



Sources: World Input-Output Database; Author's calculations.
Notes: Agriculture includes Agriculture, Forestry, and Fishing; Non-manufacturing includes Mining/Quarrying, Electricity/Gas, Water Supply, and Construction.

<Import linkage>



Sources: World Input-Output Database; Author's calculations.
Notes: Agriculture includes Agriculture, Forestry, and Fishing; Non-manufacturing includes Mining/Quarrying, Electricity/Gas, Water Supply, and Construction.

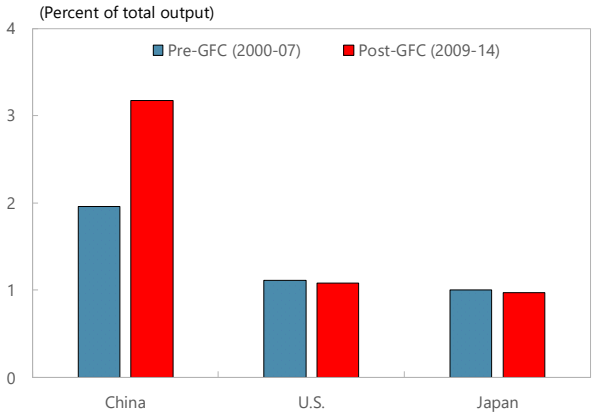
We now turn our attention to bilateral export and import linkages to Korea's three major trading partners: China, the U.S., and Japan.[8] Export and import linkages to China showed a significant increase in the post-GFC period, while those to the U.S. and Japan remained stable through the 2000s (Figure 3). The substantial increase of trade linkages to China over the 2000s may relate to the growing emergence of China's presence in the global economy, especially after China joined the World Trade Organization (WTO) in 2001. As a result of the large increase of trade linkages to China during the 2000s, the level of export linkages to China is about three times higher than that to the U.S. or Japan, and the level of import linkages to China is also the highest among these countries.

[7] We focus here on intermediate input trade, as the vertical specialization across countries is an important, growing feature of the world economy (Hummels et al. 2001; Hanson et al. 2005), and intermediate inputs account for roughly 60 percent of international trade (Johnson 2014). However, it should be noted that overall trade—including both intermediate input and final goods/services—also shows similar trends and relative levels of trade linkages across industry sectors.

[8] Top three countries accounted for 42.6 percent of Korea's total trade (sum of exports and imports) in 2018: China (23.6 percent), the U.S. (11.6 percent), and Japan (7.5 percent) (K-stat, Korea International Trade Association).

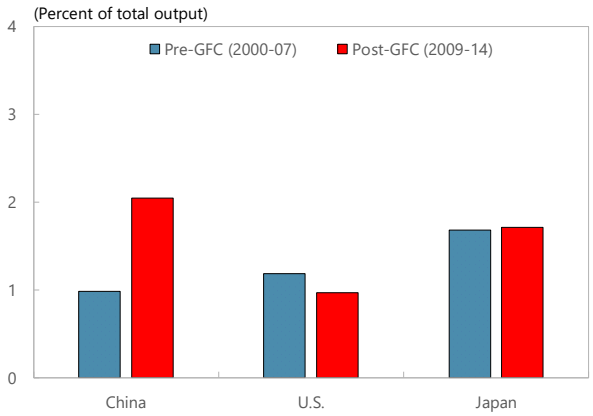
Figure 3. Trade Linkage: Bilateral

<Export linkage>



Sources: World Input-Output Database; Author's calculations.

<Import linkage>

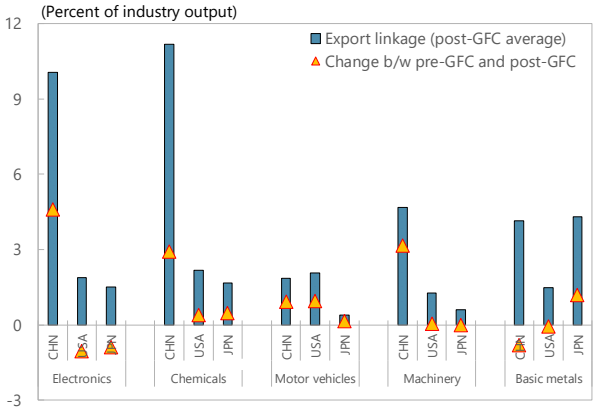


Sources: World Input-Output Database; Author's calculations.

Figure 4 reflects more detailed industry-level trade linkages to China, the U.S., and Japan for the top five manufacturing industries that account for the highest contributions to growth (i.e., electronics, chemicals, motor vehicles, machinery, and basic metals).[9] It shows that export and import linkages to China showed the greatest increase through the 2000s in most major industries, while those to the U.S. and Japan remained stable or even declined in some industries, which is consistent with the country-level trade linkages in Figure 3. In terms of the level of trade linkages, it differs across industries. Electronics are the most highly-linked to China in both exports and imports, while motor vehicles are highly export-linked to the U.S. and chemicals are highly import-linked to Japan.

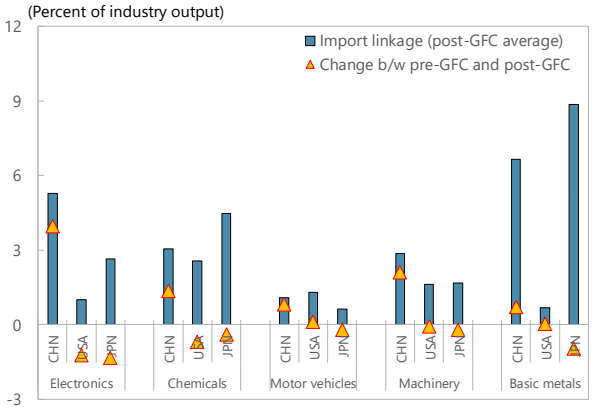
Figure 4. Trade Linkage: Top 5 Manufacturing Industries

<Export linkage>



Sources: World Input-Output Database; Author's calculations.

<Import linkage>



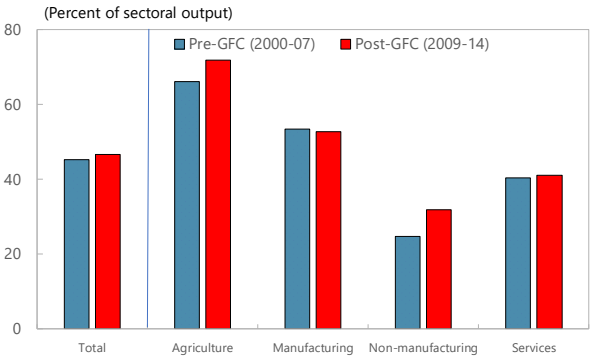
Sources: World Input-Output Database; Author's calculations.

