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Examining Industrial Interdependence Between Japan and South Korea: A FAVAR Approach

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Abstract:

This paper investigates the economic relationship between Japan and South Korea by incorporating disaggregated output measures. Using a factor-augmented vector autoregression (FAVAR) model, we conduct several experiments to test the nature of the interdependence, both in the aggregate and by sector. We find that South Korean output shocks affect the Japanese economy in a significant manner, whereas Japanese output shocks have a limited effect on South Korea. By further examining the transmission mechanism of sectoral output shocks and comparing them with the direction of sectoral trade, we find evidence of cross-border production sharing, which explains the asymmetric results seen in the aggregate output.

Keywords: business cycle synchronization, transmission, international interdependence, comovements, Japan, South Korea, East Asia, factor-augmented vector autoregressions, industrial production

JEL: F41, F47, F17, E32, C3

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1. INTRODUCTION

Japan and South Korea are undoubtedly two of the major economic players in Asia as well as in the world. Their combined PPP-adjusted GDP is $6.3 trillion, which accounts for roughly 8% of the world GDP.[3] GDP per capita is $38,528 dollars per person for Japan (ranked 28th overall) and $26,482 dollars per person for South Korea (ranked 33rd overall)[4], and both are member countries of the OECD.

Japan and South Korea's global presence is particularly large in the production of certain commodities. The two countries account for 17.2% of the global production of "motor vehicles, trailers, and semitrailers" and 15.3% of the "radio, television, and communications equipment".[5] In some industries such as semiconductors, passenger cars, and petro-chemical products, Japan and South Korea compete head to head in the global market, whereas in many other "niche" industries they provide intermediate goods to each other and form a complementary relationship.

The relationship between Japan and South Korea was the subject of a study by Selover (2004). The author used macroeconomic data between 1960 and 2002 and found that Japan had moderate transmission effects on the South Korean economy, but South Korea did not have much effect on the Japanese economy. But circumstances have changed since then. While Japan has suffered continuously from the two-decades long economic slump that has hurt its competitiveness in the global market, South Korea quickly recovered from the Asian Financial Crisis and steadily expanded its production capability thereafter. During 2003.1-2012.12, the average growth rate of the overall industrial production for South Korea was 6.7% per year while for Japan it was a meager 0.7%.[6] In terms of bilateral trade dependency, Japanese export share

[3] Source: IMF, World Economic Outlook Database, 2012.
[4] Source: United Nations, National Account Main Aggragates Database, 2013
[5] Source: Joint Study Committee, Joint Study Report for an FTA Among China, Japan and Korea, December 16, 2011.
[6] Source: OECD, Main Economic Indicators, 2013

for South Korea has mildly risen from 6% to 7%, while the South Korean export share for Japan has fallen sharply from 12% to 7%, partially substituted by the rising export share of China.[7]

At the regional level, Asia as a whole continued its extraordinary economic growth after 2002, and further increased its economic presence in the global market. Most noticeably, China has become the second largest economy in the world, surpassing Japan. At the same time, China has also become the largest trading partner for both Japan (18.1% of total exports, 21.3% of total imports) and South Korea (24.5% of exports, 15.5% of imports), surpassing the US and other developed countries.[8]

Finally, the world has experienced a dramatic shift in the trade structure during the last decade. In particular, the production activity in many sectors has become "fragmented" into several production processes that are scattered across the region. Countries involved in this form of trade have become more closely tied to each other through vertical production linkages (Hummels, Ishii, and Yi, 2001). South Korea has always been the front-runner in adopting this new form of trade, along with other smaller Asian countries such as Taiwan, Thailand, and Malaysia. Japan was initially slow in adjusting to this new trend, but it is now quickly catching up (Miroudot and Ragoussis, 2009).

In view of all the new developments, this paper aims to answer the following questions: what is the current economic relationship between Japan and South Korea? Has it changed from the finding of Selover (2004)? Does vertical production linkage explain business cycle transmission between the two countries? To address these questions, we adopt a factor-augmented vector autoregression (FAVAR) approach that utilizes a large set of time series data consisting of disaggregated industrial production output measures. The disaggregated series

[7] Source: IMF, Direction of Trade Statistics, 2012.
[8] Source: Europa Publications, The Far East and Australasia 2013, 2013

serve two purposes. First, they enlarge the information set relevant to business cycle transmission that may occur at the sector level. Second, they are used to impose restrictions to identify the orthogonal output shocks. We also utilize information from the Asian International Input-Output Table to encode the trade relationship among several major economies in the region. The impulse responses drawn from the estimated FAVAR are used to characterize the dynamics of the transmission mechanism between the two countries.

We find that recent developments may have changed the relationship between Japan and South Korea. In particular, the impulse responses show that the Japanese overall output shock no longer affect South Korea, instead the South Korean overall output shock affects Japan in a significant manner. This result is contrary to Selover (2004)'s finding. When we look at the responses of individual sectors, the same type of asymmetry is also found. For example, while output in the Japanese electrical machinery and chemical sectors responds strongly to the South Korean overall output shock, output of these sectors in South Korea does not respond to the Japanese overall output shock.

Furthermore, using sector-level output shocks in the two key sectors (electrical machinery, motor vehicles), we find the same type of asymmetric output responses for Japan and South Korea. The Japanese sectors benefit much more from South Korean sectoral output shocks than does South Korea from the same shocks occurring in Japan. The transmission mechanism, combined with the sectoral trade flows, suggests that the intermediate goods demand of South Korean sectors may have created positive spillover effects for the Japanese sectors, strongly indicating the existence of production complementarity related to these two sectors.

In addition to our above main findings, we confirm that both US and Chinese output shocks have positive spillover effects on Japan and South Korea, but the US output shock appears to have a smaller impact on the South Korean economy than it does on the Japanese economy. This result partially supports the view that Asia is "decoupling" from the rest of the world (Kose, Otrok, and Prasad, 2012). The impulse responses also show that Japan benefits more from the US and Chinese output shocks than does South Korea. Finally, we confirm that the main result is robust to the use of different datasets as well as alternative assumption regarding the observed output factor.

There are several studies that use FAVAR to examine the transmission of business cycle across borders. For example, Mumtaz and Surico (2009) study the effect of an international real activity shock on the UK economy by extracting principal components from nationally aggregated variables covering multiple countries and use short-run restrictions to identify the shock.[9] This paper differs from the existing FAVAR studies in that it is the first to employ disaggregated output measures to examine economic relationship between two countries. Our method to identify shocks is also unique and justifiable because it relies on sectoral trade information in the international input-output table. This approach is different from studies that exclusively rely on disaggregated variables, such as commodity-level trade statistics, or the international input-output tables to study industrial interdependence between different countries or different regions.

Section 2 gives the motivation for this study and a review of the literature. Section 3 explains the methodology and data used. Section 4 presents the main results. Section 5 provides further analysis using different types of output shocks. Section 6 checks the robustness of the main results. Section 7 concludes.

[9] Similar approach is also taken by Bagliano and Morana (2009), Beckman, Belke, and Czudaj (2014), Vasishtha and Maier (2013).

2. BACKGROUND

2.1 Motivation

To motivate our analysis, we start this section by updating the analysis of Selover (2004) who analyzed the business cycle transmission between South Korea and Japan during 1960-2002 using a structural vector autoregression (SVAR) approach. The SVAR model in Selover (2004) has seven endogenous variables and three exogenous variables, and the author imposes short-run restrictions to identify the structural shocks. The output measures are monthly indexes of industrial production (IIP) for Japan and South Korea. We apply the same identification strategy for three samples: 1990.01-2012.12, 1990.01-1999.12, and 2000.01-2012.12.[10]

Figure 1 shows the impulse responses for the full sample and two subsamples. The left panels show how the Japanese output responds to an unexpected innovation in the South Korean overall output ("South Korean output shock"), whereas the right panels show how the South Korean output responds to an innovation in the Japanese overall output ("Japanese output shock"). For the overall sample 1990.01-2012.12, we observe that the Japanese output responds positively to the South Korean output shock, whereas South Korean output does not respond much to the Japanese output shock. In the middle two panels (1990.01-1999.12), neither output responds significantly to an output shock in the other country. In the last two panels (2000.01-2012.12), only the Japanese output responds positively to the South Korean output shock, but the South Korean output does not respond significantly to the Japanese output shock, consistent with the overall sample. This result is opposite to the finding of Selover (2004), which finds moderate transmission of shock from Japan to South Korea but limited effects from South Korea to Japan during 1960-2002.

[10] The details of time series used for the SVAR are described in the data appendix, together with data used in the later FAVAR analysis.

There are several possible reasons why the bilateral transmission mechanism may have reversed in the recent two decades. One is the dynamic change in the global trade structure referred to as global production sharing (also known as vertical specialization, fragmentation, and outsourcing) that has occurred since the 1990s.[11] In general, if there is a vertical production linkage that involve more than two countries, focusing solely on the bilateral economic relationship could be misleading in terms of how one country is economically exposed to another (Bems, Johnson, and Yi, 2010). Vertical production linkage is most widely seen in electronics, automobiles, machine tools, and various metal products (Athukorala, 2011), which are all sectors that Japan and South Korea have relatively large shares in the global market.[12] The rapid development of global production sharing in these sectors may have contributed in changing the nature of the transmission mechanism between Japan and South Korea, in combination with other changing environments that have occurred in recent years (e.g., improved air transportation, an increased use of computers in manufacturing, an increase in industrial agglomerations within the Asia-Pacific region, lowered tariffs for intermediate goods trade, and an expansion of preferential trade agreements).[13]

Another related phenomenon is the so-called decoupling/recoupling of emerging Asia from the rest of the world. In this literature, South Korea is usually treated as part of emerging Asia whereas Japan is often treated as part of the rest of the world.[14] On one hand, Kose, Otrok and Prasad (2012) have noted that in recent years Asia has gained independence from the rest of the world in terms of achieving economic growth ("decoupling"), with the most notable changes

[11] These terms are used in slightly different contexts depending on what aspect is emphasized. For example, Hummels, Ishii, and Yi (2001) have expounded upon the notion of vertical specialization, which considers how a country's exports are produced through importing the parts and components from other countries.
[12] For empirical studies on global production sharing in individual industries, see for example Amador and Cabral (2009), Ando (2007), Kimura, Takahashi, and Hayakawa (2007), Nishitateno (2013), Sturgeon, Van Biesebroeck, and Gereffi (2008).
[13] For more discussion on the changing environment surrounding trades in general, see Helpman (2006), Hummels (2007), Kimura (2006), Orefice and Rocha (2014), Williams (2013).
[14] Japan's treatment as part of the rest of the world is partly because of its economic status as a developed country and the prolonged recession that makes it distinct from the other developing Asian countries.

happening in the fast-growing China and ASEAN countries. On the other hand, Kim, Lee and Park (2011) argue that Asia has not decoupled, but rather strengthened its ties with the rest of the world ("recoupling"). Using a panel VAR approach, Kim, Lee and Park (2011) show that positive spillover effects between the emerging East Asia (including South Korea) and the G7 countries (including Japan) have strengthened in both directions since the 2000s.[15]

2.2. Related literature

In recent years, there has been a surge of studies examining how sectoral composition affects economic interdependence. For example, Calderon, Chong, and Stein (2007) show that when the industrial compositions of two countries are similar, their business cycles tend to synchronize. Crosby (2003), Kumakura (2006), and Shin and Wang (2003) find the same conclusion for countries in the Asia-Pacific region.

There have been two leading explanations in the literature for why sectoral similarity leads to high business cycle synchronization. One is that their sectoral outputs tend to be correlated through common sector-specific shocks, resulting in the overall output correlation (e.g., Imbs, 2004). Another explanation is that if the sector pairs of two countries have a large trade volume, the international transactions from both directions would serve as a conduit for transmitting economic shocks across borders. Studies have shown that trade volume at the sector level is a robust predictor of business cycle synchronization (di Giovanni and Levchenko, 2010).[16]

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[15] Hirata and Otsu (2011) demonstrate that the efficiency improvement of South Korea and Taiwan has created a positive spillover effect on the Japanese economy since the mid-1980's. For more on the decoupling/recoupling literature, see Bordo and Helbling (2011), Kim, Kose, and Plummer (2003), Kose, Otrok, and Whiteman (2008), Park and Shin (2009).

[16] In general, the association between *overall* trade and business cycle synchronization is ambiguous. If trade reflects the comparative advantage, the business cycles of two countries are expected to be less synchronized because the industry-specific shocks would make the countries less associated with each other. However, empirical studies have found that larger trade volume is generally associated with higher degree of business cycle synchronization (Frankel and Rose, 1998; Baxter and Kouparitsas, 2005).

Recently, a third argument, focusing on the vertical linkage across fragmented production processes, has gained momentum in the literature. This is particularly useful in describing the business cycle synchronization of smaller Asian countries that specialize in certain sectors such as automobiles (e.g., Thailand) or electronics (e.g., Taiwan, Malaysia). Several theoretical models have been built to examine whether such linkages could significantly affect the economic interdependence across countries at the aggregate level.[17] However, there is as yet no firm consensus as to what form of vertical production linkage matters most for the transmission of business cycles.[18]

On the empirical front, several approaches have been established to study sectoral interdependencies across borders. One is to directly examine the trade flows between countries at the commodity level. For example, Athukorala and Yamashita (2006) and Athukorala (2011) focus on the trade in parts and components among many countries/regions. They show that in recent years Asia has gained its global presence in many information and technology related commodities, but not much presence in the automotive related commodities.

Another approach, which we adopt in our paper, is to study the international input-output table covering multiple countries and sectors. For example, utilizing the OECD input-output table of countries, Ng (2010) finds that vertical specialization affects business cycle synchronization positively.[19] Adopting a slightly different approach, Burstein, Kurz, and Tesar

[17] For example, Burstein, Kurz, and Tesar (2008) assume that goods that involve vertically integrated production process have a lower elasticity of substitution than horizontally differentiated goods. They demonstrate that if trade volume is held constant, an increase in production sharing generates a positive cross-country correlation in output. Bergin, Feenstra, and Hansen (2011) assume that offshoring sectors have a varying unit labor cost that triggers adjustment in the offshoring margin and use this mechanism to explain why offshoring industries in the low wage countries tend to have a larger volatility in employment compared to the high wage countries. Yi (2010) and Koopman, Wang, and Wei (2014) have demonstrated that when vertical specialization is present, trade cost would have magnifying effect on the trade volume. For other related studies, see Ambler, Cardia, and Zimmermann (2002) and Tesar (2008).
[18] Johnson (2014) demonstrates in his model that vertical specialization plays only a quantitatively minor role in transmitting shocks across borders. Bridgman (2013) demonstrates that trade associated with vertical specialization does not explain much of the import volatility in a country, making it questionable that it serves as an effective transmission channel.
[19] See also Bems, Johnson, and Yi (2011), Johnson and Noguera (2012). For studies that exclusively focus on Asia, see Suder, Liesch, Inomata, Mihailova, and Meng (2014), Yamazawa, Nohara, and Osada (1986).

(2008) study the input-output structure between US multinationals and their foreign affiliates by focusing on their product sharing activities at the firm level. They too confirm that (intra-firm) vertical production linkages contribute to business cycle synchronization across countries. However, the downside of this approach is that data are only available in low frequencies or for limited sample periods and hence are not well suited to study the dynamics of the transmission mechanism of business cycle. We overcome this limitation by combining the international input-output table and monthly macroeconomic time series such as industrial production.

