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Abstract

This study employs VAR-MGARCH model to investigate the spillover across the sovereign bond markets between the US and ASEAN-4 (Indonesia, Malaysia, the Philippines and Thailand) economies. The empirical results confirm the return spillover from the US to ASEAN-4, while the bidirectional influence in volatility exists between the US and ASEAN-4. Furthermore, dynamic conditional correlation (DCC) analysis is employed to depict the changing correlation in the volatility. The empirical results also show that the yields of ASEAN-4 bonds increase with the emerging market risks and the exchange rate can act as a buffer to reduce spillover. Given that ASEAN-4 governments have issued large amount of government bonds to finance their large fiscal spendings amid the Covid-19 pandemic, the return and volatility spillovers from the US to ASEAN-4 could be important factors to be mindful when the US unwinds its unconventional monetary policy and normalizes its interest rates in the medium to long term.

JEL classification: F21, F31, C32

Keywords: ASEAN-4, sovereign bond, spillovers, Multivariate-GARCH

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[2] The authors would like to thank Chaipat Poonpatpibul, Li Lian Ong, and AMRO colleagues' comments to the study. All remaining mistakes are the responsibility of the authors.

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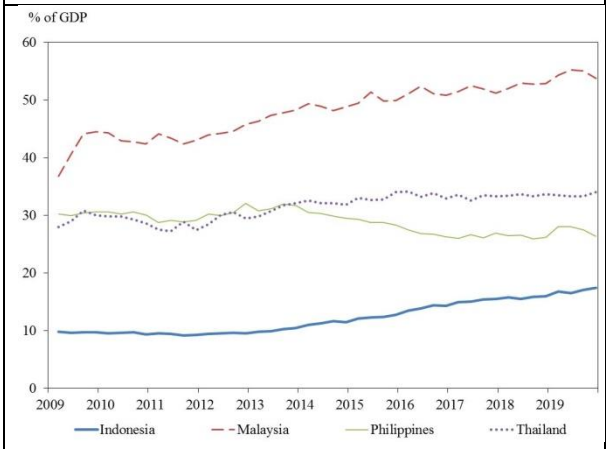
I. Introduction

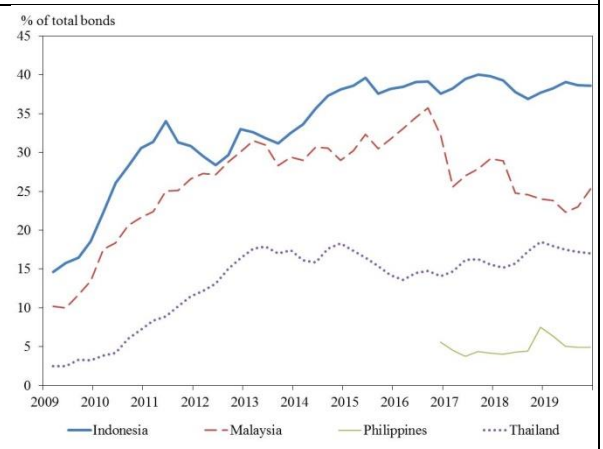
ASEAN bond markets have grown significantly since the Asian Financial Crisis, as the ASEAN governments have been putting great efforts to develop their own bond markets to diversify financial channels and to enhance financial stability. Moreover, as the main source of financing of fiscal spending, ASEAN countries have issued a significant and rising amount of government bonds (Figure 1a).[3] In the ASEAN-4 (Indonesia, Malaysia, the Philippines and Thailand) region, the amount of the government bonds held by the foreign investors has risen since the Global Financial Crisis (GFC, Figure 1b). Different domestic and external forces are affecting the ASEAN sovereign bond markets. Especially, the rising government bond issuance and the increasing foreign investment in ASEAN bonds could be explained by the easy US monetary policy after the GFC (see Burger et al., 2017). In addition, financial markets in the ASEAN-4 region are heavily influenced by the US in both real and financial channels, the return and volatility spillovers between the US and the ASEAN-4 bond markets have raised the concern of the investors and the policymakers in the region.

Figure 1 Size and Foreign Holdings of ASEAN-4 Government Bonds

(a) Government Bonds (LCY) of ASEAN-4 Economies, as % of GDP



(b) Foreign holding of Government Bonds (LCY) of ASEAN-4 Economies, % of total bonds



Source: Asian Bond Online, Asian Development Bank (ADB). See https://asianbondsonline.adb.org/data-portal/.

This study investigates the spillover across the sovereign bond markets between the US and ASEAN-4 economies. Specifically, this study aims to answer to what extent there are return[4] and volatility spillovers across the US treasury bond yields and the ASEAN-4 government bond yields. VAR model is used to study the spillover in return (mean level), and empirical

[3] Harun (2002) and Hendar (2012) discussed the government bond markets as an important financing to the government spending in Malaysia and Indonesia respectively.

[4] As this paper uses current yield, the return therefore refers to expected income return, not actual return.

results confirm the US spillover to ASEAN-4. In volatility, multivariate GARCH (MGARCH) is utilized to investigate the spillover and empirical results also show the bidirectional influence between the US and ASEAN-4. The VAR-MGARCH provides a unified framework to assess both return and volatility spillover in the same integrated model. In particular, we use the MGARCH-BEKK methodology, which allows the asymmetric volatility and shock spillovers from each endogenous variable to other endogenous variables in the model, indicating the direction of the spillover. Furthermore, by reducing the dimensionality problem, dynamic conditional correlation (DCC) analysis is employed to depict the time-varying correlation in the volatility of the US and ASEAN bond markets, revealing the influence of external conditions.

Lastly, the exogenous variables added into the VAR model, VIX and exchange rate, are significant. The former shows the yields of ASEAN-4 bonds increase with the emerging market risks, and the latter indicates the exchange rate can act as a buffer to reduce spillover. The inclusion of exogenous variables enhanced the policy study, which a deeper understanding can lead to better policy responses.

The volatility spillover among different markets has been well studied since the introduction of MGARCH methodology (e.g., Engle and Kroner, 1995 and Engle, 2002). The spillover within a region (e.g., Christiansen, 2007) and the bilateral spillover (e.g., Claeys and Vašícek, 2014) have been well studied. In particular, there is an extensive literature on bond market spillovers for the emerging economies (including ASEAN economies). For instance, Albagli et al. (2019) studied the spillovers of US monetary policy to overseas bond markets and found that there are different channels of US spillovers for different types of economies. Especially, the channel is through risk-neutral rates for advanced economies, while it is through term premia for emerging economies. Burger et al. (2017) found that when US monetary policy was easing, particularly the long-term Treasury yields were low, (i) EMEs issued more sovereign local currency (LCY) bonds and (ii) US investment in emerging market sovereign LCY bonds increased. On the other hand, Mandigma (2014) studied the integration among the sovereign bond markets between ASEAN5 (namely, Indonesia, Malaysia, the Philippines, Singapore and Thailand) and China. They found that ASEAN5 and China were affected mainly by their own shocks with some impact to and from a few ASEAN5 countries sovereign bond yields, indicating that the spillover from China to the ASEAN sovereign bond market was still limited.

This paper contributes to the literature in three ways. First, this paper examines both the return and volatility spillover between the US and the ASEAN-4 sovereign bonds quantitatively In particular, this paper focuses on the possible bidirectional spillovers between the US and the ASEAN-4, which fills a gap in the previous literature which only assessed the channels of US spillovers and its spillovers to emerging markets as a whole. Second, this paper also contributes to the literature on the policy for mitigating the external risks on the ASEAN-4 sovereign bonds. Finally, given the COVID-19 pandemic, ASEAN governments have issued much more sovereign bonds to finance their large fiscal stimulus packages, this paper contributes a better understanding of the spillovers from external conditions that the policymakers must take into consideration.

The paper is structured as follows. In Section 2, we discuss the VAR-MGARCH methodology and describe the data set. Section 3 presents the empirical results. Finally, Section 4 concludes with a summary of the main messages and policy issues.

II. Methodology and Data

In this section, we start with a brief description of our econometric framework, examining return and volatility spillovers. Then the data used in this research are discussed.

2.1 VAR-MGARCH Methodology

In this study, we investigate the spillovers from the US government bond market to each of the ASEAN-4 government bond markets in bond yields over time using a two-variable vector autoregressive (VAR) model. Then we further study the spillovers through the volatility channel by exploring the temporal dependence of the conditional variance with the multivariate generalized autoregressive conditional heteroscedasticity (MGARCH-BEKK) model (Engle and Kroner, 1995) and the dynamic conditional correlation (DCC) model (Engle, 2002).

The VAR model is specified as follows:

$$\begin{bmatrix} US_t \\ Y_t \end{bmatrix} = \begin{bmatrix} \mu_{US} \\ \mu_Y \end{bmatrix} + \sum_{j=1}^{P} \emptyset_j \begin{bmatrix} US_{t-j} \\ Y_{t-j} \end{bmatrix} + \begin{bmatrix} \varepsilon_{US,t} \\ \varepsilon_{Y,t} \end{bmatrix} \quad (1)$$

where Y_t is the bond yield of each of the ASEAN-4 markets (Indonesia, Malaysia, the Philippines, Thailand, and the whole group) and US_t the corresponding bond yield of the US Treasury bond at time *t*; *p* is the lag order of the VAR equation determined by Information Criteria, such as AIC and BIC; μ_Y and μ_{US} are the unconditional mean and $\emptyset_1$through $\emptyset_p$ are coefficient matrices. In order to check the return spillover effect from the US bonds to ASEAN-4 bonds, the significance of the sum of return spillover parameters $\left(\sum \phi_{j,21}\right)$ (impulse responses of the *h*-period ASEAN-4 government bond of country *k* to the shocks of *h*-period US Treasury bond) is required. The residuals are assumed to be multivariate normally distributed with time-vary covariance.

The conditional covariance of the residuals is assumed to take the following form:

$$\begin{bmatrix} \varepsilon_{US,t} \\ \varepsilon_{Y,t} \end{bmatrix} | I_{t-1} \sim N(0, H_t), \quad H_t = \begin{bmatrix} \sigma^2_{US,t} & \sigma_{US,Y,t} \\ \sigma_{Y,US,t} & \sigma^2_{Y,t} \end{bmatrix} \quad (2)$$

where I_{t-1} is the information set up to time *t*.