[9] The largest five industries are determined based on their share of GDP in 2014: (i) Electronics includes "Computer, electronic and optical products (C26)," and "Electrical equipment (C27);" (ii) Chemicals includes "Chemical and chemical products (C20)" and "Basic pharmaceutical products and preparations (C21)"; (iii) Motor vehicles includes "Motor vehicles, trailers and semi-trailers (C29)" and "Other transport equipment (C30)"; (iv) Machinery refers to "Machinery and equipment (C28)"; and (v) Basic metals refers to "Basic metals (C24)" in Table A.2.

Finally, we examine how vertical linkages in domestic markets evolved. Upstream (downstream) linkage is defined as the share of intermediate input supply (purchase) to (from) other industries, which measures the intensity of connectedness to other industries as upstream sellers (downstream buyers). The upstream and downstream terminology in network literature has some ambiguity. Throughout the paper, we use upstream linkage as the connectedness to buyers of an industry that shocks to a buyer flow up the input-output network, while we label downstream linkage as the connectedness to sellers of an industry that shocks to a seller flow down the input-output chain as in the existing literature (e.g., Acemoglu et al. 2016a; di Giovanni et al. 2018). Over the 2000s, both upstream and downstream linkages remained stable in the manufacturing and service sectors, while they showed a mild increase in the agriculture and non-manufacturing sectors. This implies that the significant increase of vertical linkages occurred mostly during the 1990s when the Korean economy was growing fast, while over the 2000s, the economic interconnectedness rose mostly through the rise of trade linkages. At the level of vertical linkages, both upstream and downstream linkages are relatively high in manufacturing, while upstream linkages are highest in agriculture.

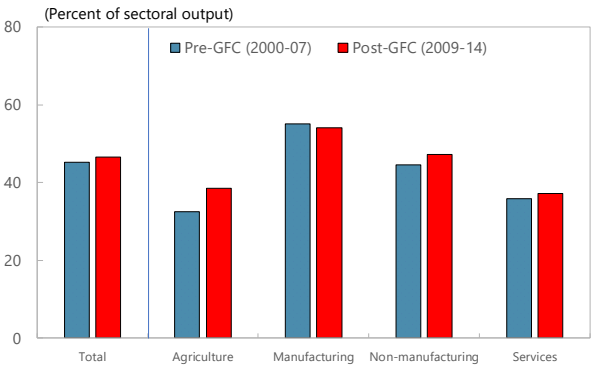
Figure 5. Vertical Linkage: Sectoral

<Upstream linkage>



Sources: World Input-Output Database; Author's calculations.
Notes: Agriculture includes Agriculture, Forestry, and Fishing; Non-manufacturing includes Mining/Quarrying, Electricity/Gas, Water Supply, and Construction.

<Downstream linkage>

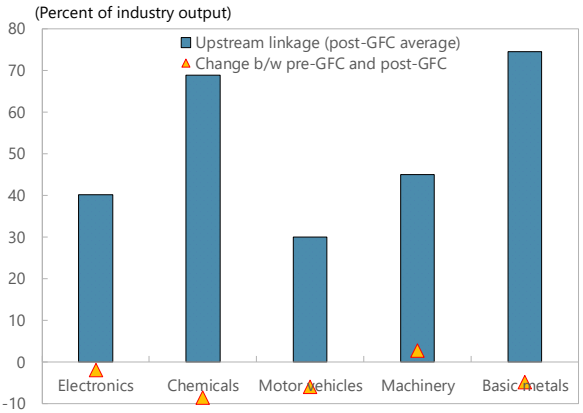


Sources: World Input-Output Database; Author's calculations.
Notes: Agriculture includes Agriculture, Forestry, and Fishing; Non-manufacturing includes Mining/Quarrying, Electricity/Gas, Water Supply, and Construction.

Figure 6 describes the more detailed industry-level vertical linkages for the top five manufacturing industries making the highest contribution to growth. Downstream linkages are high in these industries relative to overall manufacturing, while upstream linkages are relatively high in chemicals and basic metals. Similar to overall manufacturing, both upstream and downstream linkages were stable over the 2000s in most individual industries.

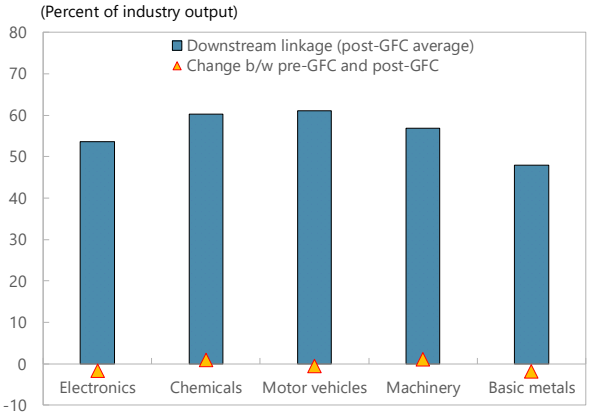
Figure 6. Vertical Linkage: Top 5 Manufacturing Industries

<Upstream linkage>



Sources: World Input-Output Database; Author's calculations.

<Downstream linkage>



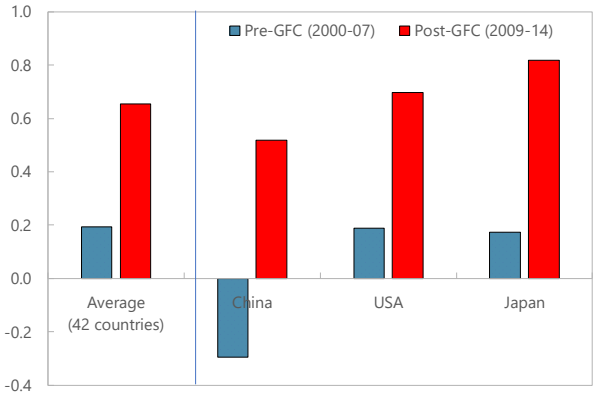
Sources: World Input-Output Database; Author's calculations.

C. International Business Cycle Comovement

This subsection studies the descriptive correlations in GDP growth and in employment growth between Korea and its trading partners (i.e., international BC comovement) which are the key relationships this paper attempts to address. Figure 7 shows that on average, GDP growth correlation with 42 countries significantly increased after the GFC, including Korea's major trading partners, China, the U.S., and Japan. At the individual country-level, we find stronger BC comovement with most sample countries after the GFC.