3. DATA AND METHOD

3.1 Factor-Augmented Vector Autoregression (FAVAR)

Compared with traditional vector autoregressions, FAVAR has the advantage of incorporating a large set of information into a few factors and using these factors in the VAR analysis. Our FAVAR model closely follows the one developed in the seminal paper of Bernanke, Boivin, and Eliasz (2005). One difference between our method and theirs is the identification strategy: in our paper shocks are identified using trade information based on the international input-output table.

Our FAVAR estimation involves two steps. First, we use principal component analysis to obtain the estimates of factors $\hat{F}_t \equiv [\hat{F}_{1,t}, \ldots, \hat{F}_{K,t}]'$ that are obtained from the large panel of dataset. These factors are expected to capture the dynamics of the international macroeconomic factors that are commonly shared across all seven countries included in our sample. The observed time series $X_t \equiv [X_{1,t}, \ldots, X_{N,t}]'$ are associated with the (unknown) factors as follows,

$$X_t = \lambda F_t + e_t, \quad (1)$$

where λ is the $N \times K$ matrix of factor loadings and $e_t \equiv [e_{1,t}, \dots, e_{N,t}]'$ is the idiosyncratic component of each series. In Equation (1), the factors and factor loadings are not separately identifiable, unless some restriction is applied. To solve this problem, we apply the commonly applied restriction $T^{-1}F'F = I$ on the factors, where $F = [F_1, \dots, F_T]'$ denotes a T x K matrix of unobserved macroeconomic factors that are stacked up over sample period t =1,…T.[20]

Second, we estimate a VAR of the form,

$$\begin{bmatrix} \tilde{F}_t \\ X_{i,t}^{obs} \end{bmatrix} = \Phi(L) \begin{bmatrix} \tilde{F}_{t-1} \\ X_{i,t-1}^{obs} \end{bmatrix} + \tilde{v}_t \,, \tag{2}$$

where $\tilde{F}_t = [\tilde{F}_{1,t}, \dots, \tilde{F}_{K,t}]'$ is the vector of estimated factors in which the direct dependence of $X_{i,t}^{obs}$ on $\hat{F}_t$ is removed (as explained below). $X_{i,t}^{obs}$ is the output series of interest and is treated as an observed factor. The choice of $X_{i,t}^{obs}$ depends on the output shock and will be switched between different indexes of industrial production. For example, when studying the effects of a Japanese output shock on South Korean output, we use the Japanese overall output as the $X_{i,t}^{obs}$. $\Phi(L)$ is a lag polynomial matrix of order P. The reduced form residuals $\tilde{v}_t \equiv [\, \tilde{v}_{F,t}, v_{i,t}^{obs}]'$ can be further expressed as,

$$\tilde{v}_t = \mathbf{R}\tilde{\varepsilon}_t, \tag{3}$$

where $\mathbf{R}$ is a square matrix and $\tilde{\varepsilon}_t \equiv [\tilde{\varepsilon}_{F,t}, \tilde{\varepsilon}_{i,t}^{obs}]'$ is the structural shock. To recover the structural shock, we adopt the standard recursiveness assumption which implies that the international factors $\tilde{F}_t$ in Equation (2) respond only with a lag to the unexpected change in the domestic output $X_{i,t}^{obs}$.

[20] The actual estimation of factors and factor loading is done as follows. First, we estimate the factors by minimizing the squared residuals in Equation (1) while treating the unknown loading as given. Next, we estimate the loadings using principal component analysis. Under some regularity conditions on the error structures, the factor loading can be consistently estimated as the first K eigenvectors of the variance-covariance matrix of X (Stock and Watson, 2005). Note that when estimating the principal components all variables (including variables of “large” countries such as US and China) receive equal weights.

In order to identify the observed output shock $\tilde{\varepsilon}_{i,t}^{obs}$, we follow the method described in Bernanke, Boivin, and Eliasz (2005). First, we select a set of slow-moving variables from the dataset that are by assumption not affected by $\tilde{\varepsilon}_{i,t}^{obs}$ contemporaneously. Second, we apply principal component analysis to these slow-moving variables to obtain factors $\hat{F}_t^s \equiv \left[\hat{F}_{1,t}^s, \ldots, \hat{F}_{K^s,t}^s\right]$. Finally, we regress $\hat{F}_t$ on $\hat{F}_t^s$ as

$$\hat{F}_t = b_0 \hat{F}_t^s + b_1 X_{i,t}^{obs} + u_t,$$

and use the regression coefficient b_1 to remove the direct dependence of $\hat{F}_t$ on $X_{i,t}^{obs}$ as follows,

$$\tilde{F}_t = \hat{F}_t - b_1 X_{i,t}^{obs}. \tag{4}$$

This procedure assures that the output shock $\tilde{\varepsilon}_{i,t}^{obs}$ is orthogonal to the shocks of the principal components, and it can be treated as an independent structural shock in the FAVAR analysis.

3.2 Identification of Shocks

The output shock is an unexpected increase in the production activity in a given country or sector that can be transmitted through trade in either intermediate or final goods.[21] Our identification strategy is to find sectors that are unlikely to respond to the output shock in a foreign country within a given month and treat those sectors' output as slow-moving variables.

For identification of the country-level output shock (e.g., a Japanese overall output shock), we first measure the trade volume between a given sector (e.g., South Korean electrical machinery) and the country in which the shock occurs (e.g., Japan). We consider both exports and imports as part of the trade volume to make sure that there is no spillover effect through either demand or supply. Next, we divide the above trade volume between the sector and the country with the overall bilateral trade volume of the two countries (e.g., Japan and South Korea)

[21] This notion of a shock is relatively close to the shocks to "real activity" or "economic activity" used in other FAVAR studies. See for example Mumtaz and Surico (2009) and Vasishta and Maier (2013).

to obtain the trade share of the sector. Finally, we compare the calculated trade share with a predetermined threshold value. In particular, if the trade share is below 0.5 percent, the sectoral output is selected as the slow-moving variable.[22]

For identification of the sector-level output shock (e.g., Japanese electrical machinery output shock), the same process is applied as above. The difference is that the trade share is now calculated as the ratio of trade volume between two sector pairs (e.g., Japanese-South Korean electrical machinery) over the trade volume between the sector of interest and the partner country (e.g., South Korea). Again, if the share falls below 0.5 percent, we select that sector's output as the slow-moving variable.

The selected slow-moving variables are used to calculate $\tilde{F}_t$ following Equation (4). We set the number of extracted factors to three based on the test in Hallin and Liska (2007).[23] In the FAVAR context, this means that we extract two unobserved factors ($K = 2$) using the principal components analysis and augment the output series of interest ($X_{i,t}^{obs}$) as the third factor. We set the number of principal components extracted from the slow-moving variables equal to K, following Bernanke *et al*. (2005). The lag length is set to $P = 2$, as suggested by the Schwarz BIC criteria.[24]

In estimation, we also include a recession dummy as an exogenous variable, guided by a visual inspection of the time series of selected variables (see Figure A.1 in the Appendix). Therefore our estimated model is modified as,

$$\begin{bmatrix} \tilde{F}_t \\ X_{i,t}^{obs} \end{bmatrix} = \Phi(L) \begin{bmatrix} \tilde{F}_{t-1} \\ X_{i,t-1}^{obs} \end{bmatrix} + \boldsymbol{\beta}_0^d d_t + \tilde{v}_t \, , \tag{5}$$

[22] We have also experimented with different threshold values (0.25%, 1%) to check the robustness of our main result. We find that the results are not very sensitive to the choice of different threshold values.
[23] We also experimented with the information criterion proposed by Bai and Ng (2007), which suggests 3-5 factors depending on the test parameters used. Even when the larger number of factors are applied, the main result in the paper remained largely unaffected.
[24] Using the Schwarz BIC criteria, some of the specifications prescribed lag lengths of one. However, for purposes of comparability we standardized by adopting a lag length of two months. The results were not very sensitive to lag length.

where d_t is the recession dummy that takes the value of one during 2007.11 – 2009.06 and zero otherwise. The dates are determined based on the recession dates of four countries (US, China, Japan, South Korea) provided by NBER for the US and OECD for the rest. For comparison purpose, the size of the shock is set to be the same for all shocks, and it is equal to a one-half percentage point of the shock variable.

3.3 Variables Used in Estimating the FAVAR

While our analysis focuses primarily on the index of industrial production of Japan and South Korea, we utilize a total of 127 macroeconomic variables of seven countries (Japan, South Korea, US, China, Taiwan, Thailand, Malaysia) collected from several sources. These countries jointly form a complicated production network in the Asia-Pacific region.[25] These variables are monthly and cover the period of 2000.01 – 2012.12 following the Asian Financial Crisis (T = 156). The list of variables consists of industrial production at the national level (for all seven countries) and by sectors (for Japan, South Korea, and the US). We additionally include trade volumes, consumer price indexes, spot exchange rates, monetary aggregates, and short-term interest rates at the national level. Trade volume is relevant because sectoral interdependence is likely to depend on the trade channel across multiple countries. The remaining variables are used in Selover (2004) to proxy the financial channel. The description of variables is provided in Table A.1 in the Appendix. All variables except for the short-term interest rates are transformed

[25] To illustrate why US, China, Taiwan matter in studying the relationship between Japan and South Korea, consider iPhone as an example. An increase in Japanese output increases the demand for iPhone in Japan, which has over 50% share in the Japanese smartphone market. As widely reported, China does most of the assembly of iPhone through Taiwanese companies (Foxconn, Pegatron), and Japanese machine tools are used in the factories. In the production process, Apple Inc. in the US provides key components such as software, while non-US companies supply some of the high-tech parts such as LCD panels, chipsets, batteries (South Korea), DRAMs, flash memories (Taiwan), cameras, inductor coils, and data storages (Japan). This example indicates that the transmission of Japanese or South Korean output shock can go through other countries in a complicated fashion. Studies point out that Thailand is now heavily involved in global supply chain of automobile (“Detroit of the East”). Malaysia has large industry Park in Penang that serves as an electronic parts and components hub in Asia.

into growth rates to attain stationarity.[26] Prior to applying the principal component analysis, these variables are further normalized.

3.4 Variables Used in Identifying Output Shocks

To compute the trade shares, we utilize the Asian International Input-Output (I-O) Table obtained from the Institute of Developing Economies-Japan External Trade Organization website. The table covers a total of nine countries (including the US) and 76 sectors, and is produced every five years. We use the year 2005 because it is the most recently available version. To apply the information in the I-O table in identifying shocks, we need to map our sectors to the sectors in the I-O table. Not every sector has a one-to-one match, but most of the mapping is fairly straightforward based on the definition provided in the I-O table. For example, Japanese output for cement and cement products (*jpn_ip_ccem_g* in our dataset) is matched with "Cement and cement products" in the I-O table (Sector code 038), whereas Japanese output for rubber products (*jpn_ip_rubber_g*) is assigned to "Tires and tubes" (Sector code 036) and "Other rubber products" (Sector code 037).[27]

Table 1 summarizes the trade volumes between Japan and South Korea at the sector level using the information in the I-O table. The table shows that electrical machinery & appliances and basic metals are the two sectors with the largest bilateral trade. These are also the sectors with relatively high shares of intermediate goods trade (column (b)), much of which occur within the same sector (column (c)).

The trade volume that a given sector trades with foreign countries is based on both exports and imports. On the exporting side, the trade volume is calculated as the sum of

[26] In general, there is no pairwise cointegration between the industrial production indexes. Thus there is no reason to estimate error correction models.
[27] The complete list of correspondence is shown in Table 2, described below.

intermediate and final demand for a given sector, whereas on the importing side the trade volume is the amount of imported intermediate goods. For example, the Japanese rubber sector has $249 million of trade with South Korea (that is, $175 million of exports plus $74 million of imports), which accounts for 0.32% of the overall trade volume between Japan and South Korea. Thus, the Japanese rubber sector qualifies as a slow-moving variable in identifying the South Korean output shock (< 0.5%).[28] The same process is repeated when identifying the sectoral shock in a given country.

4. Main Result

4.1 Principal Component Analysis

Before turning to the FAVAR results, we provide a quick overview of principal components extracted from the 127 variables used in our baseline analysis. Figure 2 reports the time series graphs of the three principal components before removing the direct dependence of the observed factor $X_{i,t}^{obs}$. All principal components show a large downward swing between 2007-2010, which likely reflects the effect of the global recession. However, the timing and the magnitude of the swings somewhat differs across principal components.

These principal components are highly correlated with macroeconomic conditions in Japan and South Korea. For example, first principal component is highly correlated with the output for both countries (*r* = 0.93 for Japan, 0.79 for South Korea), and it is also highly correlated with exports and imports for Japan (0.92 and 0.84) and spot exchange rate for South Korea (0.78). Second principal component is highly correlated with the consumer price index of Japan (-0.74), and slightly less so with the consumer price index of South Korea (-0.35). Third

[28] The Japanese rubber sector is also used to identify the Chinese output shock (used in the later analysis), since its trade share is smaller than the predetermined threshold value (0.30%<0.5%). However, it will not be used to identify the US output shock, because the ratio is 1.00% thus exceeding the 0.5% threshold.

principal component is highly correlated with the short-term interest rate of Japan (0.68) and the monetary aggregate of South Korea (0.55). This exercise confirms that the economies of Japan and South Korea are closely tied to common international factors.

4.2 The Overall Output Response to a Foreign Output Shock (Japan/South Korea)

Figure 3 shows the response of the overall output of Japan to a positive 0.5 percentage point increase in the output of South Korea and the response of South Korea to Japan. In the left panel, the output in Japan immediately increases following the South Korean output shock and it peaks around six months, which is later than that observed in the SVAR analysis (Figure 1). The positive response is also statistically significant, as shown by the 90% confidence interval.[29]

In the right panel, the output in South Korea rises slightly in response to the Japanese output shock (not statistically significant), but it quickly falls after a month and crosses the zeroline at around six months. Overall this figure confirms the earlier SVAR results as shown in Figure 1, which finds a strong transmission of a South Korean output shock to Japan but a limited effect from Japan to South Korea.

4.3 Sector-level Granger Causality Tests

We now examine how individual sectors in one country are affected by output shocks in the other country. We first test whether the overall output of South Korea Granger-causes the sectoral output of Japan and then whether the overall output of Japan Granger-causes the sectoral output of South Korea.[30] For this purpose, we use a reduced form vector autoregression

$$Y_t = \Gamma(L)Y_{t-1} + \upsilon_t$$

[29] The confidence interval is calculated using the bootstrap method proposed by Kilian (1998) and adopted by many FAVAR studies.
[30] For the concept of Granger causality see Granger (1969, 1980).

where $Y_t = [Y_{US,t}, Y_{China,t}, Y_{Jpn,t}, Y_{Kor,t}, Y_{c,j,t}]'$ is a 5×1 vector of output series. The first four variables represent the overall output at the country-level, whereas $Y_{c,j,t}$ is the sectoral output for sector j in country c, Japan and South Korea. We examine eight sectors in each country.[31] As before, all variables are expressed in growth rates and the lag length is set to two months, as suggested by the Schwarz BIC criteria.

