

Financial Spillovers in Asian Emerging Economies

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This paper explores financial spillovers between emerging Asia and advanced economies using principal component analysis to extract common shocks in Asia. We first investigate stock market spillovers across the regions and find that spillovers from emerging Asia became significant after the global financial crisis. However, our industry-level analysis shows that the increased spillovers can be attributed to the first principal component (PC) in the manufacturing sector rather than to the first PC in the financial sector. This implies that the rise of the Asian manufacturing sector in the global market played a key role in enhancing the stock market spillovers. We next examine bilateral spillovers in short-term and long-term rates. In the tapering period, we find significant spillovers in long-term rates from the first PC in emerging Asia to Europe and the United States. However, these spillovers were much smaller than the stock market spillovers in magnitude.

Keywords: bond markets, emerging Asian economies, financial spillover, stock markets

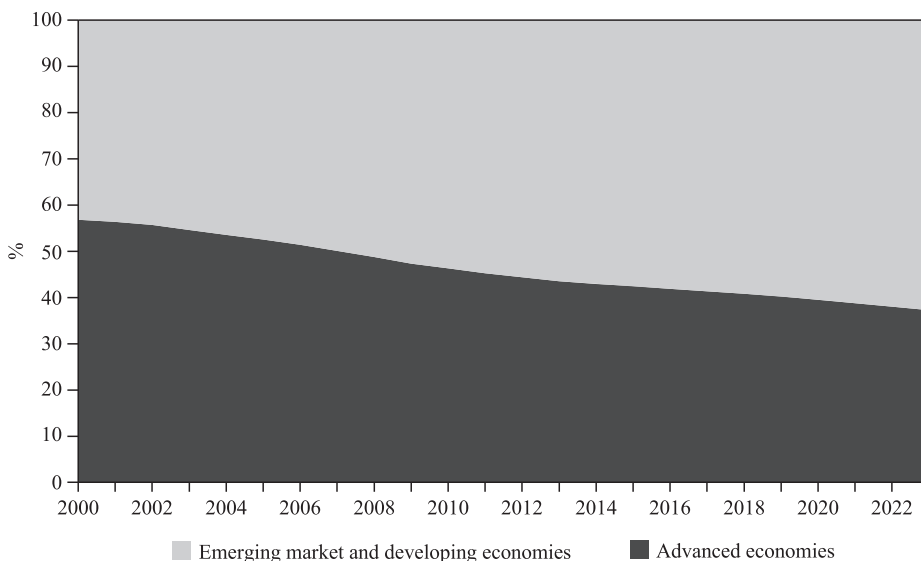
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I. Introduction

In the 2000s, emerging economies substantially increased their share in global gross domestic product (GDP). The International Monetary Fund's (IMF) *World Economic Outlook* (October 2018) suggested that the share of emerging and developing economies in world GDP based on purchasing power parity (PPP), which was 43.2% in 2000, would be 62.7% in 2023 (see figure) (IMF 2018). In integrated global production networks, emerging economies are increasingly more connected with the rest of the world. However, despite a large increase in

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Share of World Gross Domestic Product



Note: The share of world gross domestic product is based on purchasing power parity.

Source: International Monetary Fund. 2018. *World Economic Outlook, October 2018*. Washington, DC.

their disposable income, many of them have not been able to sell rights over their output in advance, that is, to create financial assets, owing to their financial underdevelopment. Therefore, despite the dramatic output growth, there still exists a view that financial markets in emerging economies have a limited role in the global financial market.

In this paper, we explore how financial spillovers between emerging East Asia and advanced economies have evolved in the 2000s. To investigate financial spillovers between emerging and advanced economies, East Asia has the following three notable features. First, emerging East Asian economies have undergone rapid industrialization and maintained exceptionally high growth rates, often called the “East Asian Miracle.” According to the IMF’s *World Economic Outlook* (October 2018), the share of emerging and developing Asia in world GDP, which was 16.7% in 2000, would be 37.8% in 2023 based on PPP. East Asia now plays a central role in global production networks (see, for example, Ito and Vézina 2016, Helble and Ngiang 2016, Aizenman and Fukuda 2017, and Shepherd 2018). Second, despite the dramatic output and trade growth, financial markets in emerging East Asia have developed at a slower pace and from a lower base until recently. In the 2000s, some Asian emerging economies started a process of financial “catching up” toward mature economies. However, various indicators suggest that the scope for financial catching up is still substantial in most of the Asian emerging economies

(see, for example, Fukuda 2013, and Ito and Kawai 2016). Third, since Asian financial markets are open when European and New York markets are closed, we may identify causality from Asian financial market shocks to Europe and the United States (US) without serious simultaneous biases. If the financial markets were open at the same time, it would be difficult to identify from which financial markets the shocks originated. But because of substantial time differences across the regions, the use of daily data in each region may allow us to identify the direction of spillover effects without serious simultaneous biases.

In the analysis, we use principal component analysis (PCA) to capture common financial shocks in Asia and estimate global vector autoregressive (GVAR) models to see bilateral spillovers across the regions. In the first part, we investigate bilateral stock market spillovers across the regions. We find that while spillovers from Asian stock markets to those in Europe and the US had been small before the global financial crisis (GFC), stock market spillovers from the first principal component (PC) in emerging Asia became significant in the post-GFC period. However, we also find that the increased spillovers were attributable to the first PC in the manufacturing sector rather than to the first PC in the financial sector. This implies that the Asian manufacturing sector's rise in the global market played a key role for enhancing stock market spillovers from emerging Asia in the post-GFC period.

In the second part, we examine bilateral spillovers in short-term and long-term rates. With short-term rates, there were no significant spillovers from the advanced economies to Asia or from Asia to the advanced economies. In contrast, with long-term rates, we find large spillovers from the advanced economies to Asia. We also find some significant spillovers from Asia to Europe and the US in long-term rates. However, spillovers from emerging Asia were much smaller in the bond markets than in the stock markets. This supports the view that bond market linkages from emerging Asia to advanced countries were, if any, small even after the GFC.

In the literature, a number of studies have investigated financial spillovers from advanced economies. The studies found that financial market shocks in advanced countries had large spillover effects on emerging market economies (EMEs), although the responses of EMEs were heterogeneous (see, for example, Gauvin, McLoughlin, and Reinhardt 2014; Engel 2016; and Aizenman, Chinn, and Ito 2017). In particular, an extensive literature suggested that US unconventional monetary policy had enormous spillover effects on EMEs after the GFC, especially on those with fragile macro fundamentals (see, for example, Rogers, Scotti, and Wright 2014; Neely 2015; Eichengreen and Gupta 2015; Rey 2016; and Tillmann 2016). Several regional studies also found that financial shocks in advanced economies had various spillover effects on emerging Asian economies (see, for example, Morgan 2011; Park and Um 2016; Fukuda 2018, 2019). However, spillovers originating from emerging markets have received relatively

scant attention in most previous studies. Gelos and Surti (2016) and Huidrom, Kose, and Ohnsorge (2016) are exceptional studies that showed the growing importance of financial spillovers from emerging economies in the 2000s especially after the GFC. However, few studies have investigated spillovers from Asian financial markets to advanced markets. It is thus important to understand the magnitude of these spillovers in the 2000s and to what extent they have increased after the GFC.