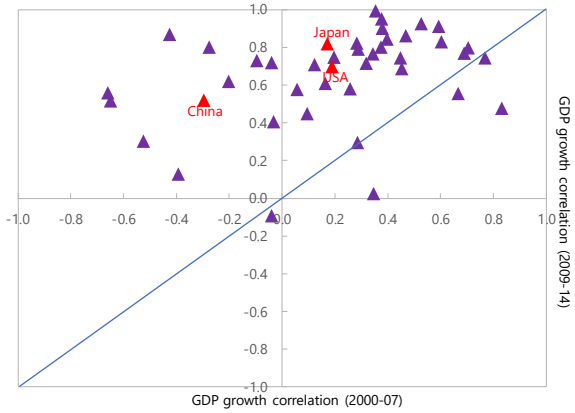
Figure 7. GDP Growth Correlation

<Top 3 trading partners>



Sources: World Input-Output Database; Author's calculations.

<42 sample countries>

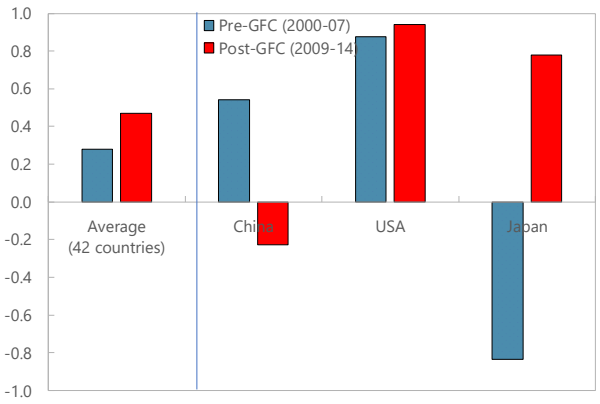


Sources: World Input-Output Database; Author's calculations.

Figure 8 describes Korea's employment growth correlation with a global economy. On average, the employment growth correlation increased somewhat after the GFC, while comovement in employment growth shows substantial variation across trading partners. More specifically, the employment correlation with some countries, including the U.S. and Japan, increased while comovement with others, including China, shows a decline after the GFC. Notably, the employment correlation with China turned from positive to negative. The quite different movements in GDP and employment growth correlations imply that divergent driving forces may have played more important roles in determining international BC comovement in GDP growth and in employment growth.

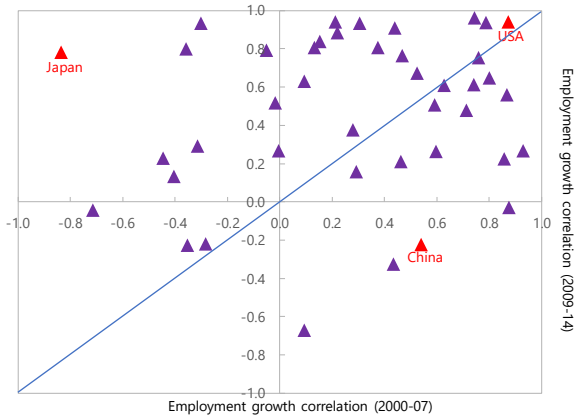
Figure 8. Employment Growth Correlation

<Top 3 trading partners>



Sources: World Input-Output Database; Author's calculations.

<42 sample countries>



Sources: World Input-Output Database; Author's calculations.

IV. Trade Linkages and International Business Cycle Comovement

This section investigates the empirical relationship between trade linkages and Korea's BC comovement with a global economy, and the role of vertical linkages in this relationship. In doing so, we attempt to identify the main economic factors behind BC comovement and further, to find its macroeconomic implications for the Korean economy.

A. Empirical Specification

We first establish a theoretical relationship for the empirical estimation. The growth rate of aggregate value added of Korea (y_{At}) can be rewritten as a function of value-added growth rates of each industry and its share in total value added:

$$y_{At} = \sum_i w_{it}\, y_{it} \qquad (1)$$

where y_{it} is the growth rate of value added of industry i, and w_{it} is the share of i's value added in total value added. Similarly, the equation applies to the relationship between growth rates of total employment and industry employment.

The correlation between Korean aggregate growth and the foreign country's GDP growth (y_{Ct}) is given by:

$$\rho(y_{At}, y_{Ct}) = \frac{\mathrm{cov}(y_{At}, y_{Ct})}{\sigma_A \sigma_C} = \frac{\mathrm{cov}(\sum_i w_{it} y_{it}, y_{Ct})}{\sigma_A \sigma_C} = \sum_i w_{it} \frac{\sigma_i}{\sigma_A} \rho(y_{it}, y_{Ct}) \qquad (2)$$

where σ_A, σ_C, and σ_i denote the standard deviation of y_{At}, y_{Ct}, and y_{it}, respectively. Equation (2) states that the aggregate correlation between the Korean economy and a foreign country is a weighted sum of the industry-level correlations. We analyze the properties of individual industry-level correlations $\rho(y_{it}, y_{Ct})$, and we can obtain the macroeconomic implications by aggregating industry-level correlations across industries. By first-differencing Equation (2) under

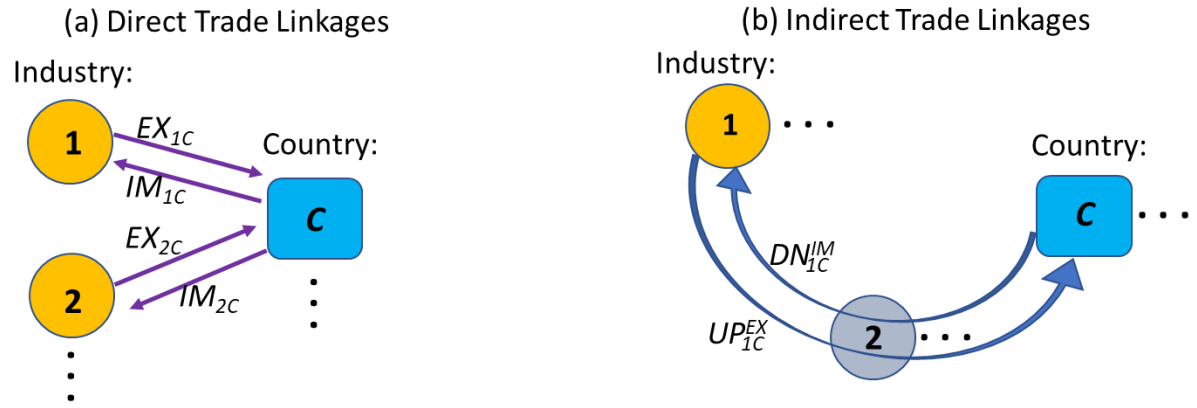
the assumption of constant $\bar{\sigma}_A$, $\bar{\sigma}_i$, and $\bar{w}_i$ between pre-GFC and post-GFC periods, we establish the following equation:[10]

$$\Delta\rho(y_{At}, y_{Ct}) = \sum_i \bar{w}_i \frac{\bar{\sigma}_i}{\bar{\sigma}_A} \Delta\rho(y_{it}, y_{Ct}) \quad (3)$$

This paper adopts the key empirical specification of di Giovanni and Levchenko (2010) and di Giovanni et al. (2018) to study the relationship of international BC comovement and trade linkages, in which industry-level and firm-level data are respectively used. We apply the main features of these papers to Korea's industry-level BC comovement with a global economy. As described in Section II, trade linkages experienced a significant change after the GFC: that is, export and import linkages increased dramatically after the GFC, along with the rise in Korea's participation in GVCs. At the same time, Korea's GDP correlation with the global economy and trading partners significantly increased.