Table 3 reports the results of the Granger causality tests in which we test the null hypotheses that Y_{Jpn} does not Granger-cause $Y_{Kor,j}$, and Y_{Kor} does not Granger-cause $Y_{Jpn,j}$. We find that the overall South Korean output Granger-causes five of the eight Japanese industries at the 5% significance level, whereas the overall Japanese industrial production also Granger-causes five of the eight South Korean sectors. However, there is an asymmetry between the two countries. For example, South Korean overall output Granger-causes sectoral outputs of Japanese electrical machinery and basic metals, but the Japanese overall output does not Granger-cause outputs of the same South Korean sectors. Likewise, the Japanese overall output Granger-causes sectoral outputs of South Korean electrical appliances and chemical, but the South Korean overall output does not Granger-cause outputs of the same Japanese sectors.

One limitation of this VAR-based test is that it cannot control for many relevant variables due to the degree of freedom constraint. For that reason we now move to the FAVAR estimation that allows us to work with a larger information set.

4.4 The Sectoral Output Response to a Foreign Output Shock (Japan/South Korea)

[31] These sectors are electrical machinery (*elecmach*), motor vehicles (*mv*), electrical appliances (*eappl* for Japan, *eequip* for South Korea), other machinery (*othmach*), basic metals (*ironsteel* for Japan*, pmetal* for South Korea), chemicals (*chem*), petroleum/coal (*petcoal*), plastics (*plastic* for Japan). These are selected based on multiple criteria such as bilateral trade volume, size of value added, and relevance in terms of production complementarity across borders. We distinguish electrical machinery and electrical appliances because they often deal with different type of markets/commodities. In some cases, sector is defined slightly differently in each country. For more detail see the Data Appendix A.

Figure 4 shows how individual sectors in one country respond to an overall output shock in the other country. The positive shock in the overall output of South Korea generates positive responses in all the sectors in Japan, but the magnitude differs substantially according to sector. The sectors that incur the largest responses are electrical machinery, basic metals, and plastics. These are also the sectors that have the highest share in terms of the intermediate goods trade (see column (b) of Table 1). In contrast, a positive Japanese output shock yields mixed responses in individual South Korean sectors. Several sectors (e.g., other machinery and basic metals) show a significantly positive response in the beginning but the responses soon fall below the zeroline. For most sectors, the responses turn negative within the first eight months (with the exception of petroleum/coal sector). The heterogeneous responses across sectors are consistent with the tepid response in the overall South Korean output in the right panel of Figure 3.

We note that the FAVAR results are not always consistent with the Granger causality test results. For example, the Granger causality test suggests no causal relationship between South Korean overall output and the Japanese electrical appliances, but the FAVAR impulse response shows strong response of Japanese electrical appliances to the South Korean overall output shock. Similarly for the petroleum/coal sector, Granger causality test suggests no causal relationship with overall output of either country, but the impulse responses of the sectoral output show a significant response.[32] This suggests the merit of working with a larger dataset when analyzing business cycle transmission.

5. FURTHER ANALYSIS

5.1 Vertical production linkage

[32] Other inconsistencies are observed in chemical and food sectors for Japan, and in electrical appliances and basic metals sector for South Korea.

Many studies have pointed out South Korea's degree of vertical specialization is among the highest in the world.[33] It is also well known that South Korea's economy is relatively dependent on electronics and auto manufacturing, both involving production process that is vertically integrated across multiple countries. It is possible that the output shock occurring in these South Korean sectors may generate a large intermediate goods demand from Japan that leads to the observed strong business cycle transmission from South Korea to Japan. Thus in this section we examine whether the asymmetric responses are due to the vertical production linkage often seen in these two sectors.

Figure 5 and 6 show the impulse responses of the shocks occurring in the electrical machinery sector and the motor vehicle sector. These shocks are identified using the slow-moving variables selected based on the international I-O table. In Figure 5, we observe that both Japan and South Korea benefit from each other's positive shock in the electrical machinery sector, but the magnitude of the response is larger for Japan than for South Korea. The same asymmetric pattern is observed for many related sectors, such as motor vehicles, chemicals, and plastics. In Figure 8, the motor vehicle shock in South Korea has a positive effect on all Japanese sectors, but the motor vehicle shock in Japan has almost no impact on South Korea.

To dig deeper, we collected information on the direction of trade in these sectors between Japan and South Korea. Table 4 presents the trade flows involving the electrical machinery sector. For trade within the electrical machinery sector, Japan has a large trade surplus against South Korea (7,687.1 – 4,428.9 = $3,259.1mil.), which implies that the South Korean electrical machinery sector has a higher demand for products from Japan, relative to Japanese electrical machinery sector's demand for South Korean products. Table 4 also shows the general trade pattern that the electrical machinery sector imports crude and processed materials from material-

[33] See for example, Hummels, Ishii, and Yi (2001) and Miroudot and Ragoussis (2009).

related sectors (e.g., plastics) and exports electronic parts and components to other machinery-related sectors (e.g., motor vehicles). The latter indicates that the products in the electrical machinery sector are mostly used as intermediate goods in the production chain, rather than as the final use products. For both of these upstream and downstream sectors, Japanese exports exceed South Korean exports in most cases. Table 5 presents the trade flows involving the motor vehicle sector. Again, Japan has a large trade surplus against South Korea within the motor vehicle sector (819.9 – 157.3 = $662.6mil.). One key difference comparing with the electrical machinery sector is that much of the across-sector trades are in the form of exports from other sectors to the motor vehicle sector.

When we compare sectoral impulse responses in Figure 5 with the trade flows in Table 4 for the electrical machinery sector, we find an interesting pattern. For three of the four upstream industries (metals, chemicals, and plastics products), the South Korean electrical machinery sector imports a relatively large amount from Japan (column (c) of Table 4), and the response of these Japanese sectors is also larger than that of South Korea. In contrast, for the petroleum/coal products, the Japanese electrical machinery sector imports a relatively large amount from South Korea (column (a) of Table 4), and we find the response of South Korean petroleum/coal sector to be larger than that of Japan. A similar pattern is also observed when we compare Figure 6 and Table 5 for the motor vehicle sector. The motor vehicle sector in South Korea imports large volume from Japanese basic metal, chemical, and other machinery sectors, which produce steel, paint, and industrial robots used in car manufacturing.

This exercise suggests that production complementarity across borders and the resulting vertical production linkages provide an important channel for business cycle transmission. The asymmetric impulse responses found here is also consistent with the earlier observation that the positive spillover effects pass from South Korea to Japan.

5.2 The Overall Output Response to a US/China Output Shock

Within the last two decades, South Korea has quickly deepened its trade relationship with China while reducing its trade dependence on the US and Japan. This is often seen as an example of the “decoupling” of emerging Asia from the rest of the world. To test this claim, we let China represent emerging Asia and the US represent the rest of the world. We then examine how the output shocks of these countries affect both Japan and South Korea.

Figure 7 shows the impulse responses for the overall and sectoral outputs of Japan and South Korea in response to a US overall output shock. For the overall output case, we observe that the Japanese output responds more positively to the US output shock than does the South Korean output. Similar pattern is found for motor vehicle, which may reflect the local assembly that Japanese automakers have conducted since early 1980’s, much earlier than South Korea.[34] For electrical machinery, Japan’s response still exceeds that of South Korea, but the confidence interval is quite wide.

Figure 8 shows the same set of responses to a Chinese overall output shock. The overall output responses of Japan and South Korea look similar in shape and slightly larger for Japan in magnitude. For the sectoral responses, both Japanese and South Korean sectors equally benefit from the Chinese output shock. This result is in line with other finding of global production sharing that reports China is heavily involved in the final assembly of electronic items and passenger cars.

[34] According to Sturgeon, Van Biesebroeck, and Gereffi (2008), the cumulative number of assembly plant investment by Japanese auto companies has reached 17 in 2004, whereas the same number for South Korean companies was two.

This experiment suggests that Japan and South Korea are positively affected by the US and China. But the positive response of South Korean output to the Chinese output shock is more significant than the response to the US shock (particularly for electrical machinery), which supports the "decoupling" view mentioned earlier. Moreover, we find that the magnitude of responses is consistent with the pattern of global production sharing in each sectors reported by many studies.

6. ROBUSTNESS CHECKS

6.1 Variable Choices

Our choice of variables in the baseline specification is primarily based on Selover (2004). In this section, we run some alternative specifications to examine the sensitivity of our results to variable choice. Specifically, three alternative FAVAR models are run: (1) exclude sectoral outputs of Japan and South Korea from the baseline, (2) exclude monetary aggregates and short-term interest rates from the baseline, and (3) add real exchange rate indexes and international reserves to the baseline. The first specification tests whether sectoral variables provide any additional information, whereas the second and third specifications test whether the transmission occurs through financial channels. The results are shown in Figure A.2 of the Appendix.

In all three specifications, Japan's response to South Korean output shock remains above South Korea's response to Japanese output shock for most of the time, which is consistent with the baseline. The largest difference is seen in the first specification in which sectoral variables are excluded. Initially South Korean output jumps up higher than the Japanese output, but then it falls sharply in the next six months. This sudden jump is most likely because a large portion of the slow-moving variables used in the baseline identification cannot be used in this specification. As a result, both outputs are allowed to respond more strongly.

Despite the improvements of policy coordination between central banks through such institutions as the Executive's Meeting of East Asia and Pacific Central Banks, our results show that financial variables do not matter much in transmitting business cycles between Japan and South Korea.

6.2 Allowing a Fast-Moving Factor

Here we consider an alternative specification in which the timing of the observed output factor is changed from the baseline specification. There may be an unobserved "fast-moving" factor that responds contemporaneously to the change in observed output factor and generates an important feedback mechanism in the estimated FAVAR. Thus we augment the vector of factors with another factor as follows,

$$\begin{bmatrix} \tilde{F}_t \\ X_{i,t}^{obs} \\ \hat{F}_{fast,t} \end{bmatrix} = \Phi(L) \begin{bmatrix} \tilde{F}_{t-1} \\ X_{i,t-1}^{obs} \\ \hat{F}_{fast,t-1} \end{bmatrix} + \tilde{v}_t ,$$

where $\hat{F}_{fast,t}$ is the principal component extracted from a set of pre-specified variables which supposedly respond to the output shock within the same month. We consider three alternative sets of fast-moving variables, and the resulting FAVAR is compared to the baseline result: (1) spot exchange rates, (2) spot exchange rates and short-term interest rates, (3) spot exchange rates, short-term interest rates, monetary aggregates, consumer price indexes, and trade volumes.

The results are shown in Figure A.3 of the Appendix. In all three specifications, the responses look very similar to the baseline, in that the Japanese response to South Korean output shock exceeds the South Korean response to Japanese output shock for most of the time horizon.

For specifications (2) and (3), the South Korean response is slightly larger for the first three months, but the gap quickly reverses thereafter.

7. CONCLUSION

This paper re-examined the interdependence between Japan and South Korea from the perspective of industrial sectors. We used sectoral industrial production indexes as a measure for output and analyzed them with a factor-augmented vector autoregression (FAVAR) model. To our knowledge there are no other papers that have used FAVAR models, in combination with international input-output tables, to directly model the sectoral interdependence between different countries.

There are two main findings in this paper. First, we find that the nature of the interdependence between Japan and South Korea has changed from the earlier period. While Japanese output shocks do not affect the South Korean economy, South Korean output shocks do affect the Japanese economy in a significant manner. Such asymmetry is found at both the aggregate and at the sectoral level. Second, we find that the same type of asymmetric spillover effect exists between Japan and South Korea in two important sectors (electrical machinery and motor vehicle sectors). This asymmetric pattern is largely consistent with the direction of trade within the sector and across related sectors. Our results indicate that cross-border production sharing can be an important business cycle transmission channel. In addition to our main results, we confirm that both the US and Chinese output shocks have positive spillover effects on Japan and South Korea, with China having a stronger effect on South Korea than the US.

These findings have important implications for the ongoing policy debate regarding free-trade agreements (FTA) such as China-Japan-Korea FTA and Regional Comprehensive

Economic Partnership. The purpose of FTAs in general is to promote stronger economic integration and freer trade and to create a win-win situation for all participating countries. Based on our findings, Japan seems to enjoy production complementarities with South Korea more than South Korea does with Japan. For the FTAs to be successful in the future, it is important that South Korea further diversifies its current industrial structure such that production complementarities in both directions can be raised.

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Table 1

Composition of Trade between Japan and South Korea

	(a) Trade vol., overall, in $mil.	(b) Trade vol., intermed. use, in $mil.	(c) Trade vol., same-sector, in $mil.
Elec.machinery & appliances (048-054)	18,854	15,654	12,976
Basic metals (041-042)	9,713	9,377	5,918
Other machinery (044-047)	8,017	3,039	1,338
Chemicals (029-033)	7,872	7,375	4,273
Petroleum/coal (034)	4,702	3,953	139
Plastics (035-037)	2,135	1,933	567
Motor vehicles (055-058)	2,026	1,113	1,023
Nonmetallic minerals (038-040)	1,431	1,277	472
Food (012-017)	1,235	660	365
Textiles/leather (018-023)	1,092	348	206
Wood/paper (024-028)	940	662	307
Agriculture (001-007)	481	375	26
Mining (008-011)	89	89	0
Trade (065-066)	14,117	9,988	3,140
Services (067-075)	1,877	1,361	759
Other sectors	3,198	1,524	465
Total	**77,781**	**58,728**	**31,972**

Note: The trade volumes are calculated as the sum of exports between the two countries. The number in the parentheses represents the 2005 Asian International Input-Output Table sectoral codes.