The MGARCH-BEKK model can be written as:

$$H_t = C' C + \sum_{i=1}^{p} A_i' \varepsilon_{t-i} \varepsilon_{t-i}' A_i + \sum_{i=1}^{p} G_i' H_{t-1} G_i \quad (3)$$

where C, A_i and G_i are 2 X 2 matrices. This form of the conditional covariance ensures all positive definite diagonal representations. In this study, for a parsimonious specification of the conditional covariance, we set the lag length of equation (3) to unity. The BEKK MGARCH model can be used to investigate the spillovers in volatility, particularly useful in providing the direction of the spillover. For instance, the shock spillover A_{12} and volatility spillover G_{12} are

significant as the US bond yield will affect ASEAN bond yield.[5] However, general MGARCH models typically suffer from dimensionality problem in estimation as the number of time-series increases. Engle (2002) proposes the dynamic conditional correlation (DCC) model to alleviate the dimensionality presented in the general MGARCH model.[6]

2.2 DCC Model

The conditional covariance H_t can be decomposed as follows:

$$H_t = D_t P_t D_t \tag{4}$$

where the conditional correlation matrix, P_t, is time-varying and defined as $P_t = Q_t^{*-1} Q_t Q_t^{*-1}$ and Q_t^* is a diagonal matrix with the square root of the *i*-th diagonal element of Q_t on its *i*-th diagonal position. With the unconditional covariance matrix $\bar{Q}$, the conditional covariance matrix of the error terms, Q_t, is defined as the following:

$$Q_t = (1 - a - b)\bar{Q} + a\varepsilon_t \varepsilon_t^{'} + bQ_{t-1} \tag{5}$$

The necessary and sufficient condition to ensure that Q_t is positive definite at all time is the sum of $a + b$ less than unity. If the value of $a + b$ close to one indicates high persistence in the conditional variance. Let $\bar{\rho}_{Y,US,t}$ be the estimated DCC coefficient (the off-diagonal element of P_t) from the system, which reveals the changing correlation between the ASEAN-4 bond yield and the US bond yield over time.

2.3 Data

In this research, the daily data on different tenors (1-year, 3-year, 5-year, 7-year and 10-year) of the bonds yields of local-currency-denominated government bond yields of ASEAN-4 (Indonesia, Malaysia, the Philippines and Thailand), and US treasury yields are used in the

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[5] For the matrix of ARCH parameters, $\boldsymbol{A} = \begin{pmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{pmatrix}$, A_{kk} measure the effect of shocks on its own country's volatility of bond yield, and the off-diagonal elements of the matrix A_{kl} capture the effect of country *k*'s shock of bond yield on country *l*'s volatility of bond yield, in order to measure the linkages or transmissions between the US and ASEAN-4. A_{12} is the effect of the US shock on the volatility ASEAN-4 bond yield; and A_{21} is the effect of ASEAN-4 shock on the volatility of the US bond yield.

For the matrix of GARCH parameters, $\boldsymbol{G} = \begin{pmatrix} G_{11} & G_{12} \\ G_{21} & G_{22} \end{pmatrix}$, G_{kk} measure the own past volatility effect on its conditional variance of bond yield, and the off-diagonal elements of the matrix G_{kl} capture "volatility spillover", which is the effect of country *k*'s past volatility of bond yield on the conditional variance of country *l*'s bond yield. Specifically, G_{12} is the effect of the US past volatility of bond yield on the conditional variance of ASEAN-4 bond yield, while G_{21} is the effect of ASEAN-4 past volatility of bond yield on the conditional variance of the US bond yield.

[6] Since the BEKK allows to assess the possible asymmetric spillovers, indicating the direction of spillovers, while DCC cannot. No method is more superior to the other. Therefore this paper applies two methods for looking the direction of spillovers (by BEKK) and the development of the spillover effects over time (by DCC). Further details of the comparison between two methods could be found in Caporin and McAleer (2012).

empirical investigation. In addition, two exogenous variables are included in the estimation. First, to capture the global emerging market risk effects, VIX, which is proxied by CBOE Emerging Markets ETF Volatility Index is used.[7] Second, to assess the impact of the exchange rate, the bilateral exchange rate between the ASEAN-4 currency and the US dollar (local currency per US dollar) also included in the model. The sample covers from 18 March 2011 to 14 November 2019, and all the data are the daily closing value downloaded from Bloomberg.[8] Table 1 shows the summary statistics of various bond yields. Since the US monetary policy was normalized since 2015, after the tapering until end-2014, we also calculate the summary statistics for two sub-periods, before and since 2015. In general, the volatilities of the ASEAN-4 bond yields were lower since 2015.

Table 1 Descriptive Statistics of Government Bond Yields

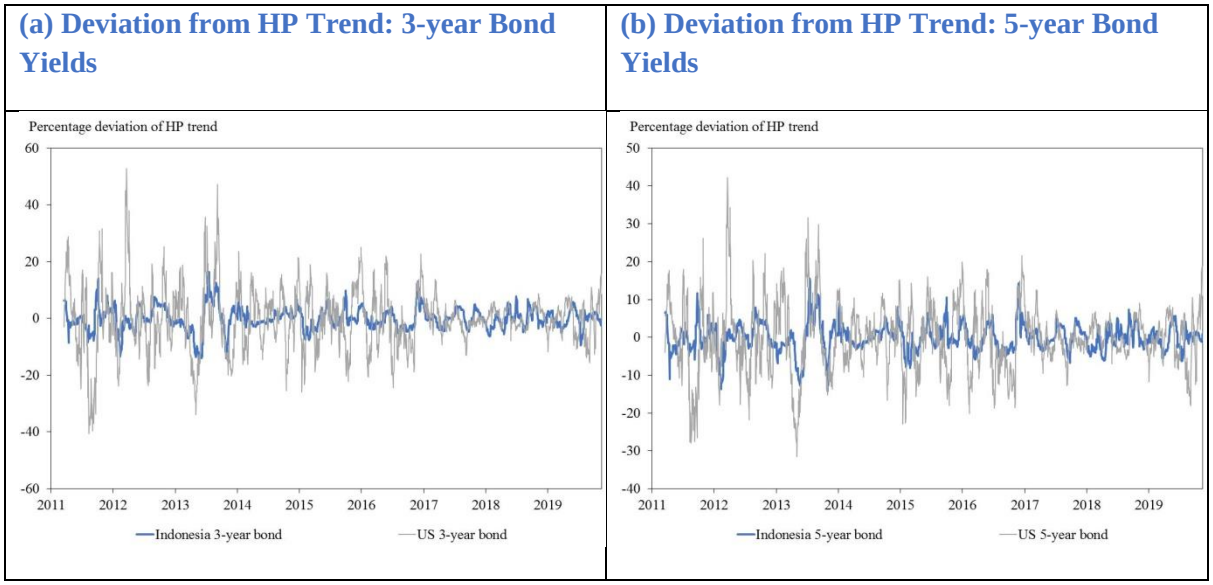
		Full sample		Before 2015		Since 2015	
Country	**Tenor**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Indonesia	1 Year	5.87	1.02	5.32	1.14	6.30	0.66
Indonesia	3 Year	6.66	1.11	6.11	1.23	7.08	0.76
Indonesia	5 Year	6.88	1.08	6.42	1.22	7.24	0.79
Indonesia	7 Year	7.20	1.04	6.77	1.20	7.54	0.73
Indonesia	10 Year	7.27	0.96	6.95	1.15	7.53	0.69
Malaysia	1 Year	3.11	0.23	3.04	0.16	3.15	0.27
Malaysia	3 Year	3.31	0.21	3.22	0.18	3.37	0.21
Malaysia	5 Year	3.52	0.22	3.42	0.20	3.60	0.20
Malaysia	7 Year	3.75	0.25	3.63	0.23	3.84	0.22
Malaysia	10 Year	3.85	0.26	3.74	0.26	3.93	0.23
Philippines	1 Year	2.71	0.88	2.67	0.30	2.73	1.09
Philippines	3 Year	3.61	1.12	2.95	0.64	3.99	1.17
Philippines	5 Year	4.48	2.06	4.72	2.75	4.29	1.26
Philippines	7 Year	4.31	1.04	4.09	0.82	4.48	1.14
Philippines	10 Year	4.65	1.09	4.43	1.18	4.82	0.98
Thailand	1 Year	2.07	0.67	2.73	0.46	1.55	0.16
Thailand	3 Year	2.22	0.69	2.93	0.36	1.67	0.23
Thailand	5 Year	2.53	0.70	3.26	0.30	1.97	0.27
Thailand	7 Year	2.73	0.70	3.45	0.24	2.17	0.32
Thailand	10 Year	2.94	0.68	3.62	0.27	2.41	0.36
US	1 Year	0.78	0.85	0.13	0.04	1.28	0.84
US	3 Year	1.18	0.73	0.61	0.26	1.63	0.66
US	5 Year	1.60	0.60	1.22	0.44	1.90	0.55
US	7 Year	1.96	0.52	1.75	0.50	2.12	0.48
US	10 Year	2.29	0.46	2.29	0.49	2.28	0.43

Sources: Bloomberg and author calculation.

[7] Details of the index could see https://fred.stlouisfed.org/series/VXEEMCLS.

[8] Using daily data is more preferable than weekly data because the volatility model can be better fitted by using daily data, while MGARCH models allow the time-varying correlation estimation which the small noise could be ignored. Moreover, given the sample is 9 years (2011 - 2019), daily data could be better as more information included. On the other hand, using weekly average could remove some noise, but it may not good for capturing the volatility in the model. In particular, different aggregating method for the weekly data may have very different results. See Baumöhl and Lyócsa (2012).

Figure 2 Government Bond Yields and Transformation



Sources: Bloomberg and author calculation.

In order to estimate the VAR-MGARCH model, all the data are transformed into stationary series.[9] Specifically, the bond yields are converted into percentage deviation of HP filter trend (which the transformation method is the same as that used in Miyajima et al., 2014). Figure 2 uses the Indonesia government bonds and the US Treasury bonds as an example to illustrate how the detrending is worked in this research.[10] Meanwhile, the growth rate of the exchange rate and the change of VIX are used.

Furthermore, to better assess the spillover effect between the US bond and the ASEAN-4 bond markets as a whole, the ASEAN-4 bond yields are aggregated as a group. The first principal components from the principal component analysis (PCA) of different tenors of ASEAN-4 bond yields are used in the primary analysis, while the data for individual countries are used as robustness checking. In the aggregate models, the equal-weight averaged index for aggregation is included.[11]

III. Empirical Results

This section presents the empirical results of the VAR-MGARCH models. Our discussion focuses on the results of the aggregate models using the first principal components in the PCA of ASEAN-4 bond yields, while the results for individual country bond yields are used as a

[9] The stationarity of the series are tested by the ADF tests. The ADF test results are available upon request.

[10] The larger magnitude (as well as the variation) for the detrended US bond returns (deviation from the trend) is observed. The US yields are lower than those ASEAN-4 counterparts (see Table 1), and the smaller number of denominator will increase the magnitude of the percentage deviated from the trend. Also, the US bond returns have the largest values in the variation (SD or range) against the mean. This also increases the magnitude of the percentage deviated from the trend.