This paper is a straightforward extension of Fukuda and Tanaka (2017) in that we explore the degree of financial spillovers from emerging Asia in the 2000s. However, it has two critical differences. First, this paper uses PCA to extract common financial shocks in Asia. The extracted financial shocks allow us to investigate the size of regional spillovers from Asian common financial shocks. A number of studies have suggested growing regional integration in Asian financial markets (see, for example, Yu, Fung, and Tam 2010; Boubakri and Guillaumin 2015; Komatsubara, Okimoto, and Tatsumi 2017; Mensah and Premaratne 2017; Didier, Llovet, and Schmukler 2017; and Sugimoto and Matsuki 2018). Given financial integration in Asia, it is important to estimate regional spillovers excluding spillovers from country-specific shocks. Second, this paper investigates bond market spillovers in addition to stock market spillovers. Bond markets have been less developed than stock markets in Asia.¹ Thus, by comparing spillovers in the two types of financial markets, we may see whether bond market linkages from emerging Asia to advanced countries were smaller owing to their financial underdevelopment.

Our empirical results suggest that financial market spillovers from advanced economies to emerging Asia were much larger than those from emerging Asia to advanced economies. This is particularly true in bond markets. However, we also find significant spillovers from Asian stock markets to advanced economies in the post-GFC period. The industry-level stock market spillovers indicate that this happened because of increased manufacturing sector shocks in emerging Asia. The impact of fundamental shocks in emerging Asia has been rising in global financial markets. This has considerably increased stock market spillovers from Asia to global financial markets even if financial markets remained less developed in Asia. However, direct financial linkages from emerging Asia to advanced countries were, if any, limited even after the GFC. Structural reforms of financial markets are still an important policy agenda in emerging Asia.

The paper proceeds as follows. After explaining our empirical methodology in section II, section III provides empirical results on stock market spillovers. Section IV extends the analysis by using industry-level stock returns. Sections V and VI investigate spillovers of short-term and long-term rates, respectively. Section VII summarizes our results and refers to their implications.

¹See AsianBondsOnline. <https://asianbondsonline.adb.org/>.

II. Empirical Methodology

To investigate bilateral spillovers between Asian and advanced financial markets, the following sections estimate GVAR models and investigate the degree of financial market spillovers by using variance decomposition. Unless the spillovers are one directional and have no further propagation, a single equation would not be enough to capture financial spillovers across the regions. In globalized economies, a financial shock has a complicated international propagation mechanism. It not only has direct and indirect spillover effects on other financial markets, but the affected financial markets also have further spillover effects on the financial market where the shocks originated. The feedback loop sometimes continues for a few days. A GVAR is a useful econometric framework to capture such multilateral financial spillovers with various feedbacks across regions.

In the analysis, we use PCA to capture total (common) financial shocks in Asia. PCA is a mathematical procedure that transforms a number of (possibly) correlated variables into a (smaller) number of uncorrelated variables called “principal components.” By using a linear combination, we calculate the first PC to account for as much of the variability in the data as possible. We then remove this variance and seek a second linear combination which explains the maximum proportion of the remaining variance. In the PCA, we use financial variables from five emerging Asian economies: Hong Kong, China; the People’s Republic of China (PRC); the Republic of Korea; Singapore; and Taipei, China. These economies have more developed financial markets than the other emerging Asian economies.

Using the first and second PCs in the Asian economies, we estimate the following GVAR:

$$Y_t = a + \sum_{j=1}^p \beta_j Y_{t-j} + \sum_{j=1}^p \gamma x_{t-j} + u_t \quad (1)$$

where Y_t is a vector of endogenous variables and x_t is an exogenous variable. The vector of endogenous variables is composed of six financial variables: a financial variable in Japan, the first and second PCs in the Asian economies, two European financial variables (in the United Kingdom [UK] and Europe), and a financial variable in the US. The exogenous variable is the daily log difference of the Chicago Board Options Exchange Volatility Index (VIX). We use VIX as an exogenous variable to account for common and systematic global factors. The estimation of the GVAR model is done recursively, with the number of lags set to 2.²

The order of the Cholesky decomposition is the variable in Japan, the first PC in Asia, the second PC in Asia, the variable in the UK, the variable in Europe, and

²Schwarz criterion chose either 1 or 2 lags in all cases and so did the Akaike information criterion. Our essential results were robust even if we set the number of lags to 1.

the variable in the US. We chose the order because Asian financial markets are open when European and New York markets are closed. Putting aside overlaps of a few hours, London and Frankfurt markets are open after Asian financial markets close, and the New York market is open after the European markets close. Thus, the use of daily data may allow us to identify spillover effects across the regions without serious simultaneous biases.

Because causality identified by GVAR is “Granger causality,” our identified spillovers do not necessarily mean “true” causality. This is because financial variables can move in anticipation of future shocks. For example, if some event is expected to happen in the UK when Asian stock markets are open, stock prices in Asia would respond earlier in anticipation of that shock in the UK. In this case, the identified Granger causality is from Asia to the UK, although the true causality is from the UK to Asia. However, noting that most of the country-specific shocks tend to occur when its local market is open, large European or US-specific events are less likely to happen when Asian markets are open. In the following analysis, we thus suppose that our GVARs approximately identify true spillovers from Asian financial shocks to European and US markets.

In addition to the above limitation, our identified spillovers may not mean “true” spillovers when important news is announced after stock markets close. In this case, our order of the Cholesky decomposition may identify some European shocks as US shocks and some US shocks as Japanese shocks. However, given the order of the Cholesky decomposition, it is unlikely that we identify shocks in Europe and the US as emerging Asian market shocks. In the Appendix, we show that our results are essentially the same, even if we control for spillover effects of shocks after the New York market closes.

Unless explained otherwise, we downloaded the data from Datastream. To the extent that the data are available, the sample period starts in January 2003 and ends in April 2018. We split the sample periods into three subsample periods: 3 January 2003 to 29 June 2007 (pre-GFC period), 1 July 2009 to 20 May 2013 (post-GFC and pretapering period), and 21 May 2013 to 27 April 2018 (tapering period). The subsample periods did not include 1 July 2007 to 30 June 2009 to exclude the effects of the GFC. We split the post-GFC period into two to allow different monetary policy regimes in the US. The break point is the date when Federal Reserve Chairman Ben Bernanke first mentioned the idea of gradually reducing or “tapering” the Federal Reserve Board’s monetary expansion.

III. Empirical Results: Stock Market Spillovers

In this section, we explore stock market spillovers between Asian and advanced financial markets. We take the log difference of daily stock market indexes and use them as endogenous variables. The stock market indexes in Asia are the

Table 1. Correlation of Principal Components with Stock Market Returns

(i) Pre-GFC period			
	1st PC	2nd PC	3rd PC
Republic of Korea	0.476	-0.059	-0.205
Hong Kong, China	0.489	0.030	-0.127
People's Republic of China	0.109	0.982	0.090
Taipei,China	0.445	-0.109	-0.265
Singapore	0.475	-0.004	-0.052
Thailand	0.315	-0.136	0.928
(ii) Post-GFC and pretapering period			
	1st PC	2nd PC	3rd PC
Republic of Korea	0.430	-0.158	-0.436
Hong Kong, China	0.466	0.073	0.076
People's Republic of China	0.310	0.897	0.166
Taipei,China	0.425	-0.120	-0.472
Singapore	0.441	-0.150	0.089
Thailand	0.354	-0.360	0.739
(iii) Tapering period			
	1st PC	2nd PC	3rd PC
Republic of Korea	0.431	-0.199	-0.413
Hong Kong, China	0.483	0.197	-0.038
People's Republic of China	0.300	0.849	0.215
Taipei,China	0.432	-0.169	-0.379
Singapore	0.440	-0.140	0.073
Thailand	0.331	-0.390	0.796

GFC = global financial crisis, PC = principal component.