Table 2

List of Slow-Moving Variables Used in Identifying Shocks

#	Variables (I-O codes)	Jpn shock	Kor shock	US shock	China shock	Jpn Elec-mach shock	Jpn MV shock	Kor Elec-mach shock	Kor MV shock
1	jpn_ip_mgs (8-60)								
2	jpn_ip_goods (12-60)								
3	jpn_ip_ironsteel_g (41)							*	
4	jpn_ip_steel_g (41)							*	
5	jpn_ip_nfmetal_g (42)								
6	jpn_ip_fmetal_g (43)							*	
7	jpn_ip_machine_g (44)							*	
8	jpn_ip_eappl_g (53-54)		*	*	*				*
9	jpn_ip_comp_g (50)								*
10	jpn_ip_mv_g (55-58)								
11	jpn_ip_car_g (55)								
12	jpn_ip_truck_g (55)								
13	jpn_ip_vparts_g (55)							*	
14	jpn_ip_mc_g (56)		*		*				*
15	jpn_ip_cars_g (55)								
16	jpn_ip_ccem_g (38)		*	*	*			*	*
17	jpn_ip_chem_g (29-33)								
18	jpn_ip_petcoal_g (34)			*				*	*
19	jpn_ip_petro_g (34)			*				*	*
20	jpn_ip_coal_g (34)			*				*	*
21	jpn_ip_plastic_g (35)								
22	jpn_ip_paper_g (27		*					*	*
23	jpn_ip_tt_g (18-22)			*				*	*
24	jpn_ip_spun_g (18)		*	*	*			*	*
25	jpn_ip_apparel_g (20-21)		*	*	*			*	*
26	jpn_ip_foods_g (12-15,17)							*	*
27	jpn_ip_dairy_g (14)		*	*	*			*	*
28	jpn_ip_bev_g (16)		*	*	*			*	*
29	jpn_ip_rubber_g (36-37)		*		*			*	
30	jpn_ip_leath_g (23)		*	*	*			*	*
31	jpn_ip_furn_g (25)		*	*	*			*	*
32	jpn_ip_wood_g (24-26)		*	*	*			*	*
33	jpn_ip_mins (8-11)		*	*	*			*	*
34	jpn_ip_elecmach_g (48-52)								
35	kor_ip_mugs (8-61)								
36	kor_ip_mgs (8-60)								
37	kor_ip_mins (8-11)	*		*	*	*			
38	kor_ip_oilgas_m (8)	*		*	*	*	*		
39	kor_ip_iron_m (9-10)	*		*	*	*	*		
40	kor_ip_nmetal_m (11)	*		*	*	*	*		
41	kor_ip_goods (12-60)								
42	kor_ip_food_g (12-15)					*	*		
43	kor_ip_bev_g (16)	*			*	*	*		
44	kor_ip_tobacc_g (17)	*		*	*	*	*		
45	kor_ip_tt_g (18-22)					*	*		
46	kor_ip_apparel_g (21)	*				*	*		
47	kor_ip_leath_g (23)	*		*		*	*		
48	kor_ip_wood_g (24-26)	*		*	*	*	*		
49	kor_ip_paper_g (27)					*	*		
50	kor_ip_print_g (28)	*		*	*	*	*		
51	kor_ip_petcoal_g (34)					*			
52	kor_ip_chem_g (29-30,33)					*			
53	kor_ip_drugs_g (31-32)				*	*	*		
54	kor_ip_plastics_g (35-37)					*			
55	kor_ip_nmetals_g (38-40)					*			
56	kor_ip_pmetal_g (41-42)								
57	kor_ip_fmetal_g (43)					*			
58	kor_ip_elecmach_g (48-52)								
59	kor_ip_watches_g (59)						*		
60	kor_ip_eequip_g (53-54)								
61	kor_ip_othmachs_g (44-47)								

Table 2 (continued)

List of Slow-Moving Variables Used in Identifying Shocks

#	Variables (I-O codes)	Jpn shock	Kor shock	US shock	China shock	Jpn Elec-mach shock	Jpn MV shock	Kor Elec-mach shock	Kor MV shock
62	kor_ip_mv_g (55)								
63	kor_ip_ot_g (56-58)								
64	kor_ip_furn_g (25)	*		*	*	*	*		
65	kor_ip_misc_g (60)	*			*	*	*		
66	kor_ip_utils (61)	*		*		*	*		
67	us_ip_mins (8-11)					*	*	*	*
68	us_ip_tt_g (18-20)	*	*		*	*	*	*	*
69	us_ip_al_g (21-23)	*				*	*	*	*
70	us_ip_wood_g (24-26)	*	*			*	*	*	*
71	us_ip_petcoal_g (34)	*			*	*	*	*	*
72	us_ip_chem_g (29-33)						*		*
73	us_ip_plastic_g (35-37)						*		*
74	us_ip_nmetal_g (38-40)	*	*		*	*	*	*	*
75	us_ip_pmetal_g (41-42)						*		
76	us_ip_fmetal_g (43)						*		
77	us_ip_machine_g (44-47)								
78	us_ip_elecmach_g (48-52)								
79	us_ip_eequip_g (53-54)		*				*		*
80	us_ip_goods (12-60)								
81	us_ip_dg_g (24-26, 38-59)								

Note: An asterisk means that the variable is chosen as the slow-moving variable in the identification of shocks. The number in the parentheses represents the 2005 International Asian Input-Output Table sectoral codes.

Table 3

Sectoral Granger Causality Tests

Japanese Sectors Relationship	p-value	South Korean Sectors Relationship	p-value
(Machinery-related sectors)			
Kor IP → Jpn Elec.machine	0.00**	Jpn IP → Kor Elec.machine	0.08
Kor IP → Jpn Motor vehicle	0.03*	Jpn IP → Kor Motor vehicle	0.04*
Kor IP → Jpn Elec.appliances	0.17	Jpn IP → Kor Elec.appliances	0.04*
Kor IP → Jpn other Machine	0.00**	Jpn IP → Kor other Machine	0.05*
(Material-related sectors)			
Kor IP → Jpn Basic Metals	0.00**	Jpn IP → Kor Basic Metals	0.15
Kor IP → Jpn Chem	0.18	Jpn IP → Kor Chem	0.05*
Kor IP → Jpn Pet/coal	0.43	Jpn IP → Kor Pet/coal	0.25
Kor IP → Jpn Plastic	0.00**	Jpn IP → Kor Plastics	0.01*

* = sig at .05 level, ** = sig at .01 level

Note: The null hypothesis the non-causality of the excluded variables, which are South Korean output ("Kor IP") and Japanese output ("Jpn IP") on the sectoral variables of each country. Sample period is 2000.1-2012.12. Lag length is $P = 2$ months.

Table 4

Trade Flows Between Japan and South Korea Involving
Electrical Machinery Sector

Sector type	Sector *j*	Japan's electrical machinery sector (a) Import from Kor *j* in $mil.	Japan's electrical machinery sector (b) Export to Kor *j* in $mil.	South Korea's electrical machinery sector (c) Import from Jpn *j* in $mil.	South Korea's electrical machinery sector (d) Export to Jpn *j* in $mil.
Shock sector	Electrical machinery (048-052)	4,428.0	7,687.1	7,687.1	4,428.0
Materials	Basic metals (041-042)	80.7	25.3	231.7	0.2
	Chemicals (029-033)	25.1	230.0	779.1	1.3
	Petroleum/coal (034)	10.7	2.4	0.7	0.0
	Plastics (035-037)	22.9	1.1	625.9	0.2
	Subtotal (029-037, 041-042)	**139.4**	**258.7**	**1,637.3**	**1.8**
Machinery	Motor vehicles (055-058)	0.0	430.3	1.7	186.3
	Electrical appliances (053-054)	35.1	120.9	0.0	191.0
	Other machineries (044-047)	41.7	230.0	21.4	59.0
	Subtotal (044-047, 053-058)	**76.8**	**781.2**	**23.1**	**436.3**
Tot. intermed. demand (001-076)		5,297.5	10,221.8	12,036.4	5,316.0
Tot. final demand		n.a.	1,308.4	n.a.	1,778.6

Note: The number in the parentheses represents the 2005 International Asian Input-Output Table sectoral codes.

Table 5

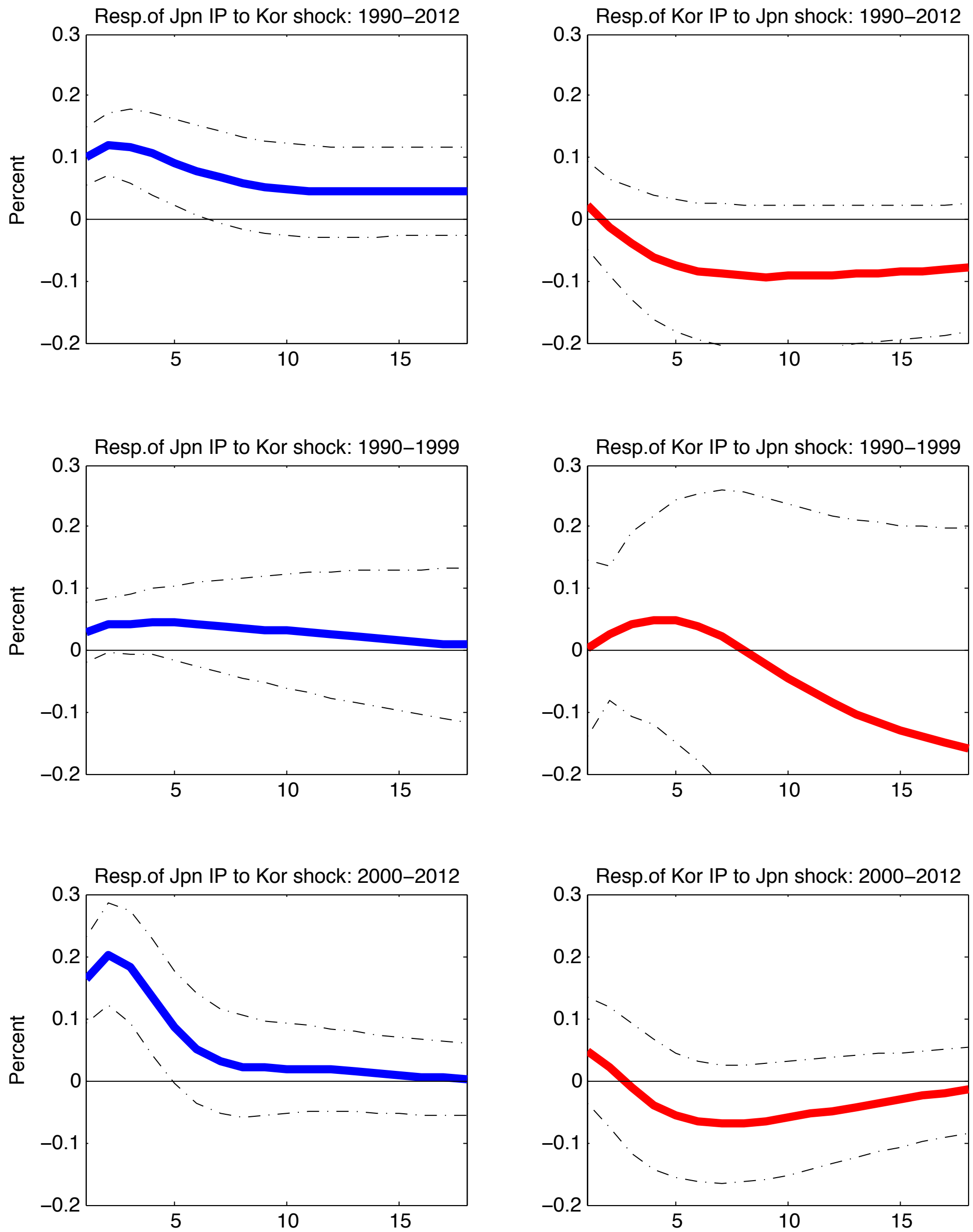
Trade Flows Between Japan and South Korea Involving
Motor Vehicles Sector

Sector type	Sector *j*	Japan's motor vehicles sector		South Korea's motor vehicles sector	
		(a) Import from Kor *j* in $mil.	(b) Export to Kor *j* in $mil.	(c) Import from Jpn *j* in $mil.	(d) Export to Jpn *j* in $mil.
Shock sector	Motor vehicles (055-058)	157.3	819.9	819.9	157.3
Materials	Basic metals (041-042)	247.4	0.4	888.2	0.0
	Chemicals (029-033)	26.5	0.9	66.3	0.0
	Petroleum/coal (034)	22.2	0.2	1.5	0.0
	Plastics (035-037)	86.2	0.1	51.3	0.0
	Subtotal (029-037, 041-042)	**382.3**	**1.6**	**1,007.3**	**0.0**
Machinery	Electrical machinery (048-052)	186.3	1.7	774.3	0.0
	Electrical appliances (053-054)	13.7	0.1	0.3	0.0
	Other machineries (044-047)	8.7	11.4	498.7	0.0
	Subtotal (044-054)	**208.6**	**13.2**	**1,273.3**	**0.0**
Tot. intermed. demand (001-076)		881.8	935.2	2,526.6	157.3
Tot. final demand		n.a.	680.4	n.a.	225.1

Note: The number in the parentheses represents the 2005 Asian International Input-Output Table sectoral codes.

Figure 1

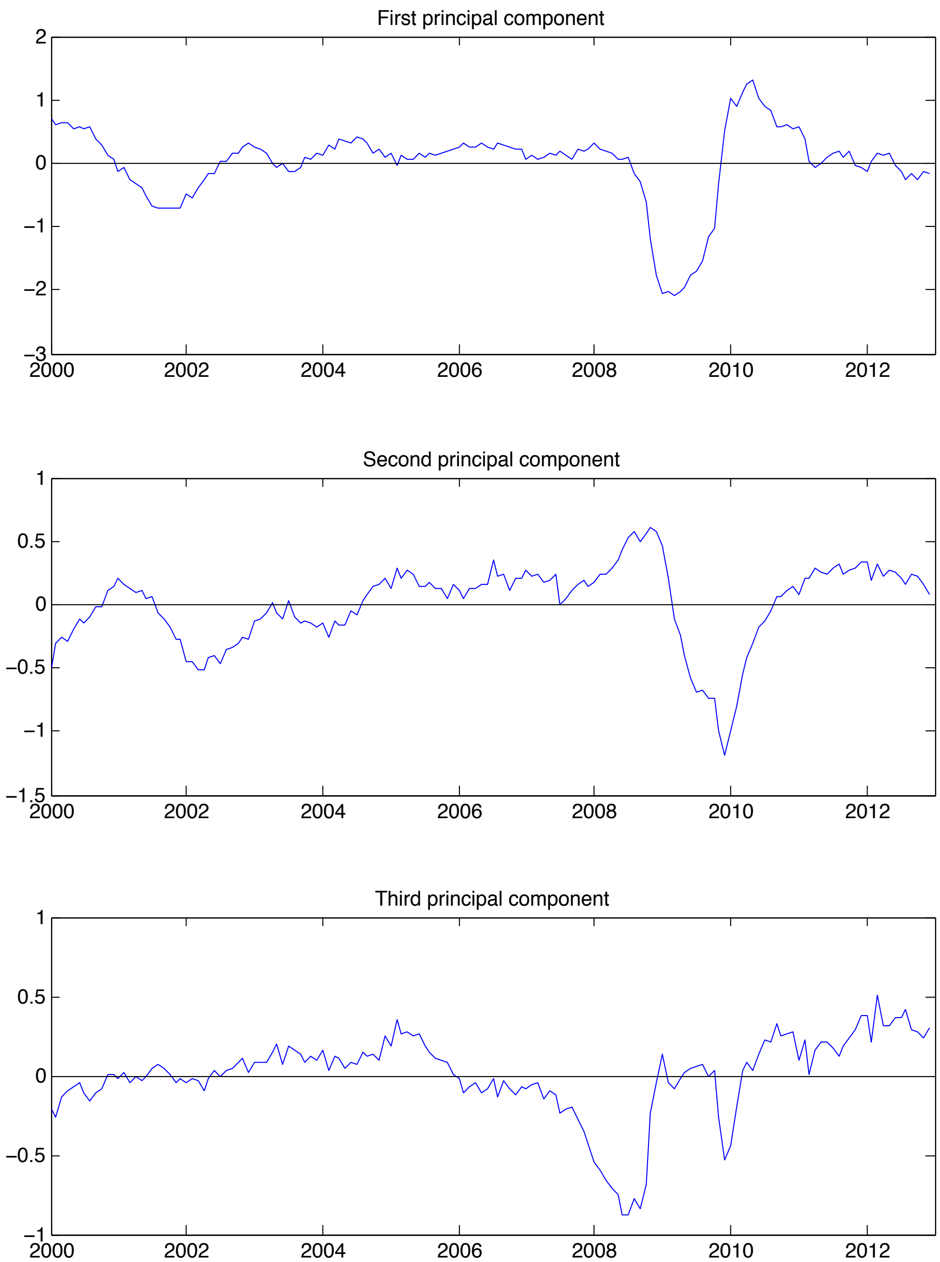
Impulse Responses of Japanese and South Korean Overall Industrial Production to Country-Level Industrial Production Shocks (SVAR)



Note: The solid line in each panel represents the impulse responses of Japanese and South Korean industrial production ("Jpn IP", "Kor IP") to a 0.5 percentage point shock in the overall industrial production in the other country ("Kor shock", "Jpn shock"). The responses are drawn using a structural vector autoregression (SVAR) described in Selover (2004). The dash-dotted lines represent the 95% confidence intervals associated with the SVAR impulse response. All variables are expressed in terms of growth rates (%).