Against this background, we attempt to test whether the rise of trade linkages played a significant role in the increase of Korea's BC comovement with its trading partners. If so, we further attempt to identify which channels—such as, exports or imports, and direct or indirect—made a significant contribution to the rise of BC comovement. Domestic industry growth can be affected by foreign countries' economies and thus tends to comove with its trading partners' GDP growth in two different channels: (i) a direct channel via direct export/import linkages to a particular country (Figure 9(a)), and (ii) an indirect channel via upstream/downstream linkages to other industries that are trading with a foreign country (Figure 9(b)).[11] These channels can play a crucial role in the transmission of economic shocks from a trading partner to a domestic industry, which in turn leads to BC comovement between Korea and its trading partners.

Figure 9. Direct and Indirect Linkages to Foreign Countries



Here EX_{iC} is the export intensity of industry *i* with country *C* (the share of *i*'s input export to *C* in *i*'s gross output), IM_{iC} is the import intensity of industry *i* with country *C* (the share of *i*'s

[10] Although the standard deviations of country- and industry-level GDP growth (σ_A and σ_i) and industry share (w_{it}) can vary non-negligibly in the long run, we can assume that the variation of these variables has been negligible over the 2000s.

[11] This paper considers only direct (first-order) trade and vertical linkages between Korea and other countries as well as between two industries, as in the existing literature (e.g., Acemoglu et al. 2016b; di Giovanni and Levchenko 2010; di Giovanni et al. 2018; Wang et al. 2018). For simplicity and empirical identification purposes, we assume indirect (higher-order) effects are not likely to be large empirically, although Acemoglu et al. (2016a) and other network literature introduce both direct and indirect trade and/or vertical linkages using a Leontief inverse matrix.

input import from *C* in *i*'s gross output), *UP* and *DN* stand for upstream and downstream linkages while superscripts *EX* and *IM* denote export and import linkages. We construct the industry-specific indices for indirect trade linkages that follow the terms in the context of "network effect" propagation adopted in Acemoglu et al. (2016a) and di Giovanni et al. (2018):

$$UP_{iC}^{EX} = \sum_j IO_{ij} \times EX_{jC} \quad (4)$$

$$DN_{iC}^{IM} = \sum_j IO_{ji} \times IM_{jC} \quad (5)$$

where IO_{ij} (upstream linkage) is defined as the share of i's input supply to j in i's gross output, and IO_{ji} (downstream linkage) denotes the share of j's input supply to i in i's gross output, respectively. Industry i can be indirectly linked to country C through its upstream linkage to industry j, which is connected in export relation with country C (UP_{iC}^{EX}). Similarly, industry i can be indirectly linked to country C through its downstream linkage to industry j which in turn is linked in import relation with country C (DN_{iC}^{IM}).

For the empirical analysis, we first consider only the direct channels of BC comovement presented in Figure 9(a). The following empirical specifications, separately for pre-GFC and post-GFC, are established to investigate whether the industry-level direct trade linkages to a foreign country are associated with a higher GDP correlation between the industry and that country.

$$\rho^{pre}(y_{it}, y_{Ct}) = \alpha^{pre} + \beta_1 EX_{iC}^{pre} + \beta_2 IM_{iC}^{pre} + \mu_i^{pre} + \delta_C^{pre} + \varepsilon_{iC}^{pre} \quad (6)$$

$$\rho^{post}(y_{it}, y_{Ct}) = \alpha^{post} + \beta_1 EX_{iC}^{post} + \beta_2 IM_{iC}^{post} + \mu_i^{post} + \delta_C^{post} + \varepsilon_{iC}^{post} \quad (7)$$

where EX_{iC} and IM_{iC} denote the export and import intensities defined above. μ_i, δ_C, and ε_{iC} denote industry fixed effects, country fixed effects, and error terms, while superscripts *pre* and *post* denote pre-GFC and post-GFC periods, respectively. We assume different industry and country fixed effects for pre-GFC and post-GFC periods, because industry-specific and country-specific fixed effects in determining international BC correlations may have experienced substantial changes in the aftermath of the GFC.

By subtracting Equation (6) from Equation (7) (i.e., by first-differencing the relationships between pre-GFC and post-GFC periods), we establish the following empirical specification:

$$\Delta\rho(y_{it}, y_{Ct}) = \alpha + \beta_1 \Delta EX_{iC} + \beta_2 \Delta IM_{iC} + \mu_i + \delta_C + \varepsilon_{iC} \quad (8)$$

We further consider the role of indirect channels via vertical (domestic) linkages in determining international BC comovement: that is, both direct and indirect channels presented in Figures 9(a) and 9(b) are considered. In addition to direct trade channels, trade linkages are expected to affect BC comovement through indirect trade linkages via vertical linkages (Figure 9(b)). These indirect trade channels likely become more important if an industry is more vertically interconnected (both upstream and downstream) within the Korean economy. Given the stable vertical linkages over the 2000s, we can define the changes in indirect linkages above as:

$$\Delta UP_{iC}^{EX} = \sum_j IO_{ij} \times \Delta EX_{jC} \quad (9)$$

$$\Delta DN_{iC}^{IM} = \sum_j IO_{ji} \times \Delta IM_{jC} \quad (10)$$

Thus, by extending Equation (8) to consider these indirect channels, the extended empirical specification is established as:[12]

$$\Delta\rho(y_{it}, y_{Ct}) = \alpha + \beta_1 \Delta EX_{iC} + \beta_2 \Delta IM_{iC} + \beta_3 \Delta UP_{iC}^{EX} + \beta_4 \Delta DN_{iC}^{IM} + \mu_i + \delta_C + \varepsilon_{iC} \quad (11)$$