Source: Authors' calculations.

Shanghai Stock Exchange Composite Index; Hong Kong Hang Seng Index; Korea Composite Stock Price Index; FTSE Straits Times Index; the weighted index of Taipei,China's stock exchange; and Stock Exchange of Thailand Index. Those in Japan, Europe, the UK, and the US are the Nikkei 225, DAX 30, FTSE 100, and Dow Jones Industrials, respectively.

Table 1 reports the correlation of the first, second, and third PCs in Asia with stock market returns in each Asian economy for the three alternative subsample periods. It shows that the first PC is positively correlated with stock market returns in all Asian economies. The correlation with the PRC's stock market returns is small for the first subsample period (pre-GFC period). However, the correlation lies almost between 0.3 and 0.5 for other Asian returns. This implies that the first PC is a weighted average of all Asian stock market returns. In contrast, the second PC has a large positive correlation only with the PRC's stock market returns. The degree of the correlation is over 0.8 for all subsample periods, which implies that the second PC reflects mainly PRC-specific returns. Similarly, the third PC has a large positive

Table 2.1 Variance Decomposition of the Principal Components in Asian Stock Returns (%)

(i) Decomposition of the 1st principal component						
	1st PC Shock	Advanced Economies				
		Total	Japan	UK	Germany	US
Pre-GFC period	57.09	41.62	24.39	6.03	3.03	8.17
Pretapering period	56.17	43.02	15.33	19.49	1.55	6.65
Tapering period	64.26	33.33	14.80	8.05	0.84	9.65
(ii) Decomposition of the 2nd principal component						
	2nd PC Shock	Advanced Economies				
		Total	Japan	UK	Germany	US
Pre-GFC period	98.59	0.99	0.15	0.08	0.33	0.43
Pretapering period	97.09	2.08	0.03	1.22	0.03	0.79
Tapering period	97.95	1.46	0.77	0.17	0.01	0.50

GFC = global financial crisis, PC = principal component, UK = United Kingdom, US = United States.

Note: The table reports the variance decomposition over 10 business days after a shock.

Source: Authors' calculations.

correlation only with Thai stock market returns. The degree of the correlation is over 0.7, which implies that the third PC reflects mainly Thai-specific returns.

Using the first and the second PCs in Asia, we estimate the GVAR formulated in the last section for the three alternative subsample periods. Tables 2.1 and 2.2 report the variance decomposition over 10 business days. These show in percentages how much of the stock price fluctuations were explained by their own and other stock market shocks over 10 business days. Our main interest is to see spillover effects between Asian stock markets and those in advanced economies. Thus, Table 2.1 reports how much of the first and second PCs in Asia were explained by shocks in Japan, the two European countries, and the US, while Table 2.2 reports how much of the stock prices in Japan, the two European countries, and the US were explained by the first and second PCs in Asia.

Table 2.1 indicates that the first PC in Asia was largely explained by stock price shocks in the advanced economies throughout the three subsample periods. More than 40% of the first PC was explained by shocks in the advanced economies in the first and second subsample periods (pre-GFC period and post-GFC and pretapering period) and more than 30% in the third subsample period (tapering period). This implies that there have been large positive spillovers from stock markets in advanced economies to Asian stock markets before and after the GFC, although the spillover effects declined significantly in the tapering period. Among the advanced economies, shocks in Japan explained most of the first PC in the first and third subsample periods, while shocks in the UK were the biggest driver in the second subsample period. Shocks in the US also explained more than 8% in the

Table 2.2 Variance Decomposition of Stock Returns in Advanced Economies (%)

(i) Japan's stock prices				
	Japan Shock	Other Advanced Economies	1st PC Shock	2nd PC Shock
Pre-GFC period	82.64	15.87	1.29	0.19
Pretapering period	70.99	27.87	0.25	0.89
Tapering period	74.84	22.18	2.38	0.61
(ii) UK stock prices				
	UK Shock	Other Advanced Economies	1st PC Shock	2nd PC Shock
Pre-GFC period	80.45	14.83	4.53	0.19
Pretapering period	74.59	9.47	14.77	1.17
Tapering period	71.09	16.00	12.00	0.92
(iii) Germany's stock prices				
	German Shock	Other Advanced Economies	1st PC Shock	2nd PC Shock
Pre-GFC period	37.19	56.53	6.03	0.25
Pretapering period	22.37	64.92	11.18	1.52
Tapering period	35.87	53.03	9.79	1.32
(iv) US stock prices				
	US Shock	Other Advanced Economies	1st PC Shock	2nd PC Shock
Pre-GFC period	62.42	34.76	2.60	0.22
Pretapering period	40.92	50.14	7.46	1.47
Tapering period	65.17	28.42	6.01	0.41

GFC = global financial crisis, PC = principal component, UK = United Kingdom, US = United States.

Note: The table reports the variance decomposition over 10 business days after a shock.

Source: Authors' calculations.

first and the third subsample periods. The only exceptions were shocks in Germany which explained only 1.55% in the second subsample period and 0.84% in the third subsample period. This may have happened because of the euro debt crisis during these periods.

However, Table 2.1 suggests that stock price shocks in the advanced economies explained very little of the second PC in Asia. Except for UK shocks in the second subsample period, any shock in the advanced economies explained less than 1% of the second PC. Even UK shocks in the second subsample period explained only 1.22%. This does not mean that there has been no positive spillover to the PRC, because the first PC is correlated with the PRC's returns. But this implies that there has been no positive spillover from the advanced economies to PRC-specific returns that were independent of stock prices in the other emerging

Asian economies. This may happen partly because of various financial regulations in the PRC and partly because of independent remarkable economic growth in the country.

In contrast, Table 2.2 shows that the first and second PCs in Asia explained only a small percentage of the stock price fluctuations in the advanced economies throughout the subsample periods. In particular, the first and second PCs' contribution to stock price fluctuations in Japan in the first and the second subsample periods were small. This implies that the stock price spillovers are asymmetric between Asia and the advanced economies. That is, spillovers from advanced economies to Asian markets have been much larger than those from Asian markets to advanced economies.

However, Table 2.2 also indicates that after the GFC, the first PC in Asia came to explain a significant percentage of stock price fluctuations in the two European countries and the US. In the second subsample period, the first PC explained 14.77% of stock fluctuations in the UK, 11.18% in Germany, and 7.46% in the US. In the third subsample period, it explained 12% in the UK, 9.79% in Germany, and 6.01% in the US. These percentages were much larger than those in the first subsample period. This implies that stock market spillovers from emerging Asia to Europe and the US, which were small before the GFC, became significantly positive after the GFC. The spillovers from Asia to the advanced economies became far from negligible even though they were still smaller than those from the advanced economies to Asia.