Figure 2

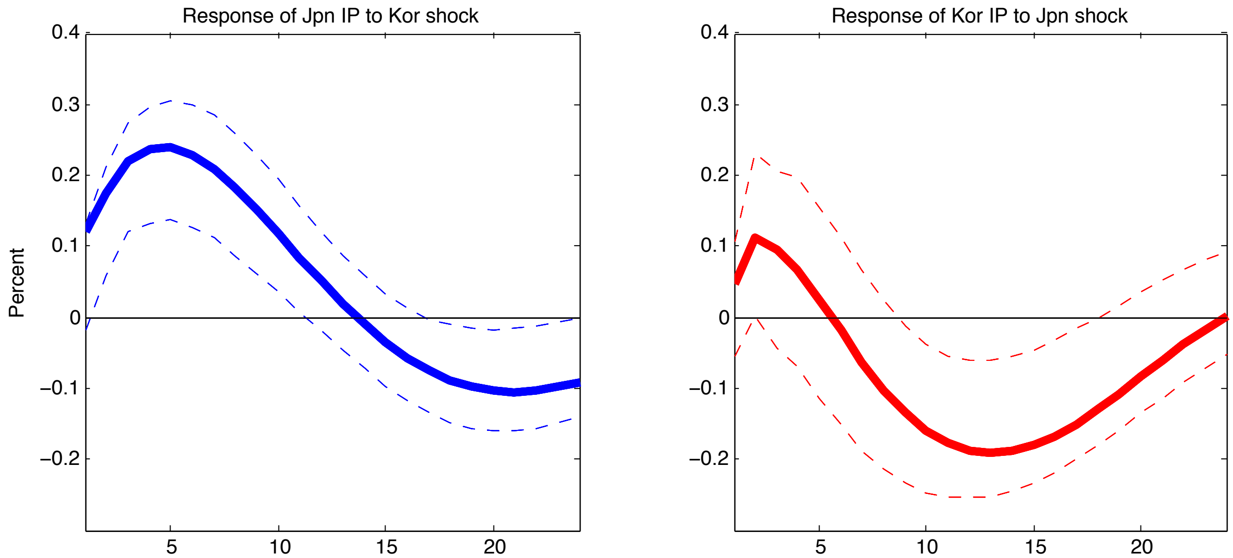
Time Series Graphs of the Principal Components



Note: Each panel presents the time series for principal components extracted from the 127 variables used in the baseline analysis. The sample period is 2000:1 – 2012:12.

Figure 3

Impulse Responses of Japanese and South Korean Overall Industrial Production to Country-Level Industrial Production Shocks (FAVAR)



Note: The solid line in each panel represents the impulse responses of Japanese and South Korean industrial production ("Jpn IP", "Kor IP") to a 0.5 percentage point shock in the overall industrial production in the other country ("Kor shock", "Jpn shock"). The responses are drawn using a factor augmented vector autoregression (FAVAR). The dashed lines represent the 90% confidence intervals associated with the FAVAR impulse response. All variables are expressed in terms of growth rates (%).

Figure 4

Impulse Responses of Japanese and South Korean Sectoral Industrial Production to Country-Level Industrial Production Shocks (FAVAR)

(a) Machinery-related sectors

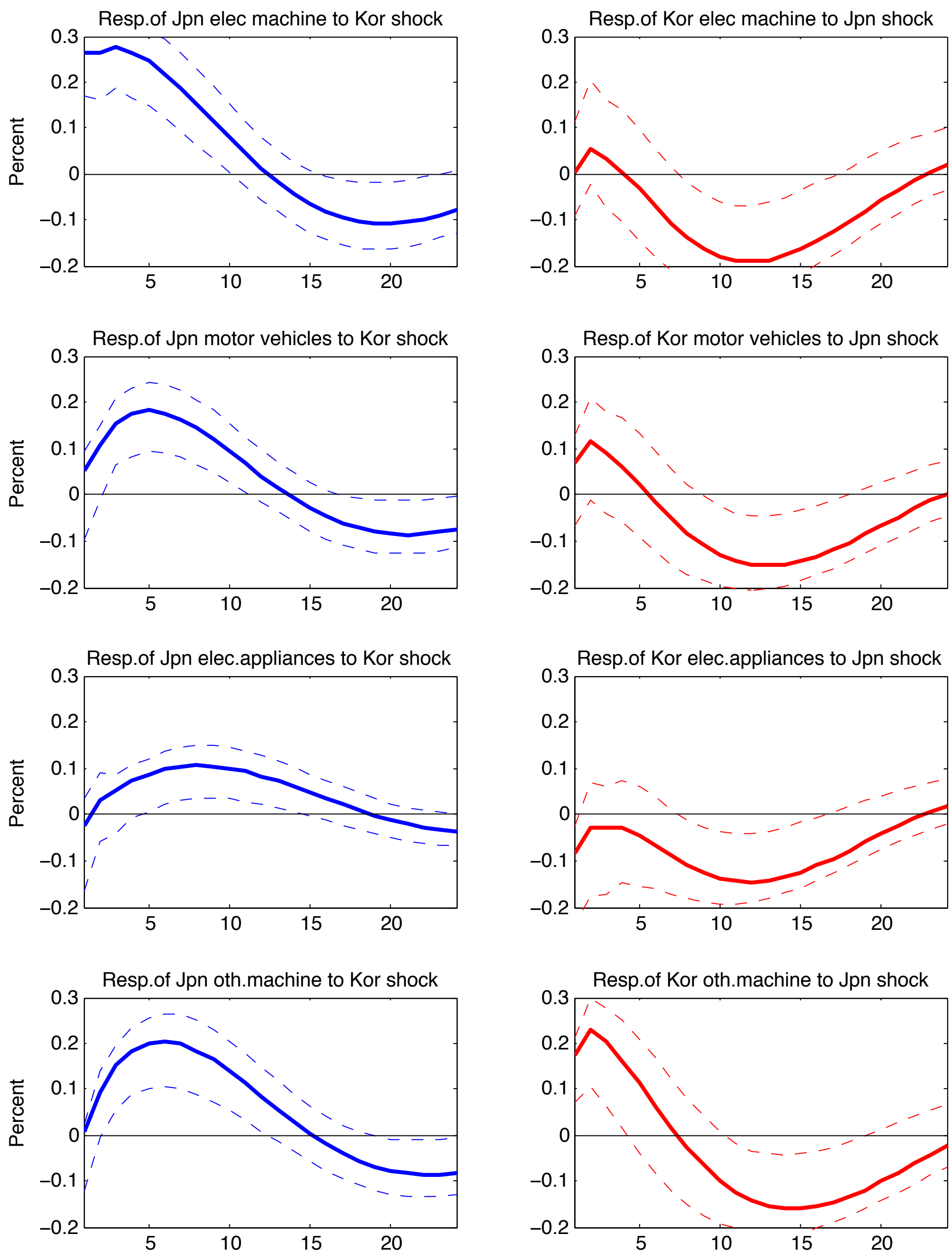
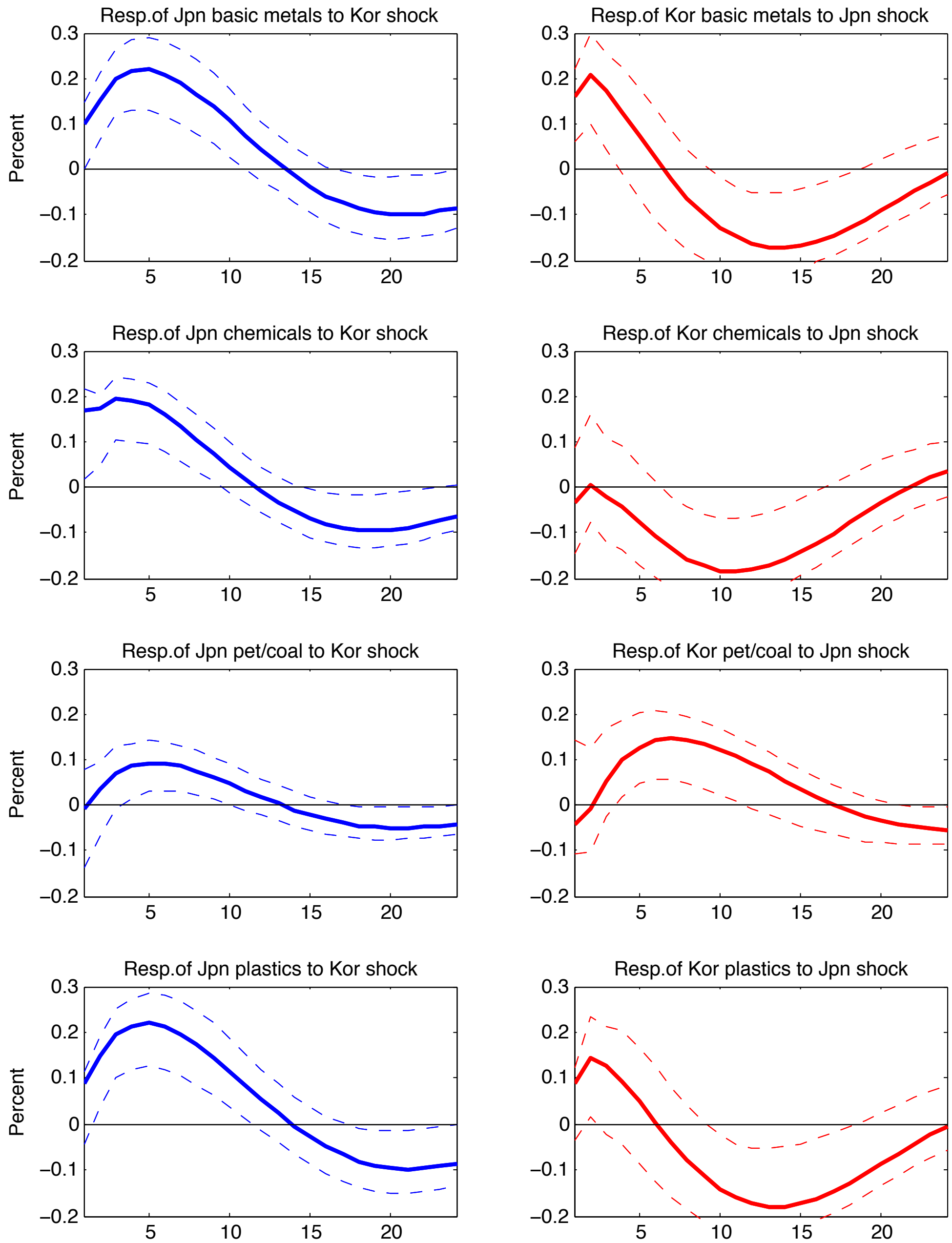


Figure 4 (continued)

Impulse Responses of Japanese and South Korean Sectoral Industrial Production to Country-Level Industrial Production Shocks (FAVAR)

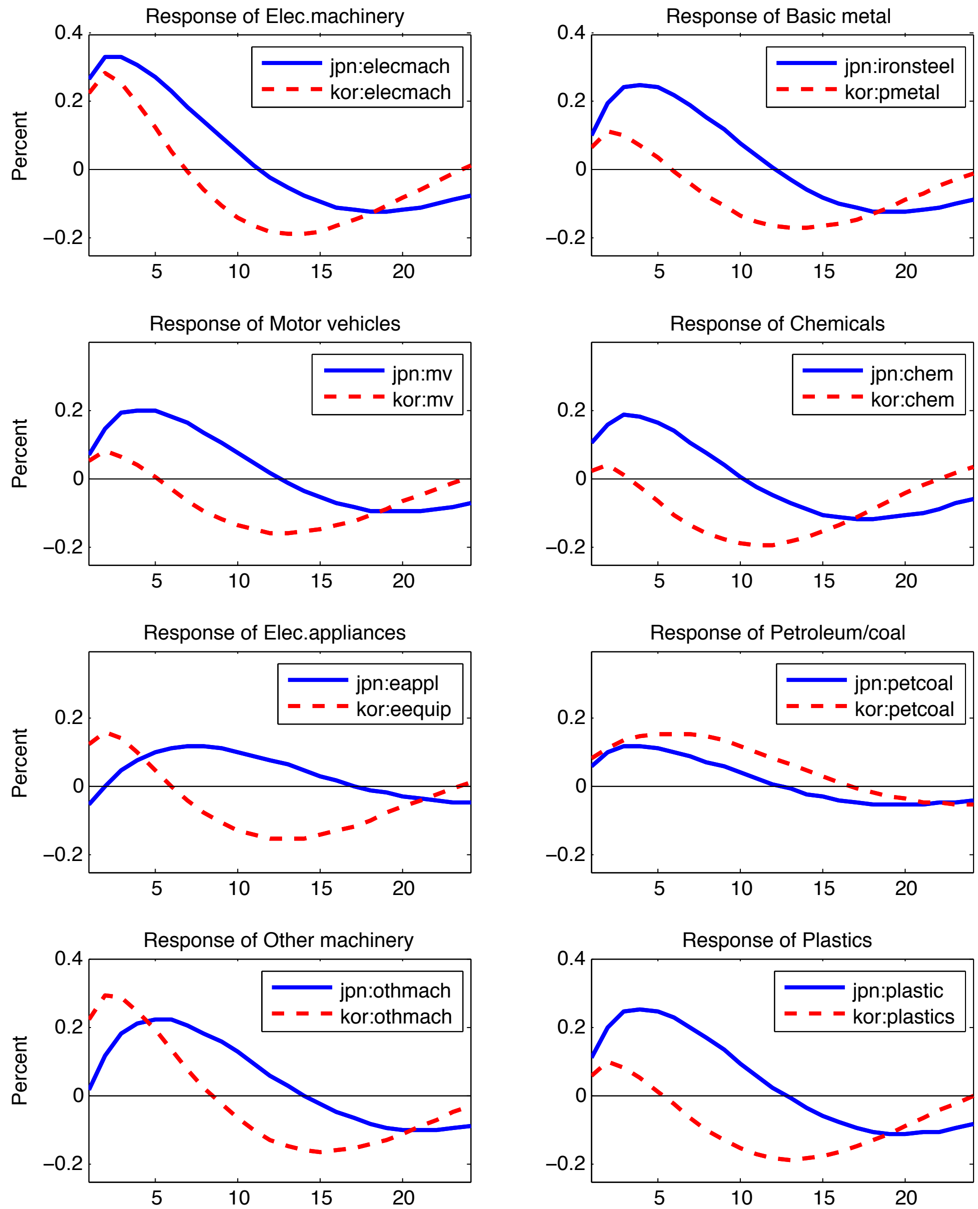
(b) Material-related sectors



Note: The solid line in each panel represents the impulse responses of Japanese and South Korean industrial production ("Jpn IP", "Kor IP") to a 0.5 percentage point shock in the overall industrial production in the other country ("Kor shock", "Jpn shock"). The responses are drawn using a factor augmented vector autoregression (FAVAR). The dashed lines represent the 90% confidence intervals associated with the FAVAR impulse response. All variables are expressed in terms of growth rates (%).