Finally, we extend the above relationships to investigate the macroeconomic implications of these industry-level findings. Using the estimates of the above Equations (8) and (11), we can decompose the estimated change in industry-level correlations with a particular foreign country to the changes in direct trade linkages and in indirect trade linkages as:

$$\widehat{\Delta\rho}(y_{it}, y_{Ct}) = \widehat{\beta_1} \Delta EX_{iC} + \widehat{\beta_2} \Delta IM_{iC} \quad (12)$$

$$\widehat{\Delta\rho}(y_{it}, y_{Ct}) = \widehat{\beta_1} \Delta EX_{iC} + \widehat{\beta_2} \Delta IM_{iC} + \widehat{\beta_3} \Delta UP_{iC}^{EX} + \widehat{\beta_4} \Delta DN_{iC}^{IM} \quad (13)$$

By combining Equations (12) and (13) with Equation (3), the estimated change in the aggregate BC correlation between Korea and country *C* can be decomposed to the contributions from direct export and import linkages (Equation (14)) and the contributions from direct and indirect trade linkages (Equation (15)) for each country:

$$\widehat{\Delta\rho}(y_{At}, y_{Ct}) = \sum_i \overline{w}_i \frac{\overline{\sigma}_i}{\overline{\sigma}_A} \left(\widehat{\beta_1} \Delta EX_{iC} + \widehat{\beta_2} \Delta IM_{iC} \right) \quad (14)$$

$$\widehat{\Delta\rho}(y_{At}, y_{Ct}) = \sum_i \overline{w}_i \frac{\overline{\sigma}_i}{\overline{\sigma}_A} \left(\widehat{\beta_1} \Delta EX_{iC} + \widehat{\beta_2} \Delta IM_{iC} + \widehat{\beta_3} \Delta UP_{iC}^{EX} + \widehat{\beta_4} \Delta DN_{iC}^{IM} \right) \quad (15)$$

B. Estimation Results

Table 1 reports the results of estimating Equations (8) and (11) using dependent variables for either Korean industry's GDP or employment growth correlations with the whole sample of 42 countries. Specifications [1] and [2] include trade linkage variables as the only explanatory variables, while [3] and [4] introduce the indirect trade linkages defined by Equations (7) and (8). As explained in the previous subsection, specifications [1] and [2] test the impact of direct trade linkages on BC comovement, while [3] and [4] can provide estimates on the effects of both direct and indirect linkages on BC comovement. Meanwhile, specifications [1]-[4] differ in the inclusion of fixed effects: that is, not just industry fixed effects, which are included in all specifications to consider industry-specific heterogeneity, but [1] and [3] include country fixed effects to consider country-specific heterogeneity while [2] and [4] include country-sector fixed effects to consider sector-specific characteristics (separately for agriculture, manufacturing, non-manufacturing, and services) in the relationship with each country.

The first four columns document the impact of increase of trade linkages after the GFC on Korean industry's GDP growth comovement with a global economy. Specifications [1] and [2], considering only direct trade linkages, show that the coefficients of export linkages are positive and significant while those of import linkages are positive but without significance. The result implies that the increase of export linkages made a significant contribution to the rise in BC comovement in the aftermath of the GFC. In specifications [3] and [4], which consider the

[12] There is some possibility that direct and indirect export variables (i.e., ΔEX_{iC} and ΔUP_{iC}^{EX}) are not fully mutually exclusive, which in turn may lead to double-counting issues from using gross exports instead of value-added exports (see Foster-McGregor and Stehrer (2013), Johnson (2014) and Koopman et al. (2014) for more details). The double-counting issue would be less critical in our analysis, as we measure export linkage in intermediate inputs. For example, intermediate inputs purchased from other industries are less likely to be used for production of intermediate input exports to other countries, but they are more likely to be used for production of final export goods.

indirect trade channels of BC comovement via vertical linkages, we find that indirect network effects of export linkages via upstream linkages are estimated to be positive and significant. This finding implies that a rise of export linkages leads to higher GDP growth comovement for industry, being higher in upstream linkages (i.e., industries being more actively involved in supplying intermediate inputs to other industries). The result is consistent with our conjecture that vertical connectedness would amplify BC comovement through input-output linkages. In sum, the estimation results confirm that the rise of export linkages (either direct or indirect) played an important role in the increase of Korea's GDP growth comovement with trading partners after the GFC.

The last four columns present the impact of the increase of trade linkages on employment growth comovement. Specifications [1] and [2] on direct trade linkages find negative and significant coefficients on import linkages, which implies that the increase of import linkages played an important role in the decline of employment growth comovement. The results are broadly in line with the main findings in Acemoglu et al. (2016b) who identified the significant role of increased import penetration from China in the decline of employment growth in the U.S. through the 2000s—that is, import from other countries may reduce employment opportunities in domestic markets. The results support that the rise of import linkages played some role in the opposite movement of Korea's employment with its trading partners: that is, the increase of imports from a foreign country likely leads to employment increase in the foreign (exporting) country but employment decline in Korea (importing country). However, the impact of changes in import linkages on employment growth comovement becomes insignificant when we introduce indirect channels via upstream/downstream linkages as in specifications [3] and [4]. This result is likely to be observed when the direct and negative impact of import penetration on employment can be offset by the indirect and positive impact of import penetration (ΔIM_{iC}) through the increase of intermediate input supply to other industries (ΔUP_{iC}^{EX}). The positive employment effects are identified in indirect upstream effects from exports in our results, while indirect downstream effects from imports are key factors in deriving positive employments in Wang et al. (2018). However, it should be noted that our model differs from Wang et al. (2018) in that we consider upstream effects from exports and downstream effects from imports while they consider both upstream and downstream effects from imports without considering any employment effects from exports.

Table 2 reports the results of estimating Equations (8) and (11) using the data on Korea's 10 largest trading partners (i.e., China, the U.S., Japan, Taiwan Province of China, and Indonesia, India, Germany, Mexico, Russian Federation, and Brazil).[13] The results for the sample of highly trade-linked countries are broadly in line with those for all sample countries in Table 1. We find that the increase of direct export linkages contributed to the rise of GDP growth comovement, with significance at the 10 percent level, while the increase of import linkages has a negative impact on employment growth comovement. However, unlike the results of all sample countries, the indirect channels via upstream/downstream linkages are not found to have a significant impact on GDP growth and employment growth comovement in all specifications, although the sign of coefficients is broadly consistent with the baseline results in Table 1.

[13] Top 10 trading partners were determined by the value of intermediate input trade (sum of intermediate input exports and imports) in 2014.