IV. Industry-Level Estimation Results

In the previous section, we found that stock market spillovers from the first PC in emerging Asia to those in Europe and the US became significant in the post-GFC period. The result indicates that even in the stock markets, common shocks in emerging Asia came to have substantial impacts on advanced countries after the GFC. However, stock market spillovers could increase because emerging Asian economies were increasingly more connected with the rest of the world in integrated global production networks. If this is the case, the spillovers do not necessarily suggest direct financial linkages from emerging Asia to advanced countries in the post-GFC period.

In this section, we investigate whether the stock market spillovers from emerging Asia in the post-GFC period originated from the financial sector or the manufacturing sector. In the analysis, we use daily industry-level stock market returns in emerging Asia and explore which sector's shocks had larger impacts on the stock prices in advanced countries. We use PCA to extract common stock price shocks of the manufacturing sector and those of the financial sector in the five emerging Asian economies for the three subsample periods. Except for the use

Table 3. Correlation of Principal Components with Industry-Level Returns

(i) Pre-GFC period						
	Manufacturing Sector			Financial Sector		
	1st PC	2nd PC	3rd PC	1st PC	2nd PC	3rd PC
Republic of Korea	0.461	0.006	-0.302	0.435	-0.239	0.092
Hong Kong, China	0.485	-0.151	-0.021	0.491	-0.037	-0.203
People's Republic of China	0.316	-0.591	0.650	0.348	0.551	-0.620
Taipei,China	0.434	0.160	-0.393	0.379	-0.549	0.126
Singapore	0.441	-0.038	-0.081	0.453	-0.094	-0.015
Thailand	0.264	0.775	0.570	0.316	0.572	0.741
(ii) Post-GFC and pretapering period						
	Manufacturing Sector			Financial Sector		
	1st PC	2nd PC	3rd PC	1st PC	2nd PC	3rd PC
Republic of Korea	0.410	-0.337	0.201	0.385	-0.415	0.439
Hong Kong, China	0.448	0.060	-0.398	0.460	0.076	-0.396
People's Republic of China	0.463	0.013	-0.260	0.454	0.047	-0.373
Taipei,China	0.374	-0.462	0.601	0.383	-0.472	0.350
Singapore	0.425	0.060	-0.373	0.420	0.064	-0.314
Thailand	0.310	0.816	0.484	0.334	0.770	0.539
(iii) Tapering period						
	Manufacturing Sector			Financial Sector		
	1st PC	2nd PC	3rd PC	1st PC	2nd PC	3rd PC
Republic of Korea	0.389	-0.248	0.584	0.314	0.679	0.495
Hong Kong, China	0.464	-0.127	-0.396	0.489	-0.143	-0.358
People's Republic of China	0.457	-0.189	-0.301	0.477	-0.110	-0.344
Taipei,China	0.401	-0.159	0.502	0.392	0.325	0.039
Singapore	0.410	0.045	-0.372	0.439	-0.070	-0.093
Thailand	0.310	0.927	0.145	0.297	-0.630	0.706

GFC = global financial crisis, PC = principal component.

Source: Authors' calculations.

of PCs in the manufacturing sector and those in the financial sector, the estimated equations are essentially the same as those in the last two sections.

Table 3 reports the correlations of the first, second, and third PCs with industry-level stock returns in each Asian market. It shows that both in the manufacturing and financial sectors, the first PC is positively correlated with industry-level stock market returns in all Asian economies. The correlations are relatively small in Thailand. However, except for a few cases in Thailand, the correlations lie between 0.3 and 0.5 for each industry-level return. This implies that the first PC is a weighted average of all Asian industry-level stock market returns. Unlike with aggregated returns, the second and third PCs in the industry-level returns do not have a dominant positive correlation with stock market returns in the PRC. Instead, in the manufacturing sector, the second PC has a large positive correlation with stock market returns only in Thailand. This is also

Table 4.1 Variance Decomposition of the Principal Components: Industry-Level Returns (%)

		(i) Decomposition of the 1st principal component					
		1st PC Shock	Advanced Economies				
			Total	Japan	UK	Germany	US
Manufacturing sector	Pre-GFC period	60.62	37.20	22.19	5.66	2.88	6.47
	Pretapering period	57.88	41.24	13.45	19.69	1.72	6.38
	Tapering period	68.25	30.48	13.75	7.64	1.18	7.91
Financial sector	Pre-GFC period	25.19	35.40	20.46	4.89	2.96	7.09
	Pretapering period	12.98	41.12	14.38	18.09	1.98	6.67
	Tapering period	22.92	31.16	13.73	8.35	1.01	8.07

		(ii) Decomposition of the 2nd principal component					
		2nd PC Shock	Advanced Economies				
			Total	Japan	UK	Germany	US
Manufacturing sector	Pre-GFC period	97.36	0.53	0.02	0.08	0.14	0.29
	Pretapering period	96.98	1.76	0.82	0.41	0.15	0.37
	Tapering period	97.12	1.83	0.81	0.96	0.03	0.02
Financial sector	Pre-GFC period	90.86	2.86	1.84	0.04	0.71	0.28
	Pretapering period	73.55	2.41	0.83	0.67	0.42	0.49
	Tapering period	80.53	2.40	0.99	0.90	0.38	0.13

GFC = global financial crisis, PC = principal component, UK = United Kingdom, US = United States.

Note: The table reports the variance decomposition over 10 business days after a shock.

Source: Authors' calculations.

true even in the financial sector, where the second PC in the second subsample period and the third PC in the first and third subsample periods have large positive correlations. This implies that either the second or the third PC reflects mainly Thai returns when using industry-level stock prices.

As in the previous section, we estimate GVARs for three alternative subsample periods: 3 January 2003 to 29 June 2007 (pre-GFC period), 1 July 2009 to 20 May 2013 (post-GFC and pretapering period), and 21 May 2013 to 27 April 2018 (tapering period). Except for the use of the first and second PCs in the manufacturing and financial sectors for emerging Asia, the set of endogenous variables, the exogenous variable, and their order are the same as those in the last section. When estimating GVARs, we ordered the first and second PCs of the manufacturing sector prior to those of the financial sector in Asia.

Tables 4.1 and 4.2 report the variance decomposition over 10 business days. For the three subsample periods, Table 4.1 reports in percentages how much of the first and second PCs in Asian manufacturing and financial sectors were explained by shocks in Japan, the two European countries, and the US, while Table 4.2 reports how much of the stock returns in Japan, the two European countries, and the US were explained by the first and second PCs in Asian manufacturing and financial sectors. In both of the tables, we find no significant spillover from advanced countries to the second PC in Asia throughout the subsample periods.

