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On the Transmission Mechanism of Asia-Pacific Yield Curve Characteristics

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Abstract

This study investigates the transmission mechanism of Asia-Pacific sovereign bond yields. Sovereign bond yields are decomposed into three latent factors (level, slope and curvature) using the Dynamic Nelson Siegel procedure proposed by Diebold and Li (2006). The yield curve transmission mechanism is examined using the time-varying parameter vector autoregressive (TVP-VAR) connectedness approach a la Antonakakis and Gabauer (2017). Findings suggest that the level factor interconnectedness is constantly higher than the interconnectedness of the slope and curvature factor. Notably, the slope factor interconnectedness strongly increased after the Global Financial Crisis (2009) illustrating the increased importance of short-term movements.

Keywords: TVP-VAR; Dynamic Connectedness; Yield Curve Decomposition; Yield Curve Spillovers.
JEL codes: C32; C5; G12; G15

1 Introduction

In the 1990s, the Asian Financial Crisis (1997) drew attention of policymakers to stabilize local bond markets in order to reduce the risk emerging from interest rate maturity mismatches. Since then various measures (such as Asian Bond markets initiative and ASEAN +3 Bond market forum) were developed to improve the stability of the local bond market. After these initiatives, the growth of the Asian bond market has become remarkable. The total size of the Asian local bond market has increased from approximately 5,357 USD billions to 23,251 USD billions in 2018. Holmes et al. (2011) find that the financial liberalization and opennesss in Asia-Pacific financial markets influenced the interest rate term structure substantially. Especially, the increased integration and elimination of capital controls led to the convergence of bond yields. In that respect, convergence can be associated with high correlation across long and short-term yield rates which can is assumed by the expectation hypothesis. The expectation hypothesis of the term structure of interest rates is a simple and appealing theory that is postulating the relationship between short-term and long-term interest rates. Intuitively speaking, it assumes that the arithmetic average of the current and expected short-term interest rate should be equal to the long-term interest rate. This theoretical relationship is essential for monetary policy interventions since changes in the monetary policy interest rate has an direct impact on the maturity spectrum of interest rates which in turn influence consumer behavior and investment decisions. However, even if this theory seems quite persuasive it lacks in its empirical support. The majority of research is rejecting the expectation hypothesis (Campbell and Shiller, 1991; Sarno et al., 2007). In particular, Hardouvelis (1994) show deviations of the G7 long-term yield rates. This finding is supported by Sutton (2000), who explain that the rejection of the expectation hypothesis is due to excess global bond yield fluctuations. Furthermore, they provide evidence that term premia in the long-term are influenced by international factor and that the degree of integration differs across the maturities. Hence, co-movements across international bond yields have essential implications on monetary policy actions, interest rate forecasts and portfolio diversification strategies. Early research studied the dynamics of term structure of interest rate in the closed economies, ignoring the international influence on the domestic term structure (Holmes et al., 2011). However, the recent increase in globalization and financial openness in financial markets worldwide has substantial influence on yield curves. In Kumar and Okimoto (2011), the integration of G7 short and long-term yields is analyzed which imply that short-term interest rates are determined by domestic monetary policy, while long-term interest rates are more influenced by global financial conditions. This is in-line with Jain-Chandra and Unsal (2014), who investigated the Asian bond market and find that long-term interest rates are influenced by global factors whereas short-term interest rates are driven by domestic monetary policy. Given this context, it is essential to examnie the transmission mechanism of sovereign bond yields. On another note, Litterman and Scheinkman (1991) find common factors for level, slope and curvature that are explaining the variation in bond yields nand hence the shape of the yield curve. Notably, Jaramillo and Weber (2013) find that yield factor vulnerability in emerging economies are not uniform across countries. For instance, Yang (2005) analyze the bond market linkages across five industrialized economies (US, Japan, Germany and Canada) and highlight that the UK and German bond market are influenced by movements of US bond yields while Japanese yield rates are found to be rather exogenous. A more torough analysis by Vo (2009) examine bond market integration between Asian and developed countries and find that Asian countries in general do not have a high degree of integration with the US market.

Thus, this study aims to analyze the time-varying interdependencies