Figure 5

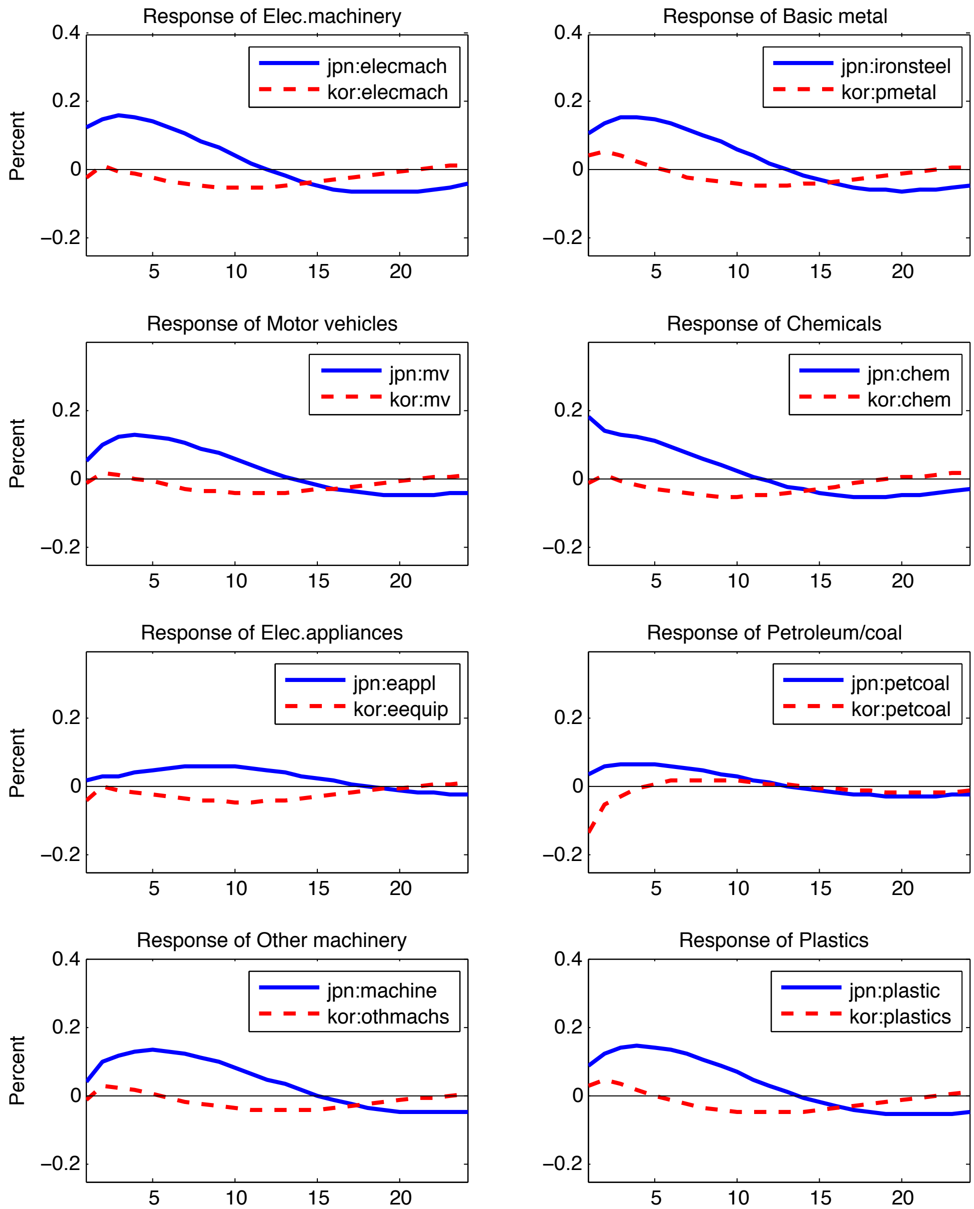
Impulse Responses of Japanese and South Korean Sectoral Industrial Production to Electrical Machinery Industrial Production Shock (FAVAR)



Note: The solid line in each panel represents the impulse responses of Japanese sectoral industrial production ("jpn:xx") to a 0.5 percentage point shock in the South Korean industrial production in electronic machinery. The dashed line presents the impulse response of South Korean sectoral industrial production ("kor:xx") to a 0.5 percentage point shock in the Japanese industrial production in electronic machinery. The responses are drawn using a factor augmented vector autoregression (FAVAR). All variables are expressed in terms of growth rates (%).

Figure 6

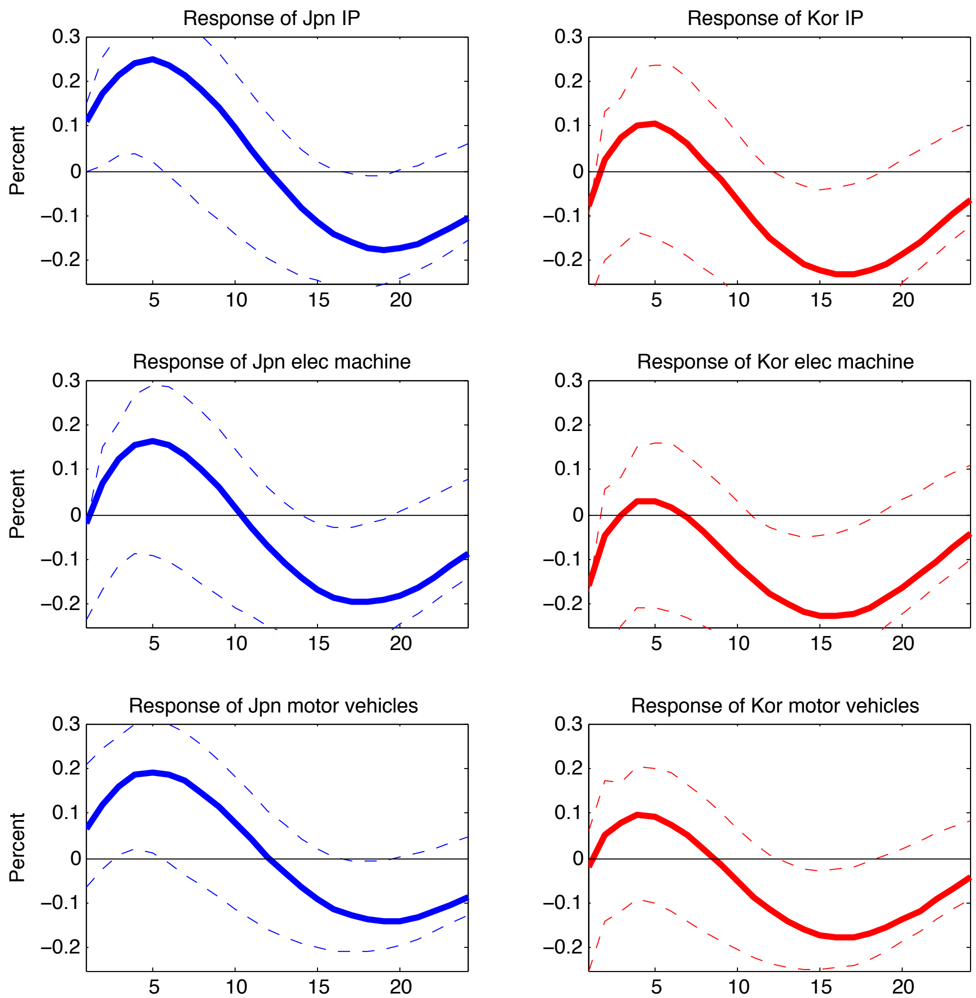
Impulse Responses of Japanese and South Korean Sectoral Industrial Production to Motor Vehicles Industrial Production Shock (FAVAR)



Note: The solid line in each panel represents the impulse responses of Japanese sectoral industrial production ("jpn:xx") to a 0.5 percentage point shock in the South Korean industrial production in motor vehicles. The dashed line presents the impulse response of South Korean sectoral industrial production ("kor:xx") to a 0.5 percentage point shock in the Japanese industrial production in motor vehicles. The responses are drawn using a factor augmented vector autoregression (FAVAR). All variables are expressed in terms of growth rates (%).

Figure 7

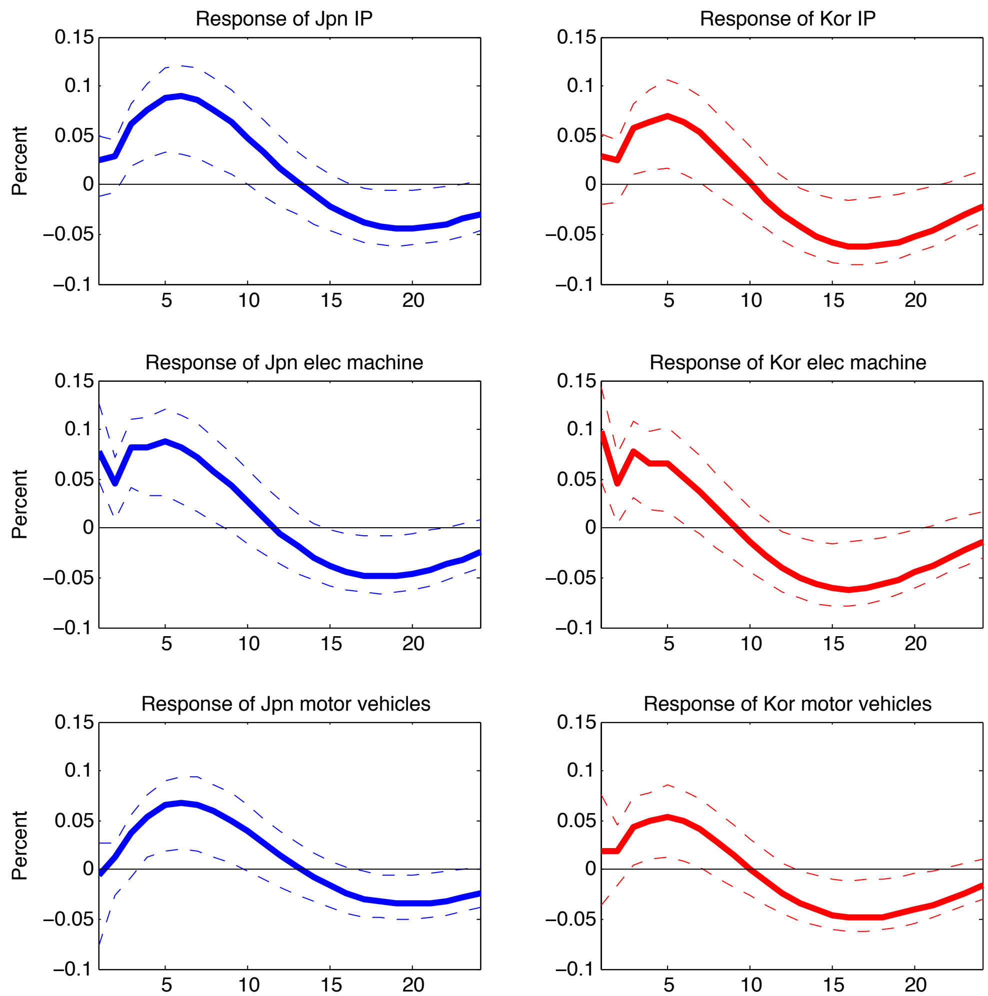
Impulse Responses of Japanese and South Korean Sectoral Industrial Production to US Industrial Production Shocks (FAVAR)



Note: The solid line in each panel represents the impulse responses of Japanese and South Korean industrial production ("Jpn IP", "Kor IP") to a 0.5 percentage point shock in the overall industrial production in the US ("US shock"). The responses are drawn using a factor augmented vector autoregression (FAVAR). The dashed lines represent the 90% confidence intervals associated with the FAVAR impulse response. All variables are expressed in terms of growth rates (%).

Figure 8

Impulse Responses of Japanese and South Korean Sectoral Industrial Production to Chinese Industrial Production Shocks (FAVAR)



Note: The solid line in each panel represents the impulse responses of Japanese and South Korean industrial production ("Jpn IP", "Kor IP") to a 0.5 percentage point shock in the overall industrial production in China ("China shock"). The responses are drawn using a factor augmented vector autoregression (FAVAR). The dashed lines represent the 90% confidence intervals associated with the FAVAR impulse response. All variables are expressed in terms of growth rates (%).

APPENDIX A: Data Used in Estimating FAVAR

The list of variables are reported in Table A.1. All series are taken from the following sources: Japanese Ministry of Economy, Trade, and Industry (METI), Bank of Korea ECOS system (BofK), Board of Governors of the Federal Reserve Systems (Fed), Ministry of Economic Affairs, Taiwan (MEA), Bank of Thailand (BOT), Bank Negara Malaysia (BNM), Malaysia External Trade Statistics (METS), Federal Reserve Economic Data (FRED), IMF International Financial Statistics database (IFS), Global Financial Database (GFD). Mnemonics are provided by the authors to reflect the contents covered.

Each variable is sub-divided into eight categories as 1. aggregate industrial production, 2. disaggregated index of industrial production, 3. trade volume, 4. consumer price index, 5. spot exchange rates, 6. money supply, 7. interest rates, 8. real exchange rate index, 9. international reserves, 10. recession indicators. Variables 1-7 are used in the baseline FAVAR estimation; 8, 9 are used in the robustness check analysis; Variables 150-153 are used to construct the recession dummy variable commonly used in all FAVAR specification. Variables with asterisk are used in the SVAR analysis of Section 2.1.

The transformation codes are 1 – no transformation or 5 – year over year growth rate. We remove outliers following the rule suggested by Stock and Watson (2005), i.e. replace observations with absolute median deviations larger than six times the interquartile range with the median value of the preceding five observations.