Table 4.2 Variance Decomposition in Advanced Economies by Industry (%)

(i) Variance decomposition of Japan's stock prices						
	Japan Shock	Other Advanced Economies	Manufacturing Sector		Financial Sector	
			1st PC Shock	2nd PC Shock	1st PC Shock	2nd PC Shock
Pre-GFC period	82.17	15.68	1.15	0.11	0.75	0.13
Pretapering period	71.28	27.32	0.56	0.08	0.36	0.40
Tapering period	74.64	22.27	2.18	0.70	0.17	0.04
(ii) Variance decomposition of UK stock prices						
	UK Shock	Other Advanced Economies	Manufacturing Sector		Financial Sector	
			1st PC Shock	2nd PC Shock	1st PC Shock	2nd PC Shock
Pre-GFC period	79.97	14.90	2.92	0.10	1.28	0.83
Pretapering period	73.69	9.83	14.77	0.44	0.58	0.68
Tapering period	71.14	16.00	11.33	0.36	1.00	0.17
(iii) Variance decomposition of Germany's stock prices						
	German Shock	Other Advanced Economies	Manufacturing Sector		Financial sector	
			1st PC Shock	2nd PC Shock	1st PC Shock	2nd PC Shock
Pre-GFC period	37.04	56.63	4.04	0.34	1.67	0.27
Pretapering period	22.37	64.62	10.92	0.42	1.03	0.63
Tapering period	35.61	53.09	9.41	0.41	1.12	0.35
(iv) Variance decomposition of US stock prices						
	US Shock	Other Advanced Economies	Manufacturing Sector		Financial Sector	
			1st PC Shock	2nd PC Shock	1st PC Shock	2nd PC Shock
Pre-GFC period	62.29	34.89	1.52	0.01	1.04	0.26
Pretapering period	41.04	50.32	7.55	0.19	0.61	0.29
Tapering period	64.85	29.32	5.04	0.30	0.37	0.12

GFC = global financial crisis, PC = principal component, UK = United Kingdom, US = United States.

Note: The table reports the variance decomposition over 10 business days after a shock.

Source: Authors' calculations.

But as in the previous section, we find large spillovers from advanced countries to the first PC in Asia throughout the subsample periods. Table 4.1 shows that in both the manufacturing and financial sectors, shocks in advanced economies explained more than 30% of the first PC in the first and third subsample periods and more than 40% in the second subsample period. Before and after the GFC, there have been large positive spillovers from stock markets in advanced economies to Asian stock markets in both sectors. However, in the manufacturing sector, around 60% of the first PC's fluctuations were explained by its own shocks. In contrast, in the financial sector, a substantial part of the first PC's fluctuations was explained by the first PC's shocks in the manufacturing sector. This implies that the financial

sector in Asia has experienced large positive stock market spillovers not only from advanced economies but also from the manufacturing sector in Asia.

As in the previous section, we can confirm that the spillovers are asymmetric between Asia and the advanced economies. Table 4.2 shows that the first PCs of Asian stock prices in the manufacturing and financial sectors contributed only a small percentage of the stock price fluctuations in advanced economies. However, looking at spillovers from Asia to the advanced economies, we see one noteworthy feature which we did not observe in the previous section.

Throughout the subsample periods, the first PC of the Asian financial sector never had significant spillover effects on the advanced countries. Throughout the subsample periods, it never explained more than 2% of stock price fluctuations in each advanced country. In contrast, the first PC in the Asian manufacturing sector had significant spillover effects on stock prices of the advanced countries after the GFC. Both in the second and third subsample periods, it explained more than 10% of UK stock price fluctuations, about 10% of German stock price fluctuations, and more than 5% of US stock price fluctuations. These features suggest that stock market spillovers from emerging Asia increased in the post-GFC period mainly because common manufacturing sector shocks in emerging Asia had significant impacts on the advanced economies.

The share of emerging Asia in global output and trading network has progressed steadily in the 2000s. Before the GFC, this increased real linkage did not intensify financial linkages much. However, in the post-GFC period, it came to have a significant impact on stock market linkages between the two regions. As a result, stock market spillovers from emerging Asia to the advanced economies increased significantly even though direct financial linkages were, if any, small even after the GFC.

V. Interest Rate Spillovers

In previous sections, we explored spillovers between Asian stock markets and those in advanced economies. In the following sections, we will examine spillovers of short-term and long-term interest rates across the regions. As in the previous sections, we calculate the variance decomposition of GVARs and investigate how much of the fluctuations can be explained by the other interest rate shocks over 10 business days. Variables in the GVARs are composed of six endogenous variables and one exogenous variable (i.e., daily log difference of VIX). The endogenous variables include the first and second PCs of the daily difference in interest rates in five Asian economies (i.e., Hong Kong, China; the People's Republic of China; the Republic of Korea; Singapore; and Taipei, China) and the daily difference in interest rates in Japan, the UK, Europe, and the US. The estimation of the GVAR model is done recursively, with the number of lags set to 2, for the three subsample periods.

The subsample periods are the same as those in the last section. However, because of missing data, the pre-GFC period is from 6 January 2006 to 29 June 2007 for short-term interest rates. Since Asian financial markets are open when European and New York markets are closed, the order of the Cholesky decomposition is an interest rate in Japan, the first PC in Asia, the second PC in Asia, an interest rate in the UK, an interest rate in Europe, and an interest rate in the US.

We first explore spillovers of short-term interest rates. For short-term interest rates of the five Asian economies, we use overnight rates (i.e., Bank of Korea base rate; Singapore Overnight Rate Average; Bangkok Interbank Offered Rate; swap overnight of Taipei, China; Shanghai Interbank Offered Rate; and Hong Kong Interbank Offered Rate) and calculate the PCs of their daily changes. For the advanced economies, we use daily changes of the uncollateralized overnight call rate in Japan, the UK bank rate, the European Central Bank main refinancing operations or deposit rate, and the US federal funds target rate. Data for these interest rates were downloaded from Datastream. However, because of the zero lower bound, we use the estimated shadow rates for short-term interest rates in advanced economies. All of the shadow rate estimates are obtained using the Leo Krippner shadow or lower bound framework with two factors (see Krippner 2015).³

Table 5 summarizes the correlations of the first, second, and third PCs with daily changes of each Asian short-term rate for the three alternative periods. Unlike with stock returns, we cannot conclude that the first PC is a weighted average of all Asian economies in the short-term rates. The second and third PCs also have large correlations only with specific economies. This may have happened not only because short-term rates were still regulated by the government in emerging Asia but also because each central bank can control its policy rate without being affected by external policy rates.

Tables 6.1 and 6.2 report the variance decomposition over 10 business days for the three subsample periods. Table 6.1 reports in percentages how much of the first and second PCs in Asian short-term rates were explained by short-term rates in the advanced economies, while Table 6.2 reports how much of the short-term rates in the advanced economies were explained by the first and second PCs in Asian short-term rates. In both tables, we find no significant spillovers in either direction throughout the subsample periods. This indicates that there were no significant spillovers either from the advanced economies to Asia or from Asia to the advanced economies. This was true even after the GFC when central banks in advanced economies adopted unconventional monetary expansion.

In the case of the European countries and the US, the variance decomposition shows that some spillovers existed. However, in the case of Asian economies, including Japan, the results show that the Asian economies' own shocks explained

³The two factors are the K-ANSM(2), a fixed 12.5 basis point lower bound, and yield curve data with maturities from 0.25 to 30 years with the sample beginning in 1995.