[11] The exchange rate index is constructed by using the domestic currency per 1 USD dollar, direct quotation for domestic countries; higher value means depreciation of the ASEAN-4 currencies.

robustness checking (see Appendix). Table 2 presents the PCA results for the ASEAN-4 bond yields in different tenors. The first components generally capture 40-50 percent of the variation, except the 1-year bonds which the first component also captures 30 percent of the variation. [12] Nevertheless, the first components have the largest explanatory power in all tenors of ASEAN bonds, indicating that the ASEAN-4 bond yields are driving by one common factor which can be called as the 'ASEAN-4 factor'.

Table 2 Principal Components of ASEAN-4 Government Bonds

	First principal component	Second principal component	Third principal component	Fourth principal component
1-year tenor bonds				
Eigenvalue	1.211	1.132	0.866	0.792
Cumulative proportion	0.303	0.586	0.802	1.000
3-year tenor bonds				
Eigenvalue	1.770	0.895	0.782	0.553
Cumulative proportion	0.442	0.666	0.862	1.000
5-year tenor bonds				
Eigenvalue	1.691	1.004	0.742	0.563
Cumulative proportion	0.423	0.674	0.859	1.000
7-year tenor bonds				
Eigenvalue	1.995	0.821	0.739	0.444
Cumulative proportion	0.499	0.704	0.889	1.000
10-year tenor bonds				
Eigenvalue	1.955	0.908	0.658	0.479
Cumulative proportion	0.489	0.716	0.880	1.000

Notes: The principal components are calculated using the bond yields expressed in terms of percentage deviations from Hodrick-Prescott (HP) trends.

3.1 VAR results

In the mean equation (VAR), we examine the relationships among the yields (returns) ASEAN-4 bonds.[13] The lag lengths of different VAR models are selected by the Schwarz information criteria. Specifically, a VAR(1) model is used in the model for PCA of 1-year bonds, while a VAR(2) model is applied for PCA of other tenors of bonds. Table 3 presents the coefficients of the VAR models for PCA of ASEAN-4 bonds with different tenors, which the exogenous variables, VIX and exchange rates are included. In the table, the sum of coefficients of different lags of the same variables is presented with the Wald test results. In sum, US bonds could affect both the US bonds and ASEAN local bonds, while the domestic bonds should affect the domestic bonds only and should not affect the US bonds.[14] As discussed in Section 2, the

[12] Since the PCA capture the comment variation, the variation of the first components should be smaller than the individual countries' bond returns.

[13] The yield is not exactly the same as the return. Specifically, the return is the total return of the investment, including both income return (e.g., interest, dividends, etc.) and asset valuation gain, while the yield is the expected income return on an investment, assuming no changes in asset valuation. However, the concept can be interchange in bonds. In the case of bonds, the value of bond is a function of yield. The changes in asset valuation could reflect in the changes in yield (as well as the yield spread). See https://www.investopedia.com/ask/answers/difference-between-yield-and-return/.

[14] The results without exogenous variables are consistent with the existing results.

variation of detrended ASEAN-4 bond returns (particularly the PCA) is significantly smaller than that of detrended US bond returns, the magnitude of the impact (i.e., the parameters in VAR models) on ASEAN bond returns due to the change in a unit of the US bond returns should be smaller than the impact from the ASEAN bond returns. The results for individual country bond series are mostly consistent with the PCA results, except 1-year bonds (US bonds do not affect ID, TH & PH bonds); and 3-year US bonds are affected by ID bonds (see Table A1 in Appendix).

Table 3 Return Spillover (VAR, ASEAN-4 vs the US)

	Endogenous variables		**Exogenous variables**	
	ASEAN bond returns	**US bond returns**	**VIX**	**Exchange rate**
1-year tenor				
ASEAN bond returns	0.961(0.006)***	0.002(0.001)***	0.012(0.005)**	14.786(2.305)***
US bond returns	-0.058(0.089)	0.918(0.009)***	0.098(0.074)	-22.044(34.667)
3-year tenor				
ASEAN bond returns	0.966(0.005)***	0.003(0.001)***	0.018(0.005)***	11.527(2.228)***
US bond returns	0.089(0.068)	0.919(0.010)***	0.079(0.061)	3.002(29.395)
5-year tenor				
ASEAN bond returns	0.955(0.005)***	0.004(0.001)***	0.027(0.004)***	11.765(2.232)***
US bond returns	0.051(0.060)	0.933(0.009)***	0.060(0.045)	-17.147(24.883)
7-year tenor				
ASEAN bond returns	0.961(0.005)***	0.005(0.001)***	0.024(0.004)***	15.232(2.146)***
US bond returns	0.054(0.047)	0.932(0.009)***	0.067(0.038)*	-36.603(20.637)*
10-year tenor				
ASEAN bond returns	0.958(0.005)***	0.007(0.001)***	0.030(0.004)***	16.033(2.279)***
US bond returns	0.017(0.038)	0.937(0.009)***	0.072(0.031)**	-34.818(16.868)**

Notes: Bond returns are bond yields that expressed in terms of percentage deviations from Hodrick-Prescott (HP) trends. VIX is the CBOE Emerging Markets ETF Volatility Index (VXEEMCLS). The exchange rate is an equal-weight averaged index of 4 currencies. Wald tests of the coefficients (sum of all lags, if more than one lag is used) are based on the Chi-squared statistics. Standard errors are in parentheses. ***, ** and * are significance at 1%, 5% and 10% levels.

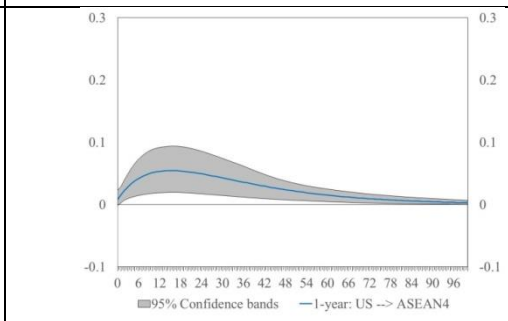
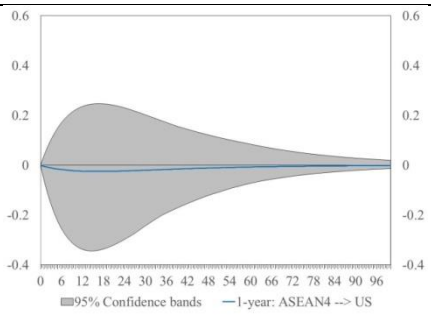
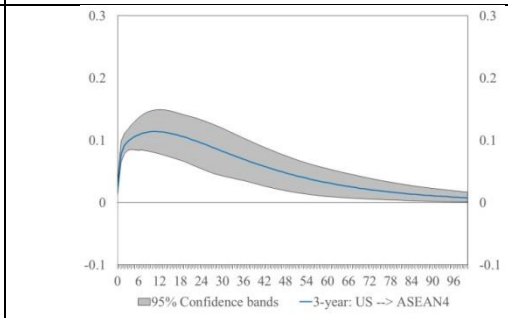
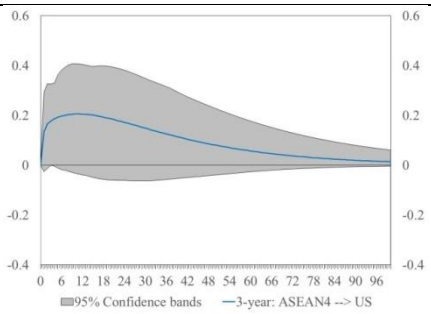
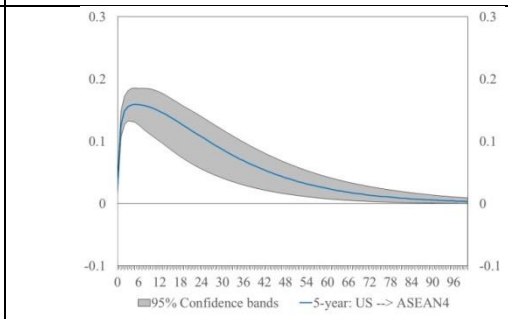
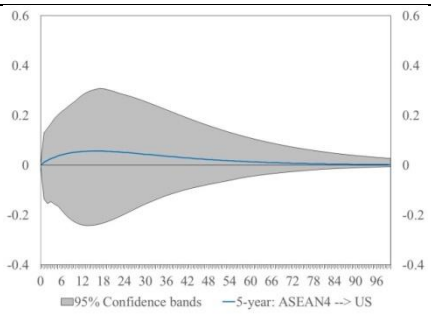
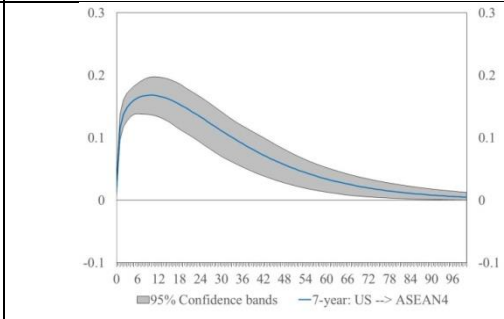
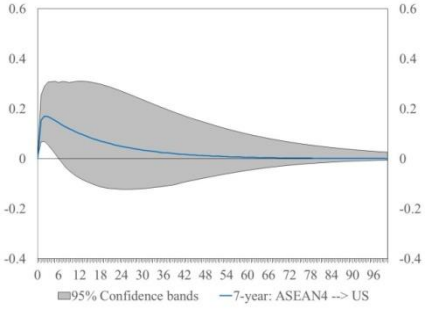
As a measure of emerging market risk, the change of VIX is significant for the domestic bonds in all PCA models. The positive coefficients mean the ASEAN-4 bond yields increased with the higher risk, representing a higher risk premium required when the emerging market risk increases.[15] The change of VIX is insignificant for the US bonds at 5% significance level except for 10-year bonds. The growth of the exchange rate index is significant for the domestic bonds in all PCA models, and it is insignificant at 5% significance level for the US bonds except the 10-year bonds. The results show that the depreciation of the ASEAN-4 currency could increase the local-currency-denoted government bond yields, suggesting that the foreign exchange policy could help to offset the impact of return spillover of the US bonds. Specifically, while depreciation of ASEAN-4 currencies leads to increase in local bond yields, appreciation could partly offset the spillover of the yield increase in the US sovereign bonds. For the results for individual countries, the results for the exogenous variables are generally consistent, but some exceptions are recorded.