Table A.1

Description of Data

1. Aggregate Industrial Production

1.	jpn_ip_oecd*	2000:01-2012:12	5	Japan: Production of Total Industry (Index 2010=100); s.a.	FRED
2.	kor_ip_oecd*	2000:01-2012:12	5	South Korea: Production of Total Industry (Index 2010=100); s.a.	FRED
3.	us_ip_fed*	2000:01-2012:12	5	US: industrial Production Index; s.a.	FRED
4.	china_ip_ifs	2000:01-2012:12	5	China: Industrial Production (growth rate); n.s.a.	IFS
5.	twn_ip_gov	2000:01-2012:12	5	Taiwan: Industrial Production Index, industry excl. buildings construction; s.a.	MEA
6.	tha_ip_gfd	2000:01-2012:12	5	Thailand: Industrial Production Volume; s.a.	FRED
7.	mys_ip_gov	2000:01-2012:12	5	Malaysia: Industrial Production Index, all divisions; n.s.a.	BNM

2. Disaggregated Index of Industrial Production (IIP)

8.	jpn_ip_mgs	2000:01-2012:12	5	Japan: IIP: Mining and manufacturing; s.a.	METI
9.	jpn_ip_goods	2000:01-2012:12	5	Japan: IIP: Manufacturing; s.a.	METI
10.	jpn_ip_ironsteel_g	2000:01-2012:12	5	Japan: IIP: Iron and steel; s.a.	METI
11.	jpn_ip_steel_g	2000:01-2012:12	5	Japan: IIP: Ordinary steel; s.a.	METI
12.	jpn_ip_nfmetal_g	2000:01-2012:12	5	Japan: IIP: Non-ferrous metals; s.a.	METI
13.	jpn_ip_fmetal_g	2000:01-2012:12	5	Japan: IIP: Fabricated structural metal products; s.a.	METI
14.	jpn_ip_othmach_g	2000:01-2012:12	5	Japan: IIP: General machinery; s.a.	METI
15.	jpn_ip_eappl_g	2000:01-2012:12	5	Japan: IIP: Household electrical machinery; s.a.	METI
16.	jpn_ip_comp_g	2000:01-2012:12	5	Japan: IIP: Electronic computers; s.a.	METI
17.	jpn_ip_mv_g	2000:01-2012:12	5	Japan: IIP: Transport equipment; s.a.	METI
18.	jpn_ip_car_g	2000:01-2012:12	5	Japan: IIP: Passenger cars; s.a.	METI
19.	jpn_ip_truck_g	2000:01-2012:12	5	Japan: IIP: Trucks; s.a.	METI
20.	jpn_ip_vparts_g	2000:01-2012:12	5	Japan: IIP: Motor vehicle parts; s.a.	METI
21.	jpn_ip_mc_g	2000:01-2012:12	5	Japan: IIP: Motorcycles; s.a.	METI
22.	jpn_ip_cars_g	2000:01-2012:12	5	Japan: IIP: Passenger cars, buses and trucks; s.a.	METI
23.	jpn_ip_ccem_g	2000:01-2012:12	5	Japan: IIP: Cement and cement products; s.a.	METI
24.	jpn_ip_chem_g	2000:01-2012:12	5	Japan: IIP: Chemicals; s.a.	METI
25.	jpn_ip_petcoal_g	2000:01-2012:12	5	Japan: IIP: Petroleum and coal products; s.a.	METI
26.	jpn_ip_petro_g	2000:01-2012:12	5	Japan: IIP: Petroleum products; s.a.	METI
27.	jpn_ip_coal_g	2000:01-2012:12	5	Japan: IIP: Coal products; s.a.	METI

28.	jpn_ip_plastic_g	2000:01-2012:12	5	Japan: IIP: Plastic products; s.a.	METI
29.	jpn_ip_paper_g	2000:01-2012:12	5	Japan: IIP: Pulp, paper and paper products; s.a.	METI
30.	jpn_ip_tt_g	2000:01-2012:12	5	Japan: IIP: Textiles; s.a.	METI
31.	jpn_ip_spun_g	2000:01-2012:12	5	Japan: IIP: Spun yarn; s.a.	METI
32.	jpn_ip_apparel_g	2000:01-2012:12	5	Japan: IIP: Clothes; s.a.	METI
33.	jpn_ip_foods_g	2000:01-2012:12	5	Japan: IIP: Foods and tobacco; s.a.	METI
34.	jpn_ip_dairy_g	2000:01-2012:12	5	Japan: IIP: Dairy products; s.a.	METI
35.	jpn_ip_bev_g	2000:01-2012:12	5	Japan: IIP: Beverages; s.a.	METI
36.	jpn_ip_rubber_g	2000:01-2012:12	5	Japan: IIP: Rubber products; s.a.	METI
37.	jpn_ip_leath_g	2000:01-2012:12	5	Japan: IIP: Leather products; s.a.	METI
38.	jpn_ip_furn_g	2000:01-2012:12	5	Japan: IIP: Furniture; s.a.	METI
39.	jpn_ip_wood_g	2000:01-2012:12	5	Japan: IIP: Wood and wood products; s.a.	METI
40.	jpn_ip_mins	2000:01-2012:12	5	Japan: IIP: Mining; s.a.	METI
41.	jpn_ip_elecmach_g	2000:01-2012:12	5	Japan: IIP: Electrical machinery (1995 version); s.a.	METI
42.	kor_ip_mugs	2000:01-2012:12	5	S. Korea: IIP: All Groups; s.a.	BofK
43.	kor_ip_mgs	2000:01-2012:12	5	S. Korea: IIP: Mining and Manufacturing; s.a.	BofK
44.	kor_ip_mins	2000:01-2012:12	5	S. Korea: IIP: Mining; s.a.	BofK
45.	kor_ip_oilgas_m	2000:01-2012:12	5	S. Korea: IIP: Mining: Petroleum, Crude Petroleum and Natural Gas; s.a.	BofK
46.	kor_ip_iron_m	2000:01-2012:12	5	S. Korea: IIP: Mining: Metal Ores; s.a.	BofK
47.	kor_ip_nmetal_m	2000:01-2012:12	5	S. Korea: IIP: Mining: Non-metallic Minerals; s.a.	BofK
48.	kor_ip_goods	2000:01-2012:12	5	S. Korea: IIP: Manufacturing; s.a.	BofK
49.	kor_ip_food_g	2000:01-2012:12	5	S. Korea: IIP: Food Products; s.a.	BofK
50.	kor_ip_bev_g	2000:01-2012:12	5	S. Korea: IIP: Beverage Products; s.a.	BofK
51.	kor_ip_tobacc_g	2000:01-2012:12	5	S. Korea: IIP: Tobacco Products; s.a.	BofK
52.	kor_ip_tt_g	2000:01-2012:12	5	S. Korea: IIP: Textiles; s.a.	BofK
53.	kor_ip_apparel_g	2000:01-2012:12	5	S. Korea: IIP: Wearing apparel, Clothing Accessories and Fur Articles; s.a.	BofK
54.	kor_ip_leath_g	2000:01-2012:12	5	S. Korea: IIP: Tanning and Dressing of Leather, Luggage and Footwear; s.a.	BofK
55.	kor_ip_wood_g	2000:01-2012:12	5	S. Korea: IIP: Wood and Products of Wood and Cork(Except Furniture); s.a.	BofK
56.	kor_ip_paper_g	2000:01-2012:12	5	S. Korea: IIP: Pulp, Paper and Paper Products; s.a.	BofK
57.	kor_ip_print_g	2000:01-2012:12	5	S. Korea: IIP: Printing and Reproduction of Recorded Media; s.a.	BofK
58.	kor_ip_petcoal_g	2000:01-2012:12	5	S. Korea: IIP: Coke, hard-coal and lignite fuel briquettes and Refined Petroleum	BofK

				Products; s.a.	
59.	kor_ip_chem_g	2000:01-2012:12	5	S. Korea: IIP: Chemicals and chemical products; s.a.	BofK
60.	kor_ip_drugs_g	2000:01-2012:12	5	S. Korea: IIP: Pharmaceuticals, Medicinal Chemicals and Botanical Products; s.a.	BofK
61.	kor_ip_plastics_g	2000:01-2012:12	5	S. Korea: IIP: Rubber and Plastic Products; s.a.	BofK
62.	kor_ip_nmetals_g	2000:01-2012:12	5	S. Korea: IIP: Non-metallic Minerals; s.a.	BofK
63.	kor_ip_pmetal_g	2000:01-2012:12	5	S. Korea: IIP: Basic Metals; s.a.	BofK
64.	kor_ip_fmetal_g	2000:01-2012:12	5	S. Korea: IIP: Fabricated Metal Products; s.a.	BofK
65.	kor_ip_elecmach_g	2000:01-2012:12	5	S. Korea: IIP: Electronic Components, Computer, Radio, Television and Communication Equipment and Apparatuses; s.a.	BofK
66.	kor_ip_watches_g	2000:01-2012:12	5	S. Korea: IIP: Medical, Precision and Optical Instruments, Watches and Clocks; s.a.	BofK
67.	kor_ip_eequip_g	2000:01-2012:12	5	S. Korea: IIP: electrical equipment; s.a.	BofK
68.	kor_ip_othmach_g	2000:01-2012:12	5	S. Korea: IIP: Other Machinery and Equipment; s.a.	BofK
69.	kor_ip_mv_g	2000:01-2012:12	5	S. Korea: IIP: Motor Vehicles, Trailers and Semitrailers; s.a.	BofK
70.	kor_ip_ot_g	2000:01-2012:12	5	S. Korea: IIP: Other Transport Equipment; s.a.	BofK
71.	kor_ip_furn_g	2000:01-2012:12	5	S. Korea: IIP: Furniture; s.a.	BofK
72.	kor_ip_misc_g	2000:01-2012:12	5	S. Korea: IIP: Other Products; s.a.	BofK
73.	kor_ip_utils	2000:01-2012:12	5	S. Korea: IIP: Electricity, gas; s.a.	BofK
74.	us_ip_mins	2000:01-2012:12	5	US: IIP: Mining (NAICS = 21); s.a. IP	Fed
75.	us_ip_tt_g	2000:01-2012:12	5	US: IIP: Textiles and products (NAICS = 313,4); s.a. IP	Fed
76.	us_ip_al_g	2000:01-2012:12	5	US: IIP: Apparel and leather goods (NAICS = 315,6); s.a. IP	Fed
77.	us_ip_wood_g	2000:01-2012:12	5	US: IIP: Wood product (NAICS = 321); s.a. IP	Fed
78.	us_ip_petcoal_g	2000:01-2012:12	5	US: IIP: Petroleum and coal products (NAICS = 324); s.a. IP	Fed
79.	us_ip_chem_g	2000:01-2012:12	5	US: IIP: Chemical (NAICS = 325); s.a. IP	Fed
80.	us_ip_plastic_g	2000:01-2012:12	5	US: IIP: Plastics and rubber products (NAICS = 326); s.a. IP	Fed
81.	us_ip_nmetal_g	2000:01-2012:12	5	US: IIP: Nonmetallic mineral product (NAICS = 327); s.a. IP	Fed
82.	us_ip_pmetal_g	2000:01-2012:12	5	US: IIP: Primary metal (NAICS = 331); s.a. IP	Fed
83.	us_ip_fmetal_g	2000:01-2012:12	5	US: IIP: Fabricated metal product (NAICS = 332); s.a. IP	Fed
84.	us_ip_machine_g	2000:01-2012:12	5	US: IIP: Machinery (NAICS = 333); s.a. IP	Fed
85.	us_ip_elecmach_g	2000:01-2012:12	5	US: IIP: Computer and electronic product (NAICS = 334); s.a. IP	Fed
86.	us_ip_eequip_g	2000:01-2012:12	5	US: IIP: Electrical equipment, appliance, and component (NAICS = 335); s.a. IP	Fed
87.	us_ip_goods	2000:01-2012:12	5	US: IIP: Manufacturing (NAICS); s.a. IP	Fed

88.	us_ip_dg_g	2000:01-2012:12	5	US: IIP: Durable manufacturing (NAICS); s.a. IP	Fed

3. Trade Volume

89.	jpn_ex_oecd	2000:01-2012:12	5	Japan: Exports: Value Goods; s.a.	FRED
90.	kor_ex_oecd	2000:01-2012:12	5	S. Korea: Exports: Value Goods; s.a.	FRED
91.	us_ex_oecd	2000:01-2012:12	5	US: Exports: Value Goods; s.a.	FRED
92.	china_ex_oecd	2000:01-2012:12	5	China: Exports: Value Goods; s.a.	FRED
93.	twn_ex_ifs	2000:01-2012:12	5	Taiwan: Goods: Value of Exports, US$; n.s.a.	FRED
94.	tha_ex_gov	2000:01-2012:12	5	Thailand: Total Exports; n.s.a.	BOT
95.	mys_ex_gov	2000:01-2012:12	5	Malaysia: Total Exports; n.s.a.	METS
96.	jpn_im_oecd	2000:01-2012:12	5	Japan: Imports: Value Goods; s.a.	FRED
97.	kor_im_oecd	2000:01-2012:12	5	S. Korea: Imports: Value Goods; s.a.	FRED
98.	us_im_oecd	2000:01-2012:12	5	US: Imports: Value Goods; s.a.	FRED
99.	china_im_oecd	2000:01-2012:12	5	China: Imports: Value Goods; s.a.	FRED
100.	twn_im_ifs	2000:01-2012:12	5	Taiwan: Goods: Value of Imports, US$; n.s.a.	FRED
101.	tha_im_gov	2000:01-2012:12	5	Thailand: Total Imports; n.s.a.	BOT
102.	mys_im_gov	2000:01-2012:12	5	Malaysia: Total Imports; n.s.a.	METS

4. Consumer Price Index (CPI)

103.	jpn_cpi_oecd*	2000:01-2012:12	5	Japan: Consumer Price Index: Total All Items, s.a.	FRED
104.	kor_cpi_oecd*	2000:01-2012:12	5	S. Korea: Consumer Price Index: All Items, n.s.a.	FRED
105.	us_cpi_oecd	2000:01-2012:12	5	US: Consumer Price Index: Total All Items, s.a.	FRED
106.	china_cpi_oecd	2000:01-2012:12	5	China: Consumer Price Index: All Items, n.s.a.	FRED
107.	tha_cpi_gfd	2000:01-2012:12	5	Thailand: Consumer Price Index; n.s.a.	FRED
108.	mys_cpi_gfd	2000:01-2012:12	5	Malaysia: Consumer Price Index; n.s.a.	FRED

5. Exchange Rates

109.	jpn_erusd_fed*	2000:01-2012:12	5	Japan/U.S. Foreign Exchange Rate; n.s.a.	FRED
110.	kor_erusd_fed*	2000:01-2012:12	5	South Korea/U.S. Foreign Exchange Rate; n.s.a.	FRED
111.	china_erusd_fed	2000:01-2012:12	5	China/U.S. Foreign Exchange Rate; n.s.a.	FRED
112.	twn_erusd_fed	2000:01-2012:12	5	Taiwan/U.S. Foreign Exchange Rate; n.s.a.	FRED
113.	tha_erusd_fed	2000:01-2012:12	5	Thailand/U.S. Foreign Exchange Rate; n.s.a.	FRED
114.	mys_erusd_fed	2000:01-2012:12	5	Malaysia/U.S. Foreign Exchange Rate; n.s.a.	FRED