Table 5. Correlation of the Principal Components with Short-Term Rates

(i) Pre-GFC period			
	1st PC	2nd PC	3rd PC
Republic of Korea	-0.342	-0.367	0.294
Hong Kong, China	0.042	-0.615	-0.103
People's Republic of China	0.703	-0.156	0.246
Taipei, China	0.114	0.353	0.800
Singapore	-0.481	0.396	-0.020
Thailand	0.376	0.425	-0.451
(ii) Post-GFC and pretapering period			
	1st PC	2nd PC	3rd PC
Republic of Korea	-0.312	-0.505	0.478
Hong Kong, China	0.292	0.283	0.410
People's Republic of China	0.666	0.195	0.283
Taipei, China	-0.200	0.459	0.515
Singapore	0.258	-0.599	0.402
Thailand	-0.517	0.239	0.310
(iii) Tapering period			
	1st PC	2nd PC	3rd PC
Republic of Korea	0.242	-0.126	-0.547
Hong Kong, China	0.672	0.019	0.131
People's Republic of China	0.636	0.058	-0.014
Taipei, China	0.178	0.696	-0.152
Singapore	0.212	-0.702	0.021
Thailand	0.094	0.062	0.812

GFC = global financial crisis, PC = principal component.
Source: Authors' calculations.

more than 90% of the short-term rate fluctuations. This indicates that the short-term rates in emerging Asia are not only independent of those in the other regions but also show no synchronization within the region.

VI. Spillovers of Long-Term Interest Rates

In the previous section, we found that there were no significant spillovers of short-term interest rates either from the advanced economies to Asia or from Asia to the advanced economies. The purpose of this section is to explore whether there were any significant spillovers of long-term interest rates between emerging Asia and advanced economies. Specifically, using daily differences of 5-year or 10-year government bond yields, we explore the spillover effects between emerging Asia and the advanced economies (i.e., Japan, Germany, the UK, and the US). Unlike short-term rates, long-term rates are difficult to control without being affected by

Table 6.1 Variance Decomposition of the Principal Components in Asian Short-Term Rates (%)

(i) Decomposition of the 1st principal component						
1st PC Shock	Advanced Economies					
	Total	Japan	UK	Euro Area	US	
Pre-GFC period	97.28	1.21	0.68	0.07	0.35	0.11
Pretapering period	98.41	1.46	1.05	0.27	0.13	0.02
Tapering period	98.90	0.56	0.35	0.06	0.12	0.04

(ii) Decomposition of the 2nd principal component						
2nd PC Shock	Advanced Economies					
	Total	Japan	UK	Euro Area	US	
Pre-GFC period	95.74	2.05	1.32	0.35	0.30	0.09
Pretapering period	99.12	0.37	0.06	0.13	0.16	0.02
Tapering period	98.78	1.15	0.17	0.26	0.10	0.61

GFC = global financial crisis, PC = principal component, UK = United Kingdom, US = United States.

Note: The table reports the variance decomposition over 10 business days after a shock.

Source: Authors' calculations.

external shocks for each central bank. It is thus likely that long-term interest rates have different spillovers across the regions. The estimated equations are essentially the same as those in previous sections, except that we use daily differences of the long-term interest rates as the endogenous variables. We estimate GVARs for the three subsample periods.

In the analysis, we use PCA to extract common changes in long-term interest rates of the five Asian economies. Table 7 reports the correlation of the first, second, and third PCs with changes in 5-year or 10-year government bond yields in each Asian economy. The table shows that in both government bond yields, the first PC is positively correlated with each Asian long-term interest rate except with Thai long-term rates. The correlations with Taipei, China's long-term rates are relatively small in the first and second subsample periods. But putting aside these outliers, the other correlations lie between 0.37 and 0.6 in 10-year government bond yields. They also tend to exceed 0.4 in 5-year government bond yields. This implies that the first PC is a weighted average of Asian long-term interest rates.

In contrast, the second PC has a large positive correlation only with Thai long-term interest rates. The degree of the correlation is over 0.8 except for 5-year government bond yields in the first subsample period, which implies that the second PC reflects mainly Thai long-term interest rates. It is likely that long-term bond markets in Thailand were still less developed and were little affected by external shocks.

Tables 8.1 and 8.2 report the variance decomposition over 10 business days for the three subsample periods. Table 8.1 reports in percentages how much of the

Table 6.2 Variance Decomposition in Advanced Economies' Short-Term Rates (%)

(i) Japan short-term shadow rates				
	Japan Shock	Other Advanced Economies	1st PC Shock	2nd PC Shock
Pre-GFC period	98.38	0.62	0.49	0.51
Pretapering period	90.18	9.61	0.17	0.04
Tapering period	94.53	5.23	0.14	0.10
(ii) UK short-term shadow rates				
	UK Shock	Other Advanced Economies	1st PC Shock	2nd PC Shock
Pre-GFC period	89.65	7.34	1.75	1.26
Pretapering period	93.07	6.86	0.06	0.01
Tapering period	91.83	1.86	0.15	6.16
(iii) Euro area short-term shadow rates				
	Euro Shock	Other Advanced Economies	1st PC Shock	2nd PC Shock
Pre-GFC period	72.50	25.48	0.13	1.90
Pretapering period	70.58	28.69	0.14	0.60
Tapering period	75.92	17.90	0.95	5.24
(iv) US short-term shadow rates				
	US Shock	Other Advanced Economies	1st PC Shock	2nd PC Shock
Pre-GFC period	71.53	27.31	0.98	0.18
Pretapering period	71.09	28.06	0.53	0.31
Tapering period	68.42	30.10	0.27	1.21

GFC = global financial crisis, PC = principal component, UK = United Kingdom, US = United States.

Note: The table reports the variance decomposition over 10 business days after a shock.

Source: Authors' calculations.

first and second PCs in Asian long-term rates were explained by shocks in the four advanced countries, while Table 8.2 reports how much of the long-term rates in the four advanced countries were explained by the first and second PCs in Asia.

Table 8.1 indicates that in both 5-year and 10-year yields, there were significant spillovers from the advanced economies to the first PC in Asia throughout the subsample periods. The spillovers were smaller than stock market spillovers. But in the first subsample period, the long-term rates in the four advanced economies explained more than 40% of the first PC. In particular, US long-term rates explained about one-fourth of the first PC in the first subsample period. In the second and third subsample periods, the explanatory power of the long-term rates in the advanced economies declined because the first PC was explained more by its own shocks. This indicates that intraregional spillovers increased in Asian bond markets after the GFC. However, even in these subsample periods, advanced

Table 7. Correlation of the Principal Components with Long-Term Rates

(i) Pre-GFC period						
	10-year bond yields			5-year bond yields		
	1st PC	2nd PC	3rd PC	1st PC	2nd PC	3rd PC
Republic of Korea	0.375	0.165	0.089	0.446	-0.304	-0.117
Hong Kong, China	0.569	0.007	-0.083	0.606	0.027	-0.137
People's Republic of China	0.419	-0.120	-0.099	0.158	0.745	0.194
Taipei, China	0.129	0.101	0.971	0.165	0.167	0.794
Singapore	0.583	0.042	-0.131	0.614	0.018	-0.100
Thailand	-0.054	0.973	-0.122	0.066	-0.569	0.538
(ii) Post-GFC and pretapering period						
	10-year bond yields			5-year bond yields		
	1st PC	2nd PC	3rd PC	1st PC	2nd PC	3rd PC
Republic of Korea	0.439	-0.077	-0.224	0.476	-0.005	0.010
Hong Kong, China	0.532	-0.065	0.267	0.474	-0.149	-0.121
People's Republic of China	0.442	-0.116	-0.048	0.408	-0.149	-0.173
Taipei, China	0.265	0.546	-0.723	0.299	0.304	0.887
Singapore	0.503	-0.163	0.260	0.521	-0.172	-0.167
Thailand	0.071	0.807	0.535	0.145	0.913	-0.374
(iii) Tapering period						
	10-year bond yields			5-year bond yields		
	1st PC	2nd PC	3rd PC	1st PC	2nd PC	3rd PC
Republic of Korea	0.457	-0.121	0.225	0.462	-0.030	0.207
Hong Kong, China	0.488	-0.048	-0.214	0.463	0.077	-0.352
People's Republic of China	0.390	0.013	0.677	0.398	-0.131	0.746
Taipei, China	0.394	0.063	-0.665	0.416	0.059	-0.498
Singapore	0.493	-0.015	-0.008	0.490	0.000	-0.049
Thailand	0.057	0.989	0.051	0.006	0.986	0.163

GFC = global financial crisis, PC = principal component.