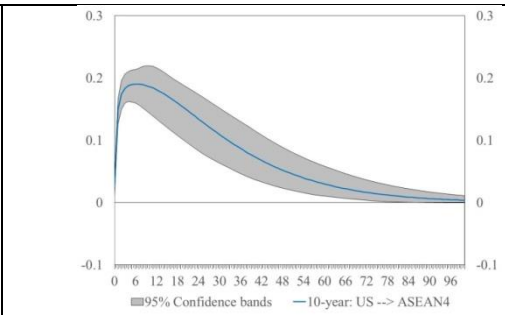
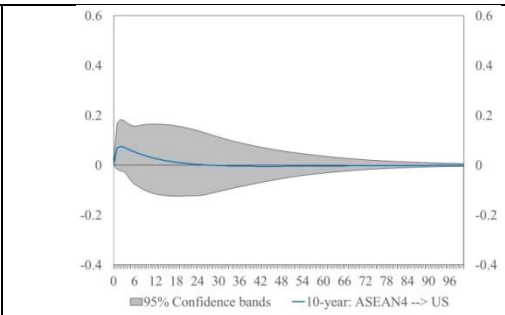
Furthermore, we also included the ASEAN-4 policy rate deviation from the US shadow Fed rate. However, it is insignificant to ASEAN-4 bonds in all models, which suggests that the

[15] The higher VIX will lower investor risk appetite which implies the tightened liquidity condition. The emerging market VIX could have the same implication, hence increases the bond yield. See CGFS (2011) and Eickmeier et al. (2013).

differentials in ASEAN-4 monetary policy against the US monetary policy did not contribute to the variation of the ASEAN-4 bonds. On the other hand, the VAR results suggest that the return spillover from the US bonds has an impact on the ASEAN-4 bond yields, which is pointing that the US monetary policy could be the main driver of the ASEAN-4 bond yields. Indeed, the US bond yields in different tenors are mainly determined by the US monetary policy through various channels (Miyajima et al., 2014), while the emerging market bonds are generally affected by the spillover of the US monetary policy (Albagli et al., 2019 and Burger et al., 2017).

Figure 3 Return Spillover: Impulse Response Functions (ASEAN-4 vs the US)

	(i) US → ASEAN-4	(ii) ASEAN-4 → US
1-year		
3-year		
5-year		
7-year		

10-year		

Notes: The exogenous variables (VIX and exchange rate) are included in the mean equations (VAR). The grey area represents 95% confidence intervals.

Figure 3 shows the impulse response functions for PCA models. Impulse response functions are consistent with the Wald test results reported in Table 3. The uni-directional return spillover exists across different tenors of government bonds, which the US bonds could affect the domestic bonds but the domestic bonds could not affect the US bonds (except 7-year ASEAN bonds affect the US bonds in the first few trading days). For the bonds of individual countries, the impulse response functions are reports in Figures A1a – A1d in Appendix. The results for individual countries are generally consistent with the PCA results that confirm the uni-directional return spillover between US bonds and ASEAN-4 bonds. However, few exceptional cases are recorded: 1-year US bonds do not affect TH & PH bonds, and 3-year US bonds are affected by ID bonds.

Comparing the impulse response functions for PCA models with and without exogenous variables, the results show that 5-, 7- and 10-year bonds have a larger impact on each other when the exogenous variables are added into the models, while 1-year bonds have a smaller impact. In most of the periods, 3-year bonds have a larger impact from the US bonds on ASEAN bonds but have a smaller impact from ASEAN bonds to the US bonds.

3.2 MGARCH-BEKK results

Then we examine the existence of the volatility spillovers between the US Treasury bonds and ASEAN-4 government bonds through the estimated MGARCH-BEKK results, in which the mean equation is the VAR models with exogenous variables presents above. Table 4 summarizes the estimates of volatility spillover coefficients (G_{12} and G_{21}) and shock spillover coefficients (A_{12} and A_{21}) for PCA models, while the estimation results for individual country bond series are shown in Table A2 in Appendix.

The results of the MGARCH-BEKK models for PCA show that there is always a uni-directional shock spillover from the US Treasury bonds to ASEAN-4 government bonds, similar to the pattern in the return spillovers. However, there are bi-directional volatility spillovers between the US Treasury bonds and ASEAN-4 government bonds. The results suggest that the ASEAN-4 government bonds are affected by the spillover effects of the US Treasury bonds in all aspects: the return, shock and volatility spillovers. On the other hand, although there is no return and shock spillovers from the ASEAN-4 government bonds, the volatility of the US Treasury bonds are also affected by the ASEAN-4 government bonds. The results for individual country bond series are generally consistent with the PCA results, although some exceptions are found in the Philippines bonds.

Table 4 Volatility Spillover (BEKK, ASEAN-4 vs the US)

	ARCH (shock)		GARCH (Volatility)	
	A_{21} (*ASEAN-4-->US*)	A_{12} (*US-->ASEAN-4*)	G_{21} (*ASEAN-4-->US*)	G_{12} (*US-->ASEAN-4*)
1-year	-0.003(0.150)	-0.015(0.002)***	8.827(0.549)***	-0.064(0.004)***
3-year	-0.244(0.156)	-0.011(0.003)***	-0.242(0.060)***	-0.002(0.000)***
5-year	0.321(0.206)	0.011(0.001)***	10.018(0.432)***	0.084(0.001)***
7-year	0.104(0.173)	0.024(0.004)***	8.567(0.387)***	-0.106(0.004)***
10-year	0.212(0.237)	-0.056(0.003)***	0.992(0.255)***	0.004(0.002)*

Notes: The exogenous variables (VIX and exchange rate) are included in the mean equations (VAR). Standard errors are in parentheses. ***, ** and * are significance at 1%, 5% and 10% levels.

3.3 DCC results

Table 5 presents the estimates of DCC models for the PCA of ASEAN-4 bond yields (the estimates for individual country series are shown in Table A3 in Appendix). The first six rows of Table 5 show that most of the estimated parameters of the univariate GARCH(1,1) models of the US Treasury bonds and the ASEAN-4 government bonds are statistically significant.

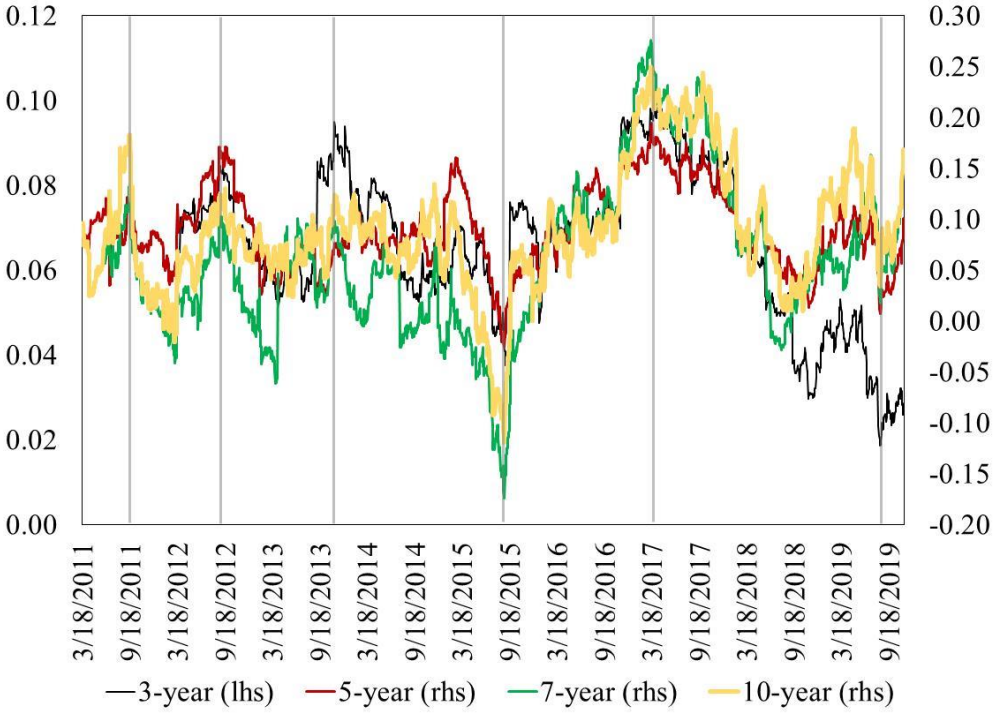
Table 5 Volatility Spillover (DCC estimates, ASEAN-4 vs the US)

	1-year	3-year	5-year	7-year	10-year
ω_{US}	0.005(0.003)	0.018(0.012)	0.017(0.011)	0.012(0.008)	0.017(0.008)**
α_{US}	0.042(0.004)***	0.047(0.008)***	0.042(0.003)***	0.036(0.003)***	0.041(0.004)***
β_{US}	0.957(0.004)***	0.952(0.008)***	0.957(0.002)***	0.963(0.001)***	0.956(0.002)***
ω_{PCA}	0.019(0.015)	0.005(0.004)	0.002(0.002)	0.024(0.011)**	0.006(0.012)
α_{PCA}	0.274(0.122)**	0.057(0.033)*	0.064(0.037)*	0.218(0.068)***	0.065(0.080)
β_{PCA}	0.534(0.262)**	0.876(0.074)***	0.916(0.061)***	0.476(0.161)***	0.858(0.214)***
a	0.015(0.016)	0.002(0.003)	0.006(0.004)	0.008(0.003)**	0.009(0.005)*
b	0.413(0.331)	0.995(0.003)***	0.984(0.009)***	0.988(0.005)***	0.985(0.008)***

Notes: The exogenous variables (VIX and exchange rate) are included in the mean equations (VAR). Standard errors are in parentheses. ***, ** and * are significance at 1%, 5% and 10% levels.

a and *b* are the coefficients for the covariance matrix. Most of them indicate high persistence in the conditional variance ($a + b > 0.5$), except 1-year bonds. Most importantly, $a + b$ are significantly different from zero (either a or b is not insignificant and $a + b > 0.2$), suggesting that the conditional covariance is time-varying. The similar results can be found in the models for individual country bond series with some exceptions.

Figure 4 Volatility Spillover: DCC (ASEAN-4 vs the US)



Notes: The vertical grey lines represent the six significant spikes, which were consistent with the market shocks: (i) mid-2011, the US fiscal cliff; (ii) mid-2012, Euro bond crisis; (iii) late 2013, Taper tantrum (iv) 2015 H2, China financial market turbulence; (v) 2017, US interest rate hike; and (vi) 2019 H2, US rate cut and US-China trade tension. Sources: Bloomberg and author calculation.