6. Money Supply

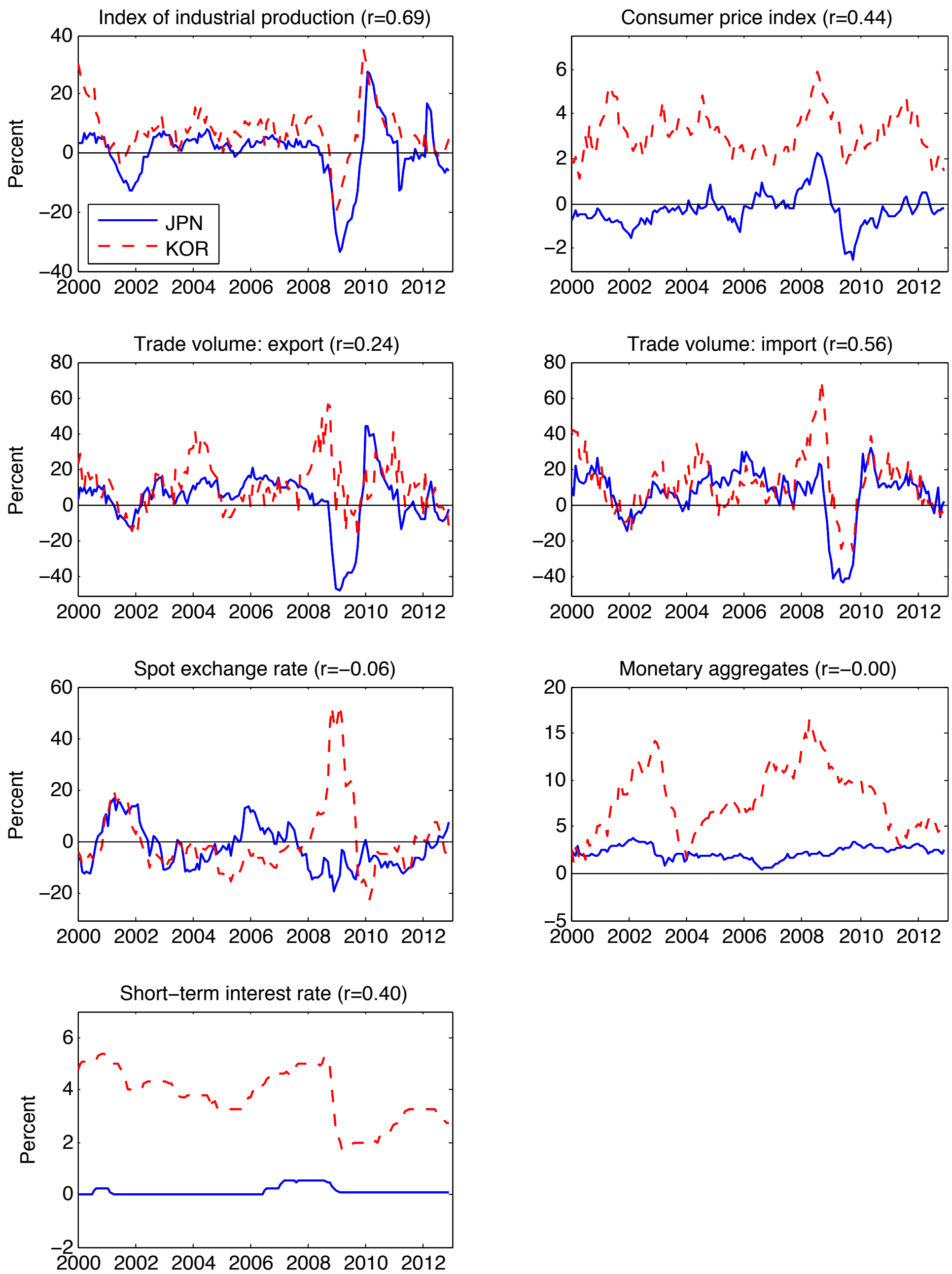
115.	jpn_m2_oecd	2000:01-2012:12	5	Japan: M2; s.a.	FRED

116.	kor_m2_oecd*	2000:01-2012:12	5	S. Korea: M2; s.a.	FRED
117.	us_m2_fed	2000:01-2012:12	5	US: M2 Money Stock; s.a.	FRED
118.	china_m2_oecd	2000:01-2012:12	5	China: M2; s.a.	FRED
119.	twn_m2_gfd	2000:01-2012:12	5	Taiwan: M2 Money Supply; n.s.a.	GFD
120.	mys_m2_gfd	2000:01-2012:12	5	Malaysia: M2 Money Supply; n.s.a.	GFD
7. Interest Rates					
121.	jpn_ir_oecd*	2000:01-2012:12	5	Japan: Immediate Rate: Less Than 24 Hours: Call Money/Interbank Rate; n.s.a.	FRED
122.	kor_ir_oecd	2000:01-2012:12	5	S. Korea: Immediate Rate: Less Than 24 Hours: Call Money/Interbank Rate; n.s.a.	FRED
123.	us_ir_oecd	2000:01-2012:12	5	US: Immediate Rate: Less Than 24 Hours: Federal Funds Rate; n.s.a.	FRED
124.	china_ir_oecd	2000:01-2012:12	5	China: Immediate Rate: Less Than 24 Hours: Call Money/Interbank Rate; n.s.a.	FRED
125.	twn_ir_gfd	2000:01-2012:12	5	Taiwan: Overnight Interbank Rate; n.s.a.	GFD
126.	tha_ir_gfd	2000:01-2012:12	5	Thailand: Overnight Interbank Money Rate; n.s.a.	GFD
127.	mys_ir_gfd	2000:01-2012:12	5	Malaysia: Overnight Interbank Rate; n.s.a.	GFD
8. Real Exchange Rate Index					
128.	jpn_rer_bis	2000:01-2012:12	5	Japan: Real Broad Effective Exchange Rate; n.s.a.	FRED
129.	kor_rer_bis	2000:01-2012:12	5	S. Korea: Real Broad Effective Exchange Rate; n.s.a.	FRED
130.	us_rer_bis	2000:01-2012:12	5	US: Real Broad Effective Exchange Rate; n.s.a.	FRED
131.	china_rer_bis	2000:01-2012:12	5	China: Real Broad Effective Exchange Rate; n.s.a.	FRED
132.	twn_rer_bis	2000:01-2012:12	5	Taiwan: Real Broad Effective Exchange Rate; n.s.a.	FRED
133.	tha_rer_bis	2000:01-2012:12	5	Thailand: Real Broad Effective Exchange Rate; n.s.a.	FRED
134.	mys_rer_bis	2000:01-2012:12	5	Malaysia: Real Broad Effective Exchange Rate; n.s.a.	FRED
135.	jpn_rer_n_bis	2000:01-2012:12	5	Japan: Real Narrow Effective Exchange Rate; n.s.a.	FRED
136.	kor_rer_n_bis	2000:01-2012:12	5	S. Korea: Real Narrow Effective Exchange Rate; n.s.a.	FRED
137.	us_rer_n_bis	2000:01-2012:12	5	US: Real Narrow Effective Exchange Rate; n.s.a.	FRED
138.	twn_rer_n_bis	2000:01-2012:12	5	Taiwan: Real Narrow Effective Exchange Rate; n.s.a.	FRED
139.	jpn_rer_p_oecd	2000:01-2012:12	5	Japan: Real Effective Exchange Rate Based on Manufacturing CPI; n.s.a.	FRED
140.	kor_rer_p_oecd	2000:01-2012:12	5	S. Korea: Real Effective Exchange Rate Based on Manufacturing CPI; n.s.a.	FRED
141.	us_rer_p_oecd	2000:01-2012:12	5	US: Real Effective Exchange Rate Based on Manufacturing CPI; n.s.a.	FRED
142.	china_p_rer_oecd	2000:01-2012:12	5	China: Real Effective Exchange Rate Based on Manufacturing CPI; n.s.a.	FRED
9. International Reserves					
143.	jpn_res_ifs	2000:01-2012:12	5	Japan: Total Reserves Excluding Gold, SDR; n.s.a.	FRED
144.	kor_res_ifs	2000:01-2012:12	5	S. Korea: Total Reserves Excluding Gold, SDR; n.s.a.	FRED

145.	us_res_ifs	2000:01-2012:12	5	US: Total Reserves Excluding Gold, SDR; n.s.a.	FRED
146.	china_res_ifs	2000:01-2012:12	5	China: Total Reserves Excluding Gold, SDR; n.s.a.	FRED
147.	twn_res_ifs	2000:01-2012:12	5	Taiwan: Total Reserves Excluding Gold, SDR; n.s.a.	FRED
148.	tha_res_gfd	2000:01-2012:12	5	Thailand: Total Foreign Exchange Reserves Excluding Gold; n.s.a.	GFD
149.	mys_res_gfd	2000:01-2012:12	5	Malaysia: Total Foreign Exchange Reserves Excluding Gold; n.s.a.	GFD
10. Other variables					
150.	jpnrecm	2000:01-2012:12	5	OECD based Recession Indicators for Japan from the Peak through the Trough	FRED
151.	korrecm	2000:01-2012:12	5	OECD based Recession Indicators for Korea from the Peak through the Trough	FRED
152.	usrecm	2000:01-2012:12	5	NBER based Recession Indicators for the United States from the Peak through the Trough	FRED
153.	chnrecm	2000:01-2012:12	5	OECD based Recession Indicators for China from the Peak through the Trough	FRED
154.	wti_gov*	2000:01-2012:12	5	Crude Oil Prices: West Texas Intermediate (WTI) - Cushing, Oklahoma	FRED

Figure A.1

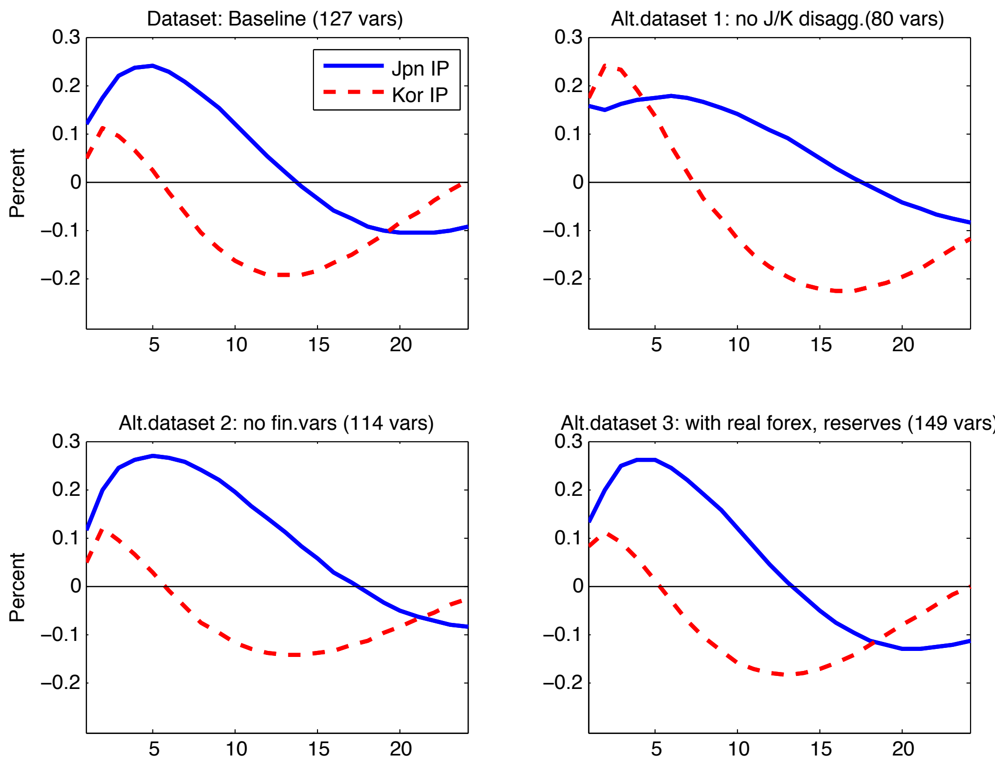
Graphs of the Major Macroeconomic Measures
for Japan and South Korea



Note: Each panel represents the time series for Japan (solid line) and South Korea (dashed line). The sample period is 2000:1 – 2012:12. r is the pairwise correlation coefficient between the Japanese and South Korean time series. All variables except the short-term interest rate are transformed into year-over-year growth rates and expressed in annual percentage terms. Spot exchange rate is exchange rate of local currency per one US dollar. For data source, see the data appendix.

Figure A.2

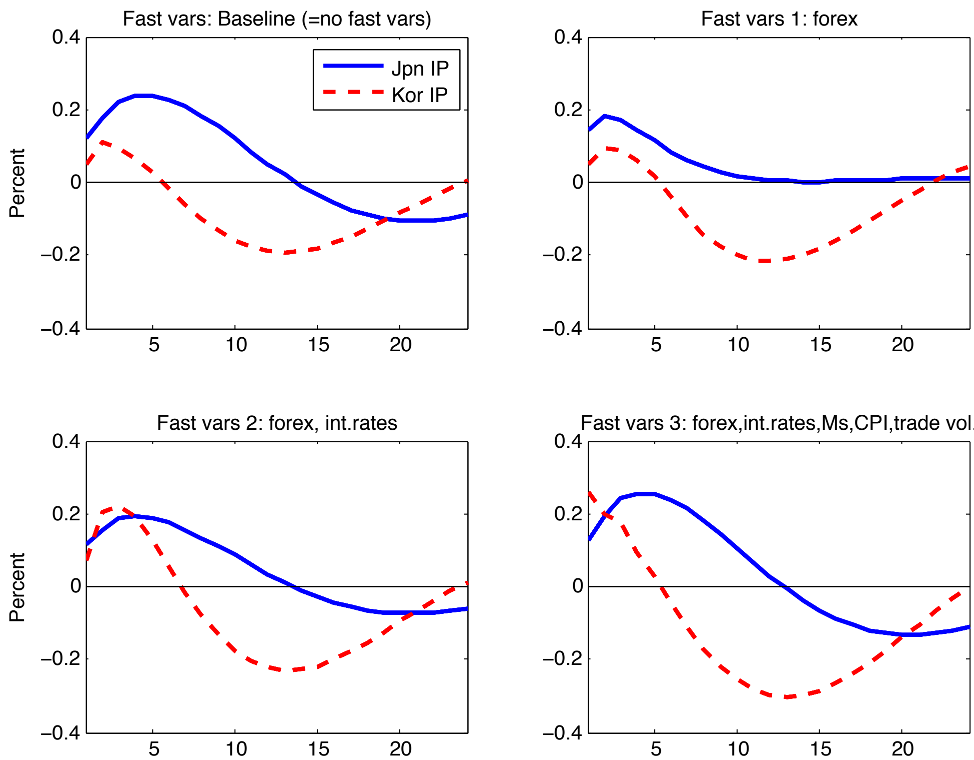
Impulse Responses of Japanese and South Korean Overall Industrial Production
With Alternative Dataset Used in the FAVAR Estimation



Note: The solid line in each panel presents the impulse response of Japanese industrial production ("Jpn IP") to a 0.5 percentage point shock in the South Korean industrial production and the dashed line presents the impulse response of South Korean industrial production ("Kor IP") to a 0.5 percentage point shock in the Japanese industrial production. Alternative Datasets are (1) exclude sectoral output of Japan and South Korea from the baseline ("no J/K disagg."), (2) exclude monetary aggregates and short-term interest rates from the baseline ("no fin.vars"), and (3) add real exchange rate indexes and international reserves to the baseline ("with real forex, reserves").The responses are drawn using a factor augmented vector autoregression (FAVAR). All variables are expressed in terms of growth rates (%).

Figure A.3

Impulse Responses of Japanese and South Korean Overall Industrial Production
Allowing a Fast-Moving Factor in the FAVAR Estimation



Note: The solid line in each panel presents the impulse response of Japanese industrial production ("Jpn IP") to a 0.5 percentage point shock in the South Korean industrial production and the dashed line presents the impulse response of South Korean industrial production ("Kor IP") to a 0.5 percentage point shock in the Japanese industrial production. Fast-moving factor is extracted from (1) spot exchange rates ("forex"), (2) spot exchange rates and short-term interest rates ("forex,int.rates"), (3) spot exchange rates, short-term interest rates, monetary aggregates, consumer price indexes, and trade volumes ("forex,int.rates,Ms,CPI,trade vol."). The responses are drawn using a factor augmented vector autoregression (FAVAR). All variables are expressed in terms of growth rates (%).