Source: Authors' calculations.

economies' shocks explained a significant part of the first PC's fluctuations in 5-year and 10-year yields. After the GFC, spillovers from advanced economies were slightly larger in 5-year yields than in 10-year yields. This may have happened because unconventional monetary policy in advanced economies had increased spillovers to Asia in 5-year yields.

In the case of the second PC, we do not infer significant spillovers from the advanced economies to Asia in 5-year yields. In 5-year yields, the Asian economies' own shocks explained most of the second PC's fluctuations throughout the subsample periods. Noting that the PRC's long-term interest rates have no correlation with the first PC but have a large correlation with the second PC, this implies that the PRC's 5-year interest rates have been determined independently. However, in the case of 10-year yields, shocks in the four advanced economies explained more than 20% of the second PC in the second and third subsample

Table 8.1 Variance Decomposition of the Principal Components in Asian Long-Term Rates (%)

		(i) Decomposition of the 1st principal component					
		1st PC Shock	Advanced Economies				
		Total	Japan	UK	Germany	US	
10-year yields	Pre-GFC period	52.31	47.37	3.30	15.04	4.33	24.69
	Pretapering period	81.82	15.43	2.59	3.92	1.75	7.17
	Tapering period	77.88	19.84	2.25	5.56	0.89	11.13
5-year yields	Pre-GFC period	56.23	43.53	2.94	12.27	2.00	26.32
	Pretapering period	72.74	22.06	2.75	6.89	1.29	11.14
	Tapering period	68.73	24.42	2.48	9.02	0.70	12.22

		(ii) Decomposition of the 2nd principal component					
		2nd PC Shock	Advanced Economies				
		Total	Japan	UK	Germany	US	
10-year yields	Pre-GFC period	56.23	43.53	2.94	12.27	2.00	26.32
	Pretapering period	70.15	29.24	3.89	6.50	4.92	13.94
	Tapering period	60.76	37.21	3.34	9.71	1.72	22.45
5-year yields	Pre-GFC period	96.58	2.42	0.47	1.11	0.36	0.49
	Pretapering period	95.95	3.39	0.79	0.35	0.08	2.18
	Tapering period	97.16	2.01	0.10	0.38	0.10	1.43

GFC = global financial crisis, PC = principal component, UK = United Kingdom, US = United States.

Note: The table reports the variance decomposition over 10 business days after a shock.

Source: Authors' calculations.

periods. This suggests that the PRC's 10-year yields experienced significant spillovers from the advanced economies after the GFC even though the PRC's 5-year yields were still controlled by the government.

In contrast, Table 8.2 shows that the first and second PCs in Asia explained only a small percentage of the long-term rate fluctuations in the advanced economies throughout the subsample periods. That is, as in the stock markets, spillover effects from advanced economies to Asia have been much larger than those from Asia to advanced economies in the long-term bond markets. Among the advanced economies, long-term rate fluctuations in Japan were explained mainly by Japan's own shocks and were explained very little by the other shocks throughout the subsample periods. This may have happened because unconventional monetary policy by the Bank of Japan induced extremely low long-term rates throughout the sample periods. Even the long-term rate fluctuations in the other advanced economies were mostly explained by their own shocks or by shocks in the other advanced economies. This is in marked contrast with stock market spillovers in which the first PC in Asia came to explain a significant percentage of stock return fluctuations in the two European countries and the US after the GFC.

After the GFC, the first and the second PCs in Asia came to explain about 5% of long-term rate fluctuations in the UK, Germany, and the US. For example, in the UK, the two components in Asia explained 5.11% of 10-year yields and

Table 8.2 Variance Decomposition in Advanced Economies' Long-Term Rates (%)

(i) Variance decomposition of Japan's long-term rates								
	10-Year Yields				5-Year Yields			
	Other				Other			
	Japan Shock	Advanced Economies	1st PC Shock	2nd PC Shock	Japan Shock	Advanced Economies	1st PC Shock	2nd PC Shock
Pre-GFC period	92.45	7.28	0.08	0.20	93.59	6.28	0.05	0.07
Pretapering period	82.42	17.10	0.16	0.32	83.32	16.44	0.21	0.04
Tapering period	86.71	11.96	0.96	0.36	93.40	6.33	0.25	0.03
(ii) Variance decomposition of UK long-term rates								
	10-Year Yields				5-Year Yields			
	Other				Other			
	UK Shock	Advanced Economies	1st PC Shock	2nd PC Shock	UK Shock	Advanced Economies	1st PC Shock	2nd PC Shock
Pre-GFC period	91.59	6.21	2.14	0.06	91.37	5.05	3.07	0.50
Pretapering period	87.75	7.14	2.62	2.49	91.62	4.87	3.32	0.19
Tapering period	86.30	7.74	2.19	3.77	91.60	3.72	4.47	0.22
(iii) Variance decomposition of Germany's long-term rates								
	10-Year Yields				5-Year Yields			
	Other				Other			
	German Shock	Advanced Economies	1st PC Shock	2nd PC Shock	German Shock	Advanced Economies	1st PC Shock	2nd PC Shock
Pre-GFC period	37.80	59.22	2.81	0.17	59.60	37.76	2.05	0.60
Pretapering period	39.92	54.38	2.28	3.42	55.88	40.88	1.49	1.75
Tapering period	41.63	53.00	2.32	3.05	51.80	41.72	2.89	3.60
(iv) Variance decomposition of US long-term rates								
	10-Year Yields				5-Year Yields			
	Other				Other			
	US Shock	Advanced Economies	1st PC Shock	2nd PC Shock	US Shock	Advanced Economies	1st PC Shock	2nd PC Shock
Pre-GFC period	38.42	57.30	3.81	0.47	69.81	28.14	1.84	0.22
Pretapering period	60.31	37.88	1.80	0.01	60.67	36.56	2.41	0.36
Tapering period	61.53	34.83	3.17	0.46	64.10	30.76	5.09	0.05

GFC = global financial crisis, PC = principal component, UK = United Kingdom, US = United States.

Note: Table reports the variance decomposition over 10 business days after a shock.

Source: Authors' calculations.