Given the time-varying conditional correlations exist, except 1-year bonds,[16] we can evaluate the change of the volatility spillovers overtime. Figure 4 depicts the time-varying conditional correlations between the US Treasury bonds and the ASEAN-4 government bonds. According to the correlation graph, the effects of the US Treasury bonds on the ASEAN-4 government bonds (the ASEAN-4 factor) varied from time to time over the sample period. Some variations show in the dynamic correlations, which could be explained by the market shocks. There are six significant spikes, and we can match them with the market shocks in the corresponding time: (i) mid-2011, the US fiscal cliff; (ii) mid-2012, Euro bond crisis; (iii) late 2013, Taper tantrum (iv) 2015 H2, China financial market turbulence; (v) 2017, US interest rate hike;[17] and (vi) 2019 H2, US rate cut and US-China trade tension. Except for 2015 H2 and 2019 H2 episodes which were mainly related to China, the volatility spillover from the US Treasury bonds to the ASEAN-4 government bonds always increased due to US or global shocks. Given the significant volatility spillover between ASEAN-4 government

[16] Lack of time-varying conditional correlation in the short tenor is due to those bonds are subject more to other short term factors not related to fundamentals or policy but e.g. market speculation.

[17] The 2017 episode for increased volatility spill-over/correlation could be a fallout of the US election results, supplementary to the interest rate hike. The Fed raised the Fed Fund target rate continuously between Dec 2016 and Dec 2018 (total 8 times). At the same time, the US yields had a jump during late 2016 to early 2017. This US yields move-up partly reflected the expectations of large fiscal spending and on the other hand there were outflows from emerging markets which led to rise in emerging bond yields as well. Lot of rebalancing happened between emerging markets and developed markets bond markets due to the rising US yields. Fed rate hikes were pretty much in the price even before the elections.

bonds with the US counterpart, the correlation of two markets increases for the shocks originated from the US but decreases for the shocks originated from China that only affects the ASEAN-4 but not for the US. Similar correlation graphs for the individual country bond series are shown in Figure A2 in Appendix.

IV. Conclusion

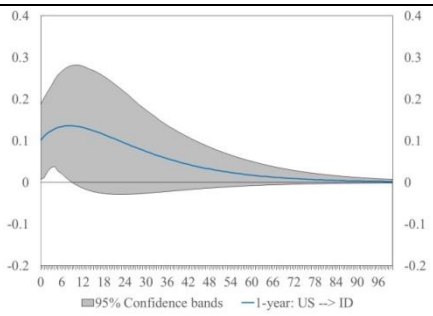
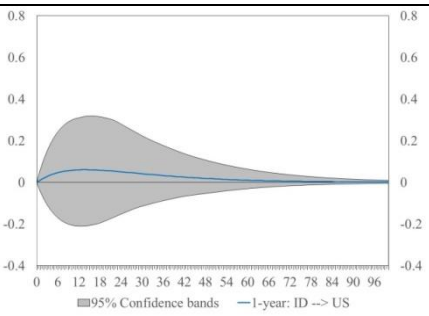
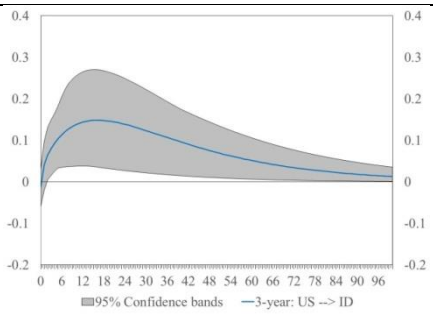
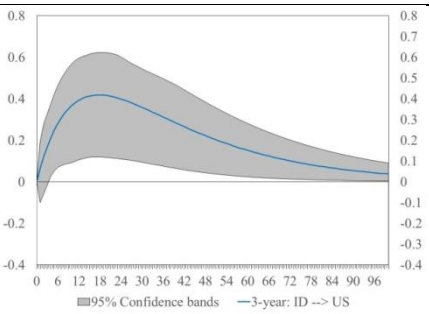
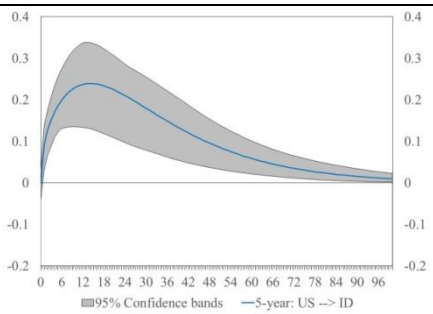
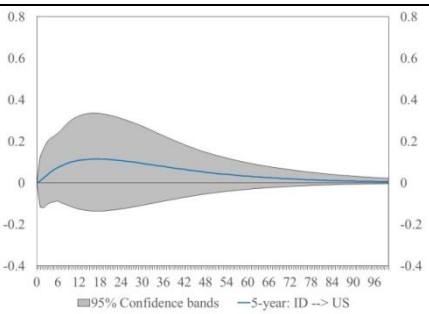
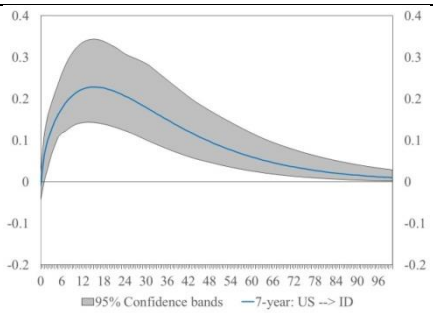
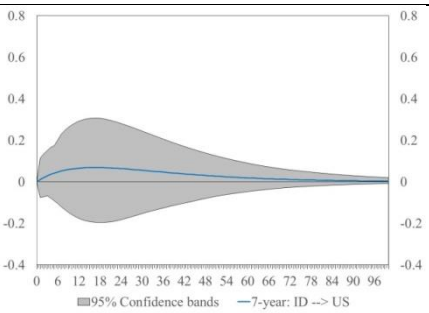
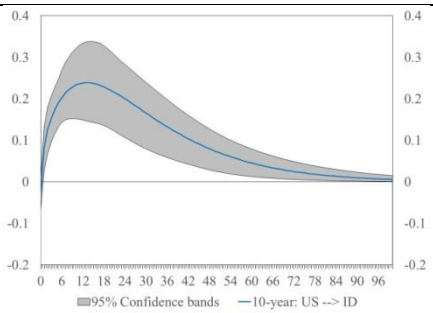
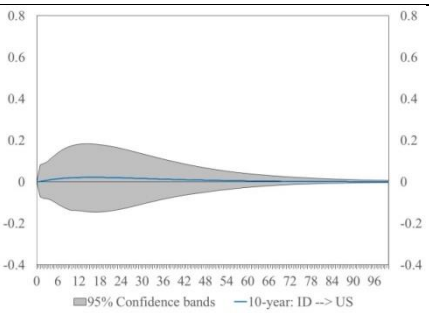
The paper provides empirical evidence for spillovers across sovereign bond markets between the US and ASEAN-4. At the mean level, the VAR results show that own bond yields are very persistent, while the US treasury yields do have return spillovers to ASEAN-4. However, the spillovers are uni-directional, while there is no spillover in the other direction. At the volatility level, the MGARCH-BEKK results confirm the bi-direction of volatility spillovers but the uni-direction of shock spillover. Furthermore, DCCs show interesting patterns over time—the volatility increased together with the shocks originated from the US or other advanced economies. Also, the two significant exogenous variables (VIX for the emerging markets and exchange rate) in the VAR models provide further recommendations for policymakers.

For the policy considerations, the results of this paper suggest that the regional policymakers have to beware of the spillovers in mean level (return) as well as in volatility level. Given the linkage between the US monetary policy and the US Treasury bonds, the policymakers should beware of the adverse spillover of the unwinding of QE and interest rate normalization in the US in the medium-to-long term on both the returns of ASEAN sovereign bonds and quantity of foreign investment on ASEAN sovereign bonds. On the other hand, the significance of VIX (COBE, EMEs) in the VAR models shows that ASEAN-4 government bond yields increase with a higher global risk, suggesting the need to keep the house in good order. Finally, the significance of the exchange rate indicates that it can act as a buffer to reduce spillover.

This paper also provides suggestions for future research. It shows that the correlations in volatility varied over time. Although we have matched the spikes in the correlations with the market shocks in the corresponding times, the factors explaining the development could be further explored in future research. In order to mitigate the adverse impact of the COVID-19 pandemic, the US Fed has implemented unlimited quantitative easing while ASEAN governments have issued much more sovereign bonds to finance their large fiscal stimulus packages. To what extent should the spillover of the US unlimited quantitative easing affecting the regional financial markets and macroeconomy be a concern to the ASEAN-4 policymakers? Future research on the spillover and its impact could be conducted by using the results of the spillovers from the US in this paper. Last but not least, besides the spillovers in the government bond markets, the spillovers between the US and ASEAN-4 taking into account the inter-relationships among different bonds and different financial markets, including bond market, foreign exchange market, stock market and derivatives market could be studied in the future.