Table 1. Impact of Trade on Business Cycle Comovement: Baseline Result

Dependent variable: GDP or Employment growth correlation

	GDP				Employment			
	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
ΔEX_{ic}	0.099*	0.121**	0.045	0.076	-0.037	-0.022	-0.072	-0.072
	(0.053)	(0.053)	(0.060)	(0.054)	(0.054)	(0.058)	(0.061)	(0.066)
ΔIM_{ic}	0.064	0.025	-0.020	0.131	-0.390***	-0.382***	-0.371	-0.241
	(0.091)	(0.105)	(0.161)	(0.183)	(0.121)	(0.134)	(0.301)	(0.328)
ΔUP_{iC}^{EX}			0.327**	0.345***			0.235	0.388*
			(0.152)	(0.132)			(0.186)	(0.218)
ΔDN_{iC}^{IM}			0.167	-0.614			-0.218	-0.787
			(0.602)	(0.666)			(1.054)	(1.166)
Industry fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed effect	Yes	No	Yes	No	Yes	No	Yes	No
Counry×sector fixed effect	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596
R^2	0.597	0.676	0.598	0.677	0.335	0.411	0.336	0.413
Number of countries	42	42	42	42	42	42	42	42

Notes: 1) Constant is included in all specifications.
2) ***, **, * indicate levels of significance at 1%, 5%, 10%, respectively.

Table 2. Impact of Trade on Business Cycle Comovement: Top 10 Trading Partners

Dependent variable: GDP or Employment growth correlation

	GDP				Employment			
	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
ΔEX_{ic}	0.087*	0.092*	0.074	0.072	-0.005	-0.007	-0.036	-0.046
	(0.051)	(0.052)	(0.059)	(0.057)	(0.056)	(0.055)	(0.067)	(0.070)
ΔIM_{ic}	0.110	0.084	0.188	0.242	-0.272**	-0.230	-0.234	-0.122
	(0.082)	(0.090)	(0.159)	(0.172)	(0.131)	(0.147)	(0.295)	(0.338)
ΔUP_{iC}^{EX}			0.121	0.200			0.220	0.303
			(0.115)	(0.129)			(0.158)	(0.212)
ΔDN_{iC}^{IM}			-0.407	-0.779			-0.302	-0.622
			(0.612)	(0.673)			(1.068)	(1.245)
Industry fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed effect	Yes	No	Yes	No	Yes	No	Yes	No
Counry×sector fixed effect	No	Yes	No	Yes	No	Yes	No	Yes
Observations	380	380	380	380	380	380	380	380
R^2	0.719	0.752	0.720	0.754	0.346	0.451	0.349	0.455
Number of countries	10	10	10	10	10	10	10	10

Notes: 1) Constant is included in all specifications.
2) ***, **, * indicate levels of significance at 1%, 5%, 10%, respectively.

We also estimate Equations (8) and (11) separately for the manufacturing sector and the service sector; the results are presented in Table 3. The results highlight that there exists some differentiation in the sign and significance of estimated coefficients between manufacturing and services. In the manufacturing sector, the increase of export linkages in either direct or indirect linkages contributed to the rise of GDP growth comovement, while the increase of import linkages played an important role in employment growth desynchronization (i.e., movement in the opposite direction). However, the role of direct and indirect trade linkages in BC comovement is not clearly identified in services, where trade linkages are relatively low compared to manufacturing.

Table 3. Impact of Trade on Business Cycle Comovement: Sectoral Estimation

Dependent variable: GDP or Employment growth correlation

	Manufacturing				Services			
	GDP		Employment		GDP		Employment	
	[1]	[2]	[1]	[2]	[1]	[2]	[1]	[2]
ΔEX_{ic}	0.095*	-0.033	-0.044	-0.130	0.367	0.356	0.063	0.131
	(0.051)	(0.065)	(0.056)	(0.087)	(0.255)	(0.263)	(0.154)	(0.179)
ΔIM_{ic}	0.036	-0.079	-0.395***	-0.800***	0.782	0.733	1.387	0.966
	(0.105)	(0.185)	(0.133)	(0.270)	(0.942)	(1.104)	(0.899)	(1.192)
ΔUP_{iC}^{EX}		0.843***		0.389		0.314		-1.470
		(0.278)		(0.367)		(1.462)		(1.895)
ΔDN_{iC}^{IM}		0.031		1.537		0.403		5.561
		(0.698)		(1.047)		(11.50)		(11.00)
Industry fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	588	588	588	588	714	714	714	714
R^2	0.513	0.519	0.288	0.291	0.610	0.610	0.412	0.413
Number of countries	42	42	42	42	42	42	42	42

Notes: 1) Constant is included in all specifications.
2) ***, **, * indicate levels of significance at 1%, 5%, 10%, respectively.

The important roles of direct and indirect trade linkages in determining BC comovement of the Korean economy with a global economy are also found in some specifications for the robustness estimation: (i) export including both intermediate input and final products (Table B.1 in Appendix B), and (ii) industries including only five major manufacturing industries (Table B.2 in Appendix B). The former robustness is meaningful, because Korea's exports in final products—which account for a significant portion of international trade—can also be affected by the global economy.[14] Meanwhile, the latter robustness is motivated by the highly concentrated and interconnected industrial structure of the Korean economy.[15] Table B.2 highlights the important role of indirect trade channels (both upstream and downstream) for the top five manufacturing industries on the GDP growth correlations, similar to the results for the manufacturing sector overall, which is likely to be driven by high vertical linkages in these industries. The results confirm that the key findings of di Giovanni et al. (2017, 2018)—that is, that the largest French firms exhibit much stronger international linkages and contribute significantly to overall international BC comovement—apply to the Korean economy at the industry-level: that is, a few large industries exhibit higher trade and vertical linkages, and contribute significantly to international BC comovement. More generally, the findings also support the growing body of literature on the importance of large firms in aggregate fluctuations (e.g., Gabaix 2011; di Giovanni et al. 2014; Carvalho and Grassi 2019).

[14] However, it should be noted that export variables are more likely to be affected by double counting issues as explained in Footnote 12.

[15] Top five industries accounted for about 75 percent of total manufacturing value added and 24 percent of GDP in 2017. Also, the industry concentration indices (top three firms' market share or Herfindahl-Hirschman index)—computed by Korea Fair Trade Commission using the "Mining and Manufacturing Survey"—also show a high concentration by the small number of firms for these industries.

C. Decomposition of Aggregate Business Cycle Correlation

Table 4 presents the decomposition of contributions to changes in aggregate correlations into those from direct export and import linkages by countries. It is computed from Equation (14) using the estimated coefficients from specification [1] in Table 1. The decomposition of GDP growth correlations documents that: (i) on average, the increase of export linkages made significant contributions to the rise of GDP growth correlation in the aftermath of the GFC; (ii) the rise of GDP growth correlation was mainly driven by the increase of GDP growth correlation with China, which can be mostly explained by the increase of export linkages with China; and (iii) GDP growth correlations with the U.S. and Japan have declined due to the decline of export and import linkages with these countries.