3.51% of 5-year yields in the second subsample period and 5.96% of 10-year yields and 4.68% of 5-year yields in the third subsample period. This implies that after the GFC, spillovers from emerging Asia to Europe and the US came to have some significance even in bond markets. But these spillovers were much smaller than the stock market spillovers in magnitude. Noting that stock market spillovers from Asia to Europe and the US increased mainly because manufacturing sector shocks in Asia had significant impacts on advanced economies, this result also supports the

view that direct financial linkages from emerging Asia to advanced countries were, if any, small even after the GFC.

VII. Concluding Remarks

In this paper, we explored how financial market spillovers between emerging Asia and advanced economies have changed in the 2000s. Stock market spillovers from emerging Asia became significant in the post-GFC period. Even in long-term rates, we found significant spillovers from emerging Asia to Europe and the US in the tapering period. However, bond market spillovers were much smaller than stock market spillovers in magnitude. More importantly, the industry-level analysis showed that the stock market spillovers originated mostly from common shocks in the manufacturing sector rather than from those in the financial sector. The financial spillovers from emerging Asia increased in the post-GFC period because emerging Asian economies were increasingly more connected with the rest of the world in integrated global production networks. This supports the view that direct financial market linkages from emerging Asia to advanced countries were, if any, limited even after the GFC.

In the 2000s, emerging Asia underwent rapid industrialization in integrated global production networks and their real fundamental shocks came to have substantial spillover effects on advanced economies. Our empirical results are consistent with the view that even though the financial market in emerging Asia has been less developed, the increased role of Asian economies in integrated global production networks raised spillovers from emerging Asia in the global financial markets. However, limited direct financial linkages from emerging Asia to advanced countries are still important policy agenda even after the GFC. This is particularly true in Asian bond markets. In emerging Asia, we probably need further structural reforms of financial markets, which may contribute to solving persistent external imbalances in the global financial markets.

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Appendix. Shocks after the New York Stock Market Closes

In the main text, the order of the Cholesky decomposition in the global vector autoregressions (GVARs) was set to be the variable in Japan, the first and second PCs in Asia, the variable in the United Kingdom, the variable in Europe, and the variable in the United States (US). We chose the order because Asian financial markets are open before European and New York markets open. However, in the US, some important news may be announced after the New York market closes. One may have concern that our order of the Cholesky decomposition would identify some shocks in the US as Japanese market shocks. The purpose of this Appendix is to show that our results are essentially the same even if we control for spillover effects of shocks after the New York market closes.

In the analysis, we split daily changes of Japan's stock price index into "daytime change" and "nighttime change." The "daytime change" in date t is the change of Nikkei 225 from 9:15 a.m. to 3:30 p.m. in date t . The "nighttime change" in date t is the change of Nikkei 225 from 3:30 p.m. in date $t-1$ to 9:15 a.m. in date t . In the GVARs, the order of the Cholesky decomposition was set to be the daytime change in Japan, the first and second PCs in Asia, the variable in the United Kingdom, the variable in Europe, the variable in the US, and the nighttime change in

Table A1.1 Variance Decomposition of the Principal Components in Asian Stock Returns (%)

(i) Decomposition of the 1st principal component							
	1st PC Shock	Advanced Economies					
		Total	Japan	UK	Germany	US	Nighttime
Pre-GFC period	62.59	36.02	18.39	6.08	2.93	8.57	0.05
Pretapering period	55.94	43.26	14.80	19.70	1.61	7.03	0.12
Tapering period	63.64	34.10	14.92	8.32	0.77	9.96	0.14

(ii) Decomposition of the 2nd principal component							
	2nd PC Shock	Advanced Economies					
		Total	Japan	UK	Germany	US	Nighttime
Pre-GFC period	98.36	1.20	0.30	0.07	0.33	0.42	0.08
Pretapering period	96.95	2.27	0.09	1.24	0.03	0.84	0.07
Tapering period	98.16	1.33	0.56	0.16	0.01	0.51	0.08

GFC = global financial crisis, PC = principal component, UK = United Kingdom, US = United States.
Source: Authors' calculations.

Japan. Given the order of the Cholesky decomposition, it is natural to suppose that the “daytime change” would reflect shocks in Japan, while the “nighttime change” would reflect shocks after the New York market closes but before Asian markets open.

By using the new order of the Cholesky decomposition, we examine stock market spillovers between Asian and advanced financial markets. The estimated equations are the same as those in section III, except that we use “daytime change” and “nighttime change.” Using the first and the second PCs in Asia, we estimate the GVARs for the three subsample periods. Tables A1.1 and A1.2 summarize the results of the variance decompositions. Table A1.1 reports in percentages how much of the first and second PCs in Asia were explained by shocks in the advanced economies, while Table A1.2 reports how much of stock prices in the advanced economies were explained by the first and second PCs in Asia.

In both of the tables, the contributions of “daytime change” in Tables A1.1 and A1.2 are very similar to those of Japan’s daily stock returns in Tables 2.1 and 2.2. More importantly, the first and second PCs in Asia and the stock returns in the other advanced countries have very similar contributions in Tables A1.1 and A1.2 to those in Tables 2.1 and 2.2. This implies that our results are essentially the same as those in section III even if we split daily changes of Japan’s stock price index into “daytime change” and “nighttime change.”

This happened because spillovers due to “nighttime change” are, if any, very small in our estimated GVARs. For example, in Table A1.1, the contributions of the “nighttime change” are less than 0.1% in explaining the first and second PCs in Asia. This implies that even if some important news were announced after the

Table A1.2 Variance Decomposition in Advanced Economies' Stock Returns (%)

(i) Japan's stock prices				
	Japan Shock	Other Advanced Economies	1st PC Shock	2nd PC Shock
Pre-GFC period	97.40	2.04	0.23	0.33
Pretapering period	95.66	3.76	0.48	0.09
Tapering period	97.84	1.23	0.38	0.55
(ii) UK stock prices				
	UK Shock	Other Advanced Economies	1st PC Shock	2nd PC Shock
Pre-GFC period	79.92	15.11	4.76	0.21
Pretapering period	74.40	10.94	13.49	1.17
Tapering period	41.59	46.21	10.81	1.39
(iii) Germany's stock prices				
	German Shock	Other Advanced Economies	1st PC Shock	2nd PC Shock
Pre-GFC period	37.24	55.43	7.05	0.28
Pretapering period	22.33	66.38	9.79	1.50
Tapering period	35.91	51.89	10.81	1.39
(iv) US stock prices				
	US Shock	Other Advanced Economies	1st PC Shock	2nd PC Shock
Pre-GFC period	62.36	35.00	2.43	0.21
Pretapering period	40.81	51.40	6.30	1.49
Tapering period	64.96	28.75	5.88	0.42
(v) Nighttime stock prices				
	Nighttime Shock	Other Advanced Economies	1st PC Shock	2nd PC Shock
Pre-GFC period	47.83	46.17	5.91	0.09
Pretapering period	49.14	46.05	3.33	1.48
Tapering period	49.08	46.51	4.12	0.29

GFC = global financial crisis, PC = principal component, UK = United Kingdom, US = United States.

Source: Authors' calculations.

New York market closed, the news had negligible spillover effects on Asian stock returns. As a result, even if we control their spillover effects, we still find that stock market spillovers from emerging Asia became far from negligible in the post-GFC period, although financial market spillovers from the advanced economies to Asia were much larger than those from Asia to the advanced economies.