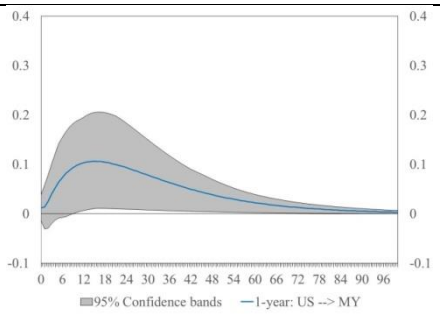
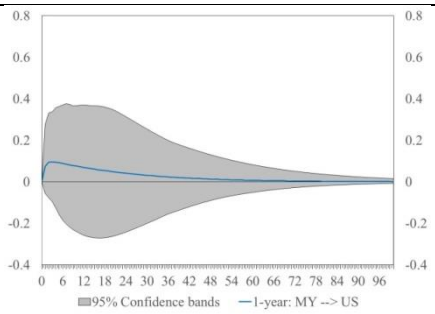
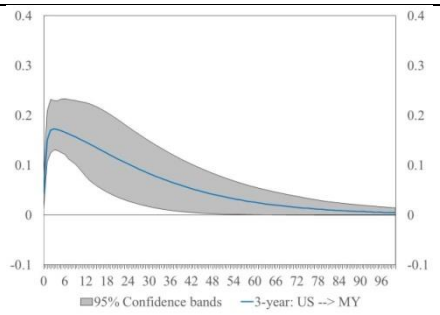
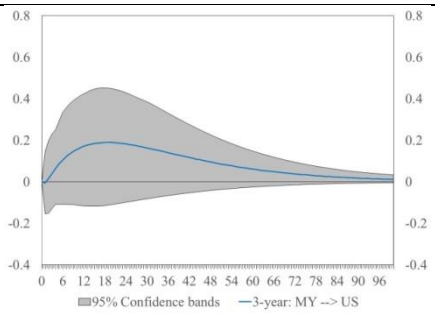
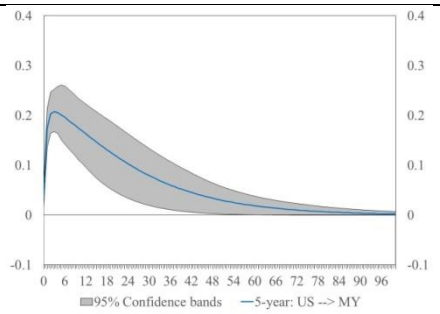
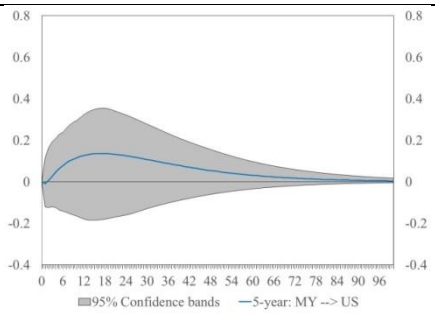
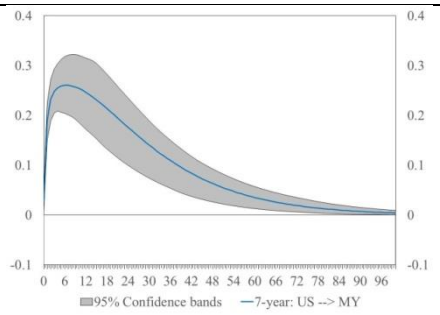
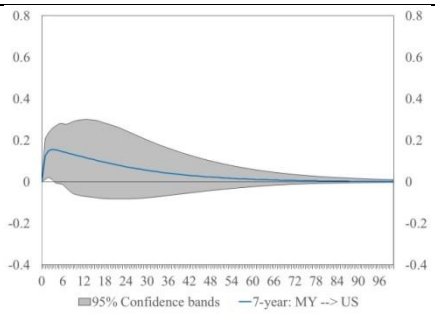
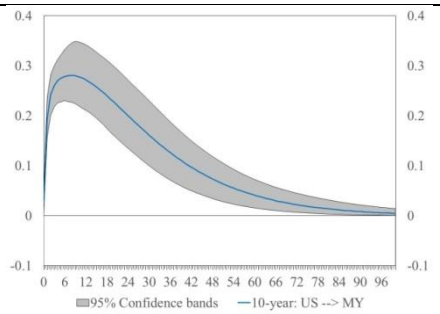
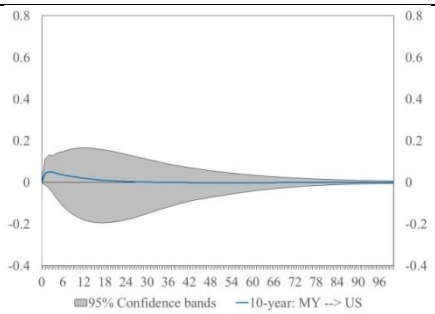
Appendix

Figure A1a Return Spillover: Impulse Response Functions (Indonesia vs the US)

	(i) US → Indonesia	(ii) Indonesia → US
1-year		
3-year		
5-year		
7-year		
10-year		

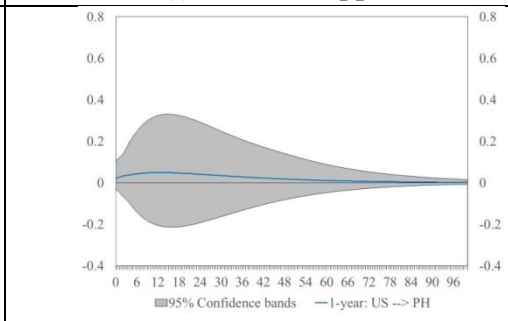
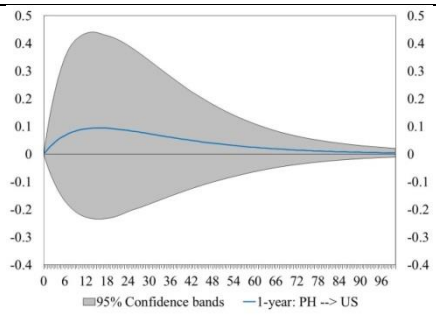
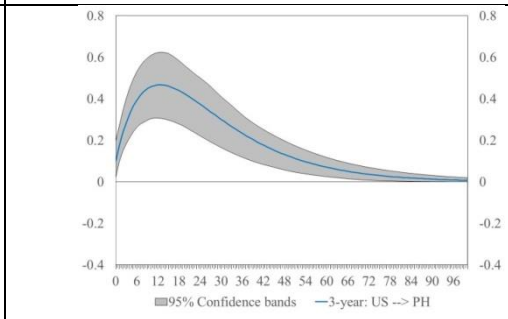
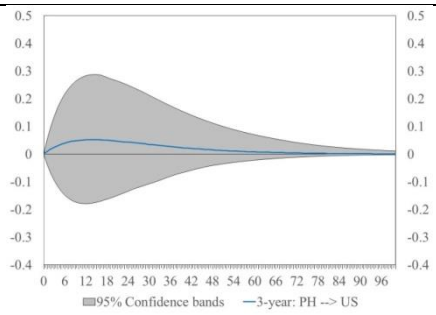
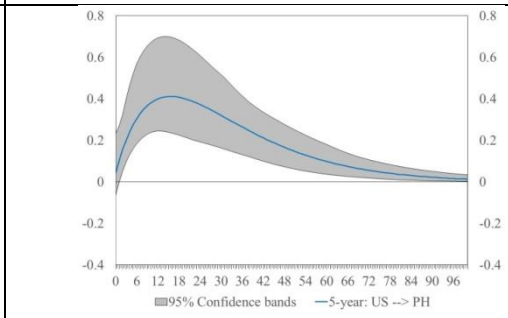
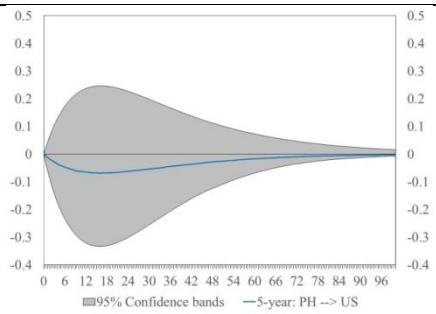
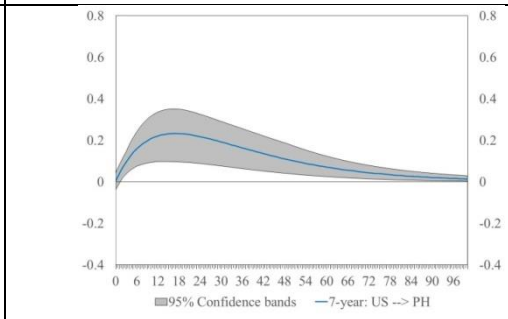
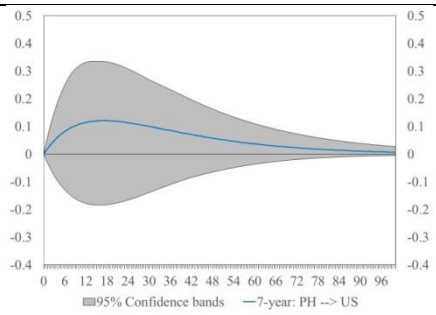
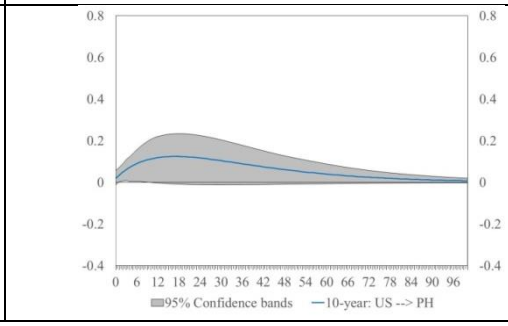
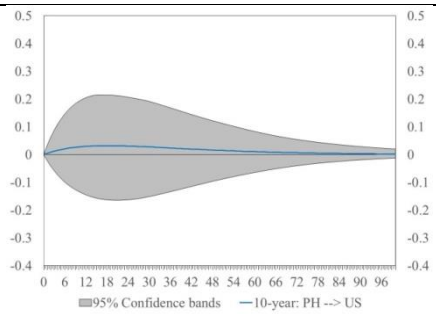
Notes: The exogenous variables (VIX and exchange rate) are included in the mean equations (VAR). The grey area represents 95% confidence intervals.

Figure A1b Return Spillover: Impulse Response Functions (Malaysia vs the US)