For employment growth correlations, the decomposition reveals that: (i) on average, the changes of import linkages made important contributions to the recent increase of employment growth desynchronization; (ii) employment growth desynchronization was mainly driven by the rise of employment growth desynchronization with China, which can be mostly explained by the increase of import linkages with China;[16] and (iii) employment synchronization with the U.S. and Japan slightly increased due to the decline of import linkages with those countries. The findings support that the drastic increase of export and import linkages with China over the 2000s was the dominant factor determining that the Korean economy's BC became more affected by a global economy.

Table 4. Decomposition of BC Correlation: Direct Trade Linkage

			GDP			Employment		
Country	ΔEX	ΔIM	$\Delta\widehat{\rho_A}$	$\Delta\widehat{\rho_A}\|EX$	$\Delta\widehat{\rho_A}\|IM$	$\Delta\widehat{\rho_A}$	$\Delta\widehat{\rho_A}\|EX$	$\Delta\widehat{\rho_A}\|IM$
China	0.628	0.244	0.219	0.176	0.043	-0.289	-0.063	-0.225
U.S.	-0.041	-0.083	-0.026	-0.012	-0.014	0.074	0.008	0.066
Japan	-0.119	-0.110	-0.043	-0.022	-0.021	0.123	0.026	0.096
Average	0.156	0.017	0.050	0.048	0.003	-0.031	-0.010	-0.021

Notes: 1) ΔEX and ΔIM are weighted by value added.
2) This table reports the results of decomposition in (12) using the estimates from specification [1] Table 1.
3) We assume w_i, σ_A, σ_i as constant and use average during the sample period in computation of (12).

Table 5 reports the decomposition from Equation (15) using the estimated coefficients from specification [3] in Table 1. It decomposes the contribution to changes in aggregate correlations into contributions from indirect export and import linkages via upstream and downstream linkages by countries as well as contributions from direct export and import linkages. The results on direct linkages are similar to the findings in Table 4, with some difference in magnitude, which can be explained by inclusion of indirect trade linkages. The decomposition on direct and indirect linkages documents that: (i) indirect export linkages with China via upstream linkages were the most important contributor to the increase of GDP growth correlations, and (ii) direct import linkages with China contributed the most to employment growth desynchronization. In addition, overall estimated contribution would be larger for GDP growth correlations but smaller (in absolute value) for employment growth correlations relative to Table 4, which considers only direct linkages. This implies that indirect export and import linkages can be additional channels of GDP correlations, but they can act as offsetting factors for negative employment effects, as

[16] The result is consistent with Acemoglu et al.'s (2016b) analysis of the U.S. that documented empirically that import penetration from China had adverse impacts on U.S. employment in the 2000s.

the increased import in a certain industry can also create some additional employment in its vertically linked industries. However, the difference was partly driven by the fact that contributions to BC correlations from direct and indirect trade linkages may not be mutually exclusive.

Table 5. Decomposition of BC Correlation: Direct and Indirect Trade Linkages

					GDP					Employment				
Country	ΔEX	ΔIM	ΔUP^{EX}	ΔDN^{IM}	$\Delta\widehat{\rho_A}$	$\Delta\widehat{\rho_A}\|EX$	$\Delta\widehat{\rho_A}\|IM$	$\Delta\widehat{\rho_A}\|UP^{EX}$	$\Delta\widehat{\rho_A}\|DN^{IM}$	$\Delta\widehat{\rho_A}$	$\Delta\widehat{\rho_A}\|EX$	$\Delta\widehat{\rho_A}\|IM$	$\Delta\widehat{\rho_A}\|UP^{EX}$	$\Delta\widehat{\rho_A}\|DN^{IM}$
China	0.628	0.244	37.34	10.47	0.440	0.080	-0.013	0.327	0.046	-0.109	-0.123	-0.214	0.303	-0.074
U.S.	-0.041	-0.083	-1.684	-4.189	-0.030	-0.005	0.004	-0.010	-0.019	0.092	0.015	0.063	-0.014	0.029
Japan	-0.119	-0.110	-4.869	-5.813	-0.065	-0.010	0.007	-0.032	-0.029	0.135	0.051	0.092	-0.048	0.040
Average	0.156	0.017	10.26	0.154	0.115	0.022	-0.001	0.095	-0.001	0.039	-0.019	-0.020	0.080	-0.002

Notes: 1) ΔEX, ΔIM, ΔUP^{EX} and ΔDN^{IM} are weighted by value added.
2) This table reports the results of decomposition in (13) using the estimates from specification [3] Table 1.
3) We assume w_i, σ_A, σ_i as constant and use average during the sample period in computation of (13).

V. CONCLUDING REMARKS

Korea's participation in global trade increased dramatically during the 1990s and 2000s; trade openness almost doubled between 1990 and 2011. At the same time, the production structure became more vertical, as intermediate input accounts for an increasing share in total output, mainly by the rise of intermediate input trade. Korea's export and import linkages showed a large increase in all industry sectors, particularly in manufacturing, through the 2000s. It is also notable that in the same period, Korea's GDP growth correlation with many foreign countries increased.

This paper modifies the empirical model of di Giovanni and Levchenko (2010), and di Giovanni et al. (2018) to explore the impacts of the rise in trade linkages on BC comovement in Korea, utilizing the fact that trade linkages and BC comovement increased in Korea in the aftermath of the GFC. The main findings of this paper are summarized as follows. International BC comovement is found at the industry-level in Korea: (i) industry that is highly export-linked to a country (either directly or indirectly) exhibits stronger comovement with that country's GDP growth; and (ii) industry that is highly import-linked to a country exhibits stronger negative comovement with that country's employment growth; and (iii) the results show differentiation across industry sectors (manufacturing or services). Having established these results, we quantify the relative importance of the various channels for aggregate BC comovement: (i) the increase of trade with China contributed the most to the aggregate BC comovement, and (ii) the impact of trade linkages on BC comovement was propagated domestically via vertical linkages. This result implies that the Korean economy can be significantly affected by a few countries that are highly trade-linked and/or a few industries (being also dominated by a few large firms) that are highly linked to other industries and that account for a large share of international trade.

The industrial analysis of the Korean economy's international BC comovement identifies the potential transmission channels of external economic shocks to the Korean economy, which provide some feasible policy responses to attenuate the adverse effects from external shocks. In addition, this paper is unique in analyzing the role of changes in trade linkages in determining international BC comovement, as previous literature focused on the role of different levels of trade linkages at the industry- or firm-level. The paper also contributes to the literature by

separately identifying: (i) export and import channels; and (ii) differentiated roles of trade and vertical linkages in BC comovement for GDP growth and employment growth.

Extending the analysis to an alternative measure of trade linkages using value-added exports—which can be more relevant in assessing the impact of changes in the participation in GVCs on international BC comovement—would be an interesting future research. Trade linkages may have different features across countries and industries between gross exports used in this paper and value-added exports documented in the recent literature (e.g., Foster-McGregor and Stehrer 2013; Johnson 2014; Koopman et al. 2014). The analysis can be extended to consider higher-order interconnections across industries to capture the possibility of "cascade effects" whereby productivity shocks to a sector are propagated not only on its immediate downstream customers, but also on the rest of the economy (e.g., Acemoglu et al. 2012, 2016a).

Appendix A: Data

Table A.1. Data Description and Source

Variable	Description	Source
GDP (Y_C)	Real gross domestic product of country *C*	IMF World Economic Outlook
Real value added (Y_i)	Industry *i* 's gross value added /*i* 's price level in gross value added	World Input-Output Database (2016)
Employment (E_C)	Number of persons engaged in total industry	World Input-Output Database (2016)
Employment (E_i)	Number of persons engaged in industry *i*	World Input-Output Database (2016)
Export linkage (EX_{iC})	Industry *i* 's input export to country *C* /*i* 's gross output	World Input-Output Database (2016)
Import linkage (IM_{iC})	Industry *i* 's input import from country *C* /*i* 's gross output	World Input-Output Database (2016)
Upstream linkage (IO_{ij})	Industry *i* 's input supply to industry *j* /*i* 's gross output	World Input-Output Database (2016)
Downstream linkage (IO_{ji})	Industry *i* 's input purchase from industry *j* /*i* 's gross output	World Input-Output Database (2016)

Table A.2. List of Industries

Industry Sector	ISIC Rev.4	Description
Agriculture (3)	A01	Crop and animal production, hunting and related service activities
	A02	Forestry and logging
	A03	Fishing and aquaculture
Manufacturing (14)	C10-C12	Food products, beverages and tobacco products
	C13-C15	Textiles, wearing apparel and leather products
	C16	Wood and of products of wood and cork, except furniture; etc.
	C17-C18	Paper and paper products; printing and reproduction of recorded media
	C19	Coke and refined petroleum products
	C20-C21	Chemicals and chemical products; basic pharmaceutical products and preparations
	C22	Rubber and plastic products
	C23	Other non-metallic mineral products
	C24	Basic metals
	C25	Fabricated metal products, except machinery and equipment
	C26-C27	Computer, electronic and optical products; Electrical equipment
	C28	Machinery and equipment n.e.c.
	C29-C30	Motor vehicles, trailers and semi-trailers; other transport equipment
	C31-C32	Furniture; other manufacturing
Non-manufacturing (4)	B	Mining and quarrying
	D	Electricity, gas, steam and air conditioning supply
	E36-E39	Water collection, treatment and supply; sewerage; waste collection, treatment and disposal activities; materials recovery; etc.
	F	Construction
Services (17)	G45	Wholesale and retail trade and repair of motor vehicles and motorcycles
	G46	Wholesale trade, except of motor vehicles and motorcycles
	G47	Retail trade, except of motor vehicles and motorcycles
	H49-H52	Land and via pipelines, water, air transport; warehousing and support activities
	H53	Postal and courier activities
	I	Accommodation and food service activities
	J58-J60	Publishing activities; motion picture, video and television programme production, sound recording and music publishing activities; etc.
	J61	Telecommunications
	J62-J63	Computer programming, consultancy and related activities; information service activities
	K64-K66	Financial service activities; insurance, reinsurance and pension funding; activities auxiliary to financial services and insurance activities
	L	Real estate activities
	M69-M75	Legal and accounting activities; activities of head offices; management consultancy activities; architectural and engineering activities, technical testing and analysis; scientific research and development; advertising and market research; other professional, scientific and technical activities; veterinary activities
	N	Administrative and support service activities
	O84	Public administration and defence; compulsory social security
	P85	Education
	Q	Human health and social work activities
	R-S	Other service activities

Appendix B: Robustness

Table B.1. Impact of Trade on Business Cycle Comovement: Overall Export

Dependent variable: GDP or Employment growth correlation

	GDP				Employment			
	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
ΔEX_{ic}	0.019	0.020	0.006	0.010	-0.016	-0.015	-0.018	-0.019
	(0.015)	(0.017)	(0.015)	(0.015)	(0.017)	(0.018)	(0.019)	(0.020)
ΔIM_{ic}	0.124	0.101	-0.001	0.132	-0.392***	-0.372***	-0.335	-0.204
	(0.097)	(0.123)	(0.164)	(0.186)	(0.118)	(0.130)	(0.304)	(0.336)
ΔUP_{iC}^{EX}			0.163**	0.182**			0.042	0.114
			(0.072)	(0.078)			(0.115)	(0.129)
ΔDN_{iC}^{IM}			0.193	-0.439			-0.324	-0.895
			(0.573)	(0.620)			(1.047)	(1.171)
Industry fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed effect	Yes	No	Yes	No	Yes	No	Yes	No
Counry×sector fixed effect	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596
R^2	0.596	0.675	0.597	0.676	0.335	0.411	0.335	0.412
Number of countries	42	42	42	42	42	42	42	42

Notes: 1) Constant is included in all specifications.
2) ***, **, * indicate levels of significance at 1%, 5%, 10%, respectively.

Table B.2. Impact of Trade on Business Cycle Comovement: Top 5 Manufacturing Industries

Dependent variable: GDP or Employment growth correlation

	Top 5 manufacturing industries			
	GDP		Employment	
	[1]	[2]	[1]	[2]
ΔEX_{ic}	-0.003	-0.527***	-0.023	-0.496**
	(0.116)	(0.148)	(0.130)	(0.209)
ΔIM_{ic}	0.190	-1.358**	-0.548**	-2.313***
	(0.213)	(0.585)	(0.244)	(0.842)
ΔUP_{iC}^{EX}		2.120***		1.845**
		(0.579)		(0.745)
ΔDN_{iC}^{IM}		5.833***		6.668**
		(2.014)		(3.060)
Industry fixed effect	Yes	Yes	Yes	Yes
Country fixed effect	Yes	Yes	Yes	Yes
Observations	210	210	210	210
R^2	0.483	0.511	0.340	0.354
Number of countries	42	42	42	42

Notes: 1) Constant is included in all specifications.
2) ***, **, * indicate levels of significance at 1%, 5%, 10%, respectively.

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