	(i) US → Malaysia	(ii) Malaysia → US
1-year		
3-year		
5-year		
7-year		
10-year		

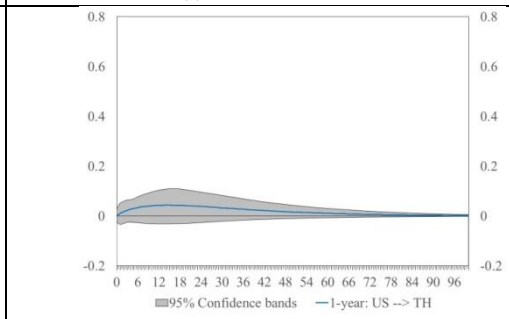
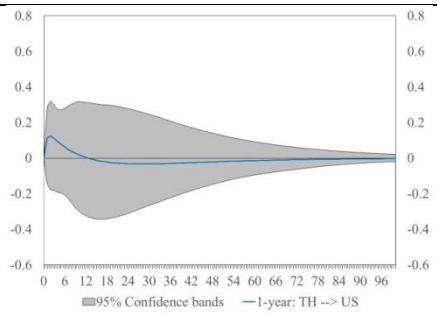
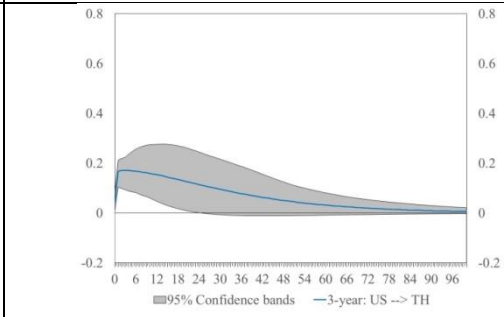
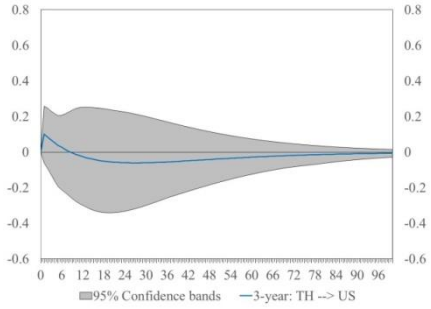
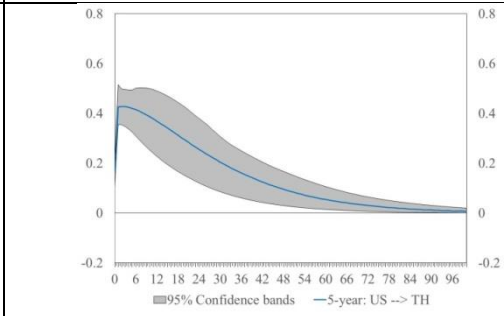
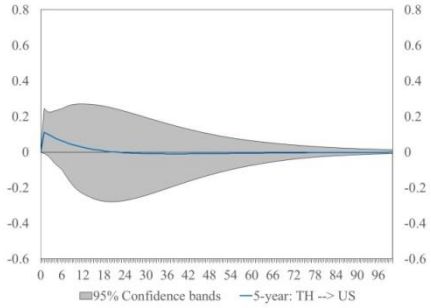
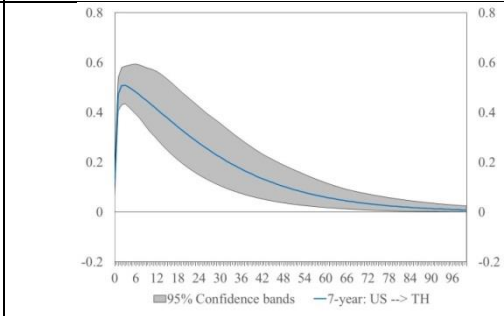
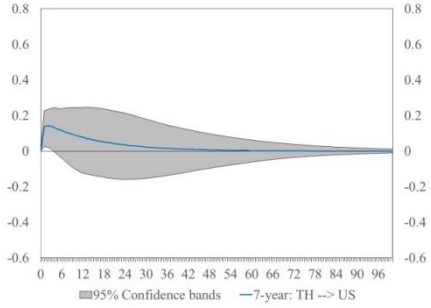
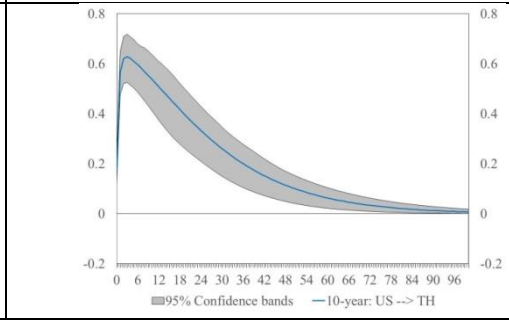
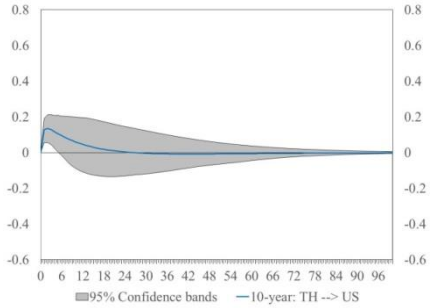
Notes: The exogenous variables (VIX and exchange rate) are included in the mean equations (VAR). The grey area represents 95% confidence intervals.

Figure A1c Return Spillover: Impulse Response Functions (the Philippines vs the US)

	(i) US → Philippines	(ii) Philippines → US
1-year		
3-year		
5-year		
7-year		
10-year		

Notes: The exogenous variables (VIX and exchange rate) are included in the mean equations (VAR). The grey area represents 95% confidence intervals.

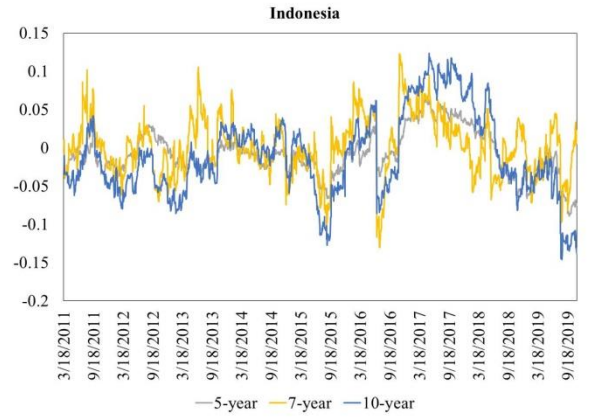
Figure A1d Return Spillover: Impulse Response Functions (Thailand vs the US)

	(i) US → Thailand	(ii) Thailand → US
1-year		
3-year		
5-year		
7-year		
10-year		

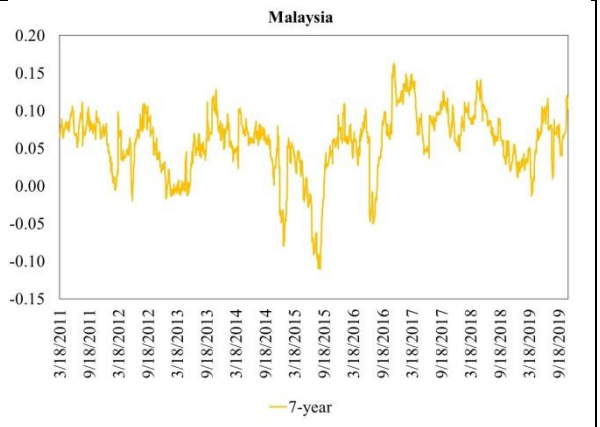
Notes: The exogenous variables (VIX and exchange rate) are included in the mean equations (VAR). The grey area represents 95% confidence intervals.

Figure A2 Volatility Spillover: DCC (Individual Countries vs the US)

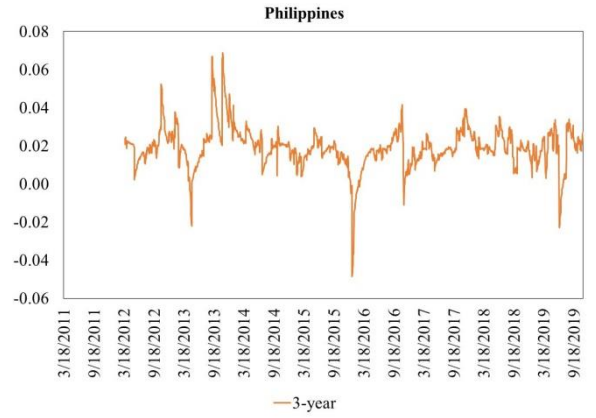
Indonesia vs the US



Malaysia vs the US



The Philippines vs the US



Thailand vs the US

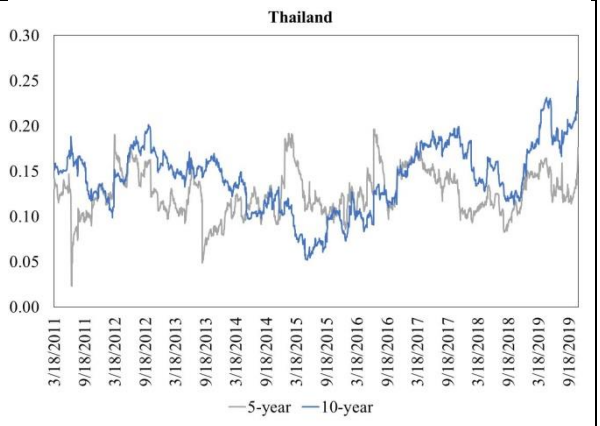


Table A1 Return Spillover (VAR, Individual Countries vs the US)

(a) Indonesia vs the US

	Endogenous variables		Exogenous variables	
	Indonesia bond returns	**US bond returns**	**VIX**	**Exchange rate**
1-year tenor				
Indonesia bond returns	0.946(0.007)***	0.003(0.003)	0.067(0.025)***	30.666(7.535)***
US bond returns	0.005(0.017)	0.914(0.009)***	0.071(0.064)	2.358(19.196)
3-year tenor				
Indonesia bond returns	0.967(0.005)***	0.005(0.002)***	0.072(0.012)***	14.792(3.546)***
US bond returns	0.058(0.022)***	0.926(0.008)***	0.061(0.054)	4.253(16.287)
5-year tenor				
Indonesia bond returns	0.956(0.005)***	0.009(0.002)***	0.064(0.012)***	16.586(3.572)***
US bond returns	0.017(0.019)	0.935(0.008)***	0.059(0.045)	-4.327(13.380)
7-year tenor				
Indonesia bond returns	0.957(0.005)***	0.010(0.003)***	0.071(0.012)***	16.657(3.568)***
US bond returns	0.010(0.016)	0.938(0.008)***	0.060(0.037)	-7.165(11.049)
10-year tenor				
Indonesia bond returns	0.947(0.006)***	0.014(0.003)***	0.095(0.013)***	12.083(3.999)***
US bond returns	0.004(0.013)	0.941(0.008)***	0.068(0.031)**	-6.713(9.212)

(b) Malaysia vs US

	Endogenous variables		Exogenous variables	
	Malaysia bond returns	**US bond returns**	**VIX**	**Exchange rate**
1-year tenor				
Malaysia bond returns	0.964(0.005)***	0.003(0.001)*	0.020(0.010)*	32.630(3.726)***
US bond returns	0.011(0.030)	0.913(0.009)***	0.073(0.064)	16.283(23.018)
3-year tenor				
Malaysia bond returns	0.963(0.005)***	0.003(0.001)**	0.030(0.009)***	15.949(3.377)***
US bond returns	0.035(0.030)	0.930(0.008)***	0.052(0.054)	17.044(19.744)
5-year tenor				
Malaysia bond returns	0.951(0.006)***	0.005(0.002)***	0.031(0.008)***	17.538(2.990)***
US bond returns	0.031(0.030)	0.934(0.008)***	0.055(0.045)	7.610(16.152)
7-year tenor				
Malaysia bond returns	0.948(0.006)***	0.011(0.002)***	0.032(0.009)***	17.923(3.064)***
US bond returns	0.024(0.024)	0.934(0.009)***	0.058(0.037)	-9.558(13.410)
10-year tenor				
Malaysia bond returns	0.948(0.006)***	0.014(0.002)***	0.033(0.009)***	15.965(3.021)***
US bond returns	0.005(0.020)	0.940(0.008)***	0.068(0.031)**	-4.565(10.869)

(c) The Philippines vs the US

	Endogenous variables		Exogenous variables	
	Philippine bond returns	**US bond returns**	**VIX**	**Exchange rate**
1-year tenor				
Philippine bond returns	0.956(0.007)***	0.001(0.005)	-0.034(0.040)	-22.835(18.312)
US bond returns	0.007(0.012)	0.917(0.009)***	0.099(0.074)	-27.559(33.817)
3-year tenor				
Philippine bond returns	0.935(0.008)***	0.022(0.004)***	0.000(0.031)	-14.732(14.223)
US bond returns	0.006(0.015)	0.923(0.009)***	0.083(0.060)	36.460(27.850)
5-year tenor				
Philippine bond returns	0.946(0.007)***	0.020(0.005)***	0.052(0.030)*	3.115(15.937)
US bond returns	-0.005(0.010)	0.935(0.008)***	0.081(0.044)*	-5.230(22.931)
7-year tenor				
Philippine bond returns	0.948(0.007)***	0.013(0.004)***	0.022(0.018)	15.129(9.340)
US bond returns	0.015(0.014)	0.935(0.008)***	0.080(0.036)**	-10.260(19.273)
10-year tenor				
Philippine bond returns	0.951(0.007)***	0.008(0.004)*	0.028(0.017)	31.396(9.193)***
US bond returns	0.004(0.011)	0.940(0.007)***	0.079(0.029)***	-19.381(15.416)

(d) Thailand vs US

	Endogenous variables		Exogenous variables	
	Thailand bond returns	**US bond returns**	**VIX**	**Exchange rate**
1-year tenor				
Thailand bond returns	0.968(0.005)***	0.001(0.001)	-0.005(0.008)	1.286(4.401)
US bond returns	-0.004(0.038)	0.912(0.009)***	0.094(0.065)	-42.388(35.444)
3-year tenor				
Thailand bond returns	0.960(0.006)***	0.004(0.002)*	0.014(0.016)	27.036(8.246)***
US bond returns	-0.007(0.021)	0.934(0.008)***	0.076(0.055)	-50.201(29.366)*
5-year tenor				
Thailand bond returns	0.947(0.007)***	0.012(0.003)***	0.065(0.018)***	34.211(9.508)***
US bond returns	0.001(0.017)	0.936(0.008)***	0.072(0.046)	-39.143(24.025)
7-year tenor				
Thailand bond returns	0.954(0.006)***	0.014(0.004)***	0.044(0.019)**	28.440(9.759)***
US bond returns	0.006(0.012)	0.937(0.008)***	0.071(0.038)*	-39.394(19.755)**
10-year tenor				
Thailand bond returns	0.951(0.006)***	0.021(0.005)***	0.047(0.018)***	44.853(9.250)***
US bond returns	0.003(0.011)	0.938(0.009)***	0.077(0.031)**	-38.951(16.124)**

Notes: Bond returns are bond yields that expressed in terms of percentage deviations from Hodrick-Prescott (HP) trends. VIX is the CBOE Emerging Markets ETF Volatility Index (VXEEMCLS). The exchange rate is an equal-weight averaged index of 4 currencies. Wald tests of the coefficients (sum of all lags, if more than one lag is used) are based on the Chi-squared statistics. Standard errors are in parentheses. ***, ** and * are significance at 1%, 5% and 10% levels.

Table A2 Volatility Spillover (BEKK, Individual Countries vs the US)

(a) Indonesia vs the US

	ARCH (shock)		GARCH (Volatility)	
	A_{21} (*Indonesia-->US*)	A_{12} (*US--> Indonesia*)	G_{21} (*Indonesia-->US*)	G_{12} (*US--> Indonesia*)
1-year	-0.064(0.045)	-0.010(0.006)*	0.076(0.184)	0.012(0.004)***
3-year	-0.054(0.160)	0.036(0.010)***	4.051(0.126)***	-0.197(0.005)***
5-year	-0.018(0.079)	-0.008(0.006)	0.038(0.043)	0.000(0.002)
7-year	-0.173(0.067)***	-0.014(0.006)**	1.694(0.444)***	0.179(0.043)***
10-year	-0.007(0.019)	-0.004(0.010)	0.242(0.100)***	0.020(0.017)

(b) Malaysia vs US

	ARCH (shock)		GARCH (Volatility)	
	A_{21} (*Malaysia-->US*)	A_{12} (*US--> Malaysia*)	G_{21} (*Malaysia-->US*)	G_{12} (*US--> Malaysia*)
1-year	-0.015(0.040)	-0.005(0.003)	-0.018(0.121)	-0.008(0.006)
3-year	0.238(0.090)***	0.037(0.005)***	3.243(0.092)***	-0.087(0.003)***
5-year	0.000(0.065)	0.017(0.005)***	-0.017(0.184)	0.019(0.006)***
7-year	-0.420(0.068)***	-0.073(0.005)***	4.334(0.073)***	0.183(0.001)***
10-year	-0.126(0.077)	0.051(0.009)***	3.661(0.099)***	-0.252(0.007)***

(c) The Philippines vs US

	ARCH (shock)		GARCH (Volatility)	
	A_{21} (*Philippines-->US*)	A_{12} (*US--> Philippines*)	G_{21} (*Philippines-->US*)	G_{12} (*US--> Philippines*)
1-year	0.007(0.017)	0.001(0.002)	-0.007(0.018)	0.000(0.001)
3-year	-0.473(0.163)***	0.167(0.009)***	0.126(0.037)***	-0.021(0.006)***
5-year	0.178(0.127)	-0.100(0.004)***	0.138(0.119)	0.008(0.015)
7-year	0.095(0.080)	-0.040(0.003)***	-0.060(0.053)	-0.002(0.004)
10-year	-0.058(0.061)	0.011(0.005)***	0.042(0.045)	0.002(0.005)

(d) Thailand vs US

	ARCH (shock)		GARCH (Volatility)	
	A_{21} (*Thailand-->US*)	A_{12} (*US--> Thailand*)	G_{21} (*Thailand-->US*)	G_{12} (*US--> Thailand*)
1-year	-0.073(0.153)	-0.002(0.002)	0.066(0.142)	-0.003(0.003)
3-year	-0.093(0.115)	0.028(0.008)***	2.889(0.070)***	-0.274(0.008)***
5-year	-0.049(0.040)	0.094(0.017)***	0.089(0.032)***	-0.010(0.004)***
7-year	-0.266(0.053)***	0.116(0.012)***	0.161(0.031)***	-0.012(0.007)*
10-year	0.098(0.034)***	0.025(0.017)	-1.312(0.039)***	0.429(0.013)***

Notes: The exogenous variables (VIX and exchange rate) are included in the mean equations (VAR). Standard errors are in parentheses. ***, ** and * are significance at 1%, 5% and 10% levels.

Table A3 Volatility Spillover (DCC estimates, Individual Countries vs the US)

(a) Indonesia vs the US

	1-year	3-year	5-year	7-year	10-year
w_{US}	0.006(0.004)	0.019(0.013)	0.018(0.011)	0.015(0.009)	0.017(0.009)**
a_{US}	0.044(0.004)***	0.048(0.007)***	0.042(0.003)***	0.041(0.003)***	0.041(0.004)***
b_{US}	0.955(0.003)***	0.951(0.007)***	0.957(0.002)***	0.958(0.002)***	0.956(0.002)***
w_{ID}	0.114(0.052)**	0.020(0.009)**	0.073(0.024)***	0.017(0.012)	0.023(0.016)
a_{ID}	0.191(0.042)***	0.134(0.037)***	0.398(0.109)***	0.139(0.053)***	0.131(0.053)**
b_{ID}	0.808(0.036)***	0.851(0.036)***	0.577(0.087)***	0.853(0.058)***	0.851(0.063)***
a	0.012(0.017)	0.004(0.017)	0.003(0.004)	0.010(0.006)	0.006(0.004)
b	0.283(0.178)	0.573(0.175)***	0.991(0.004)***	0.957(0.044)***	0.989(0.006)***

(b) Malaysia vs US

	1-year	3-year	5-year	7-year	10-year
w_{US}	0.005(0.003)	0.019(0.013)	0.018(0.011)	0.015(0.009)	0.017(0.009)**
a_{US}	0.042(0.004)***	0.045(0.005)***	0.042(0.003)***	0.041(0.003)***	0.042(0.004)***
b_{US}	0.957(0.003)***	0.954(0.004)***	0.957(0.002)***	0.958(0.002)***	0.956(0.003)***
w_{MY}	0.023(0.019)	0.022(0.015)	0.047(0.018)***	0.041(0.015)***	0.024(0.008)***
a_{MY}	0.135(0.080)*	0.128(0.050)**	0.294(0.090)***	0.316(0.099)***	0.290(0.075)***
b_{MY}	0.829(0.106)***	0.834(0.071)***	0.591(0.112)***	0.625(0.093)***	0.695(0.063)***
a	0.024(0.019)	0.000(0.013)	0.006(0.010)	0.009(0.007)	0.000(0.009)
b	0.000(0.419)	0.199(1.177)	0.797(0.083)***	0.973(0.031)***	0.664(1.846)

(c) The Philippines vs US

	1-year	3-year	5-year	7-year	10-year
w_{US}	0.005(0.003)	0.013(0.009)	0.018(0.011)	0.013(0.008)	0.018(0.009)**
a_{US}	0.041(0.004)***	0.034(0.003)***	0.042(0.003)***	0.037(0.003)***	0.042(0.004)***
b_{US}	0.958(0.003)***	0.965(0.002)***	0.957(0.002)***	0.962(0.001)***	0.955(0.003)***
w_{PH}	0.001(0.484)	0.005(0.178)	0.012(0.468)	0.004(2.939)	0.002(0.073)
a_{PH}	0.068(26.245)	0.016(0.590)	0.223(8.455)	0.040(14.817)	0.047(2.089)
b_{PH}	0.791(308.472)	0.956(24.624)	0.753(16.978)	0.887(26.541)	0.881(25.467)
a	0.000(0.004)	0.005(0.033)	0.002(0.014)	0.000(0.010)	0.001(0.013)
b	0.830(10.831)	0.945(1.004)	0.598(0.046)***	0.560(0.088)***	0.705(0.254)***

(d) Thailand vs US

	1-year	3-year	5-year	7-year	10-year
w_{US}	0.006(0.004)	0.020(0.013)	0.017(0.011)	0.015(0.009)	0.017(0.009)**
a_{US}	0.044(0.004)***	0.047(0.007)***	0.042(0.003)***	0.040(0.003)***	0.041(0.004)***
b_{US}	0.955(0.004)***	0.952(0.007)***	0.957(0.002)***	0.959(0.002)***	0.956(0.002)***
w_{TH}	0.092(0.692)	0.033(0.017)*	0.168(0.162)	0.616(0.361)*	0.033(0.019)*
a_{TH}	0.692(1.529)	0.036(0.015)**	0.111(0.081)	0.649(0.612)	0.059(0.019)***
b_{TH}	0.307(2.119)	0.939(0.017)***	0.780(0.173)***	0.263(0.252)	0.924(0.025)***
a	0.042(0.023)*	0.009(0.042)	0.005(0.007)	0.030(0.016)*	0.004(0.002)
b	0.179(0.160)	0.000(4.878)	0.973(0.034)***	0.475(0.727)	0.994(0.003)***

Notes: The exogenous variables (VIX and exchange rate) are included in the mean equations (VAR). Standard errors are in parentheses. ***, ** and * are significance at 1%, 5% and 10% levels.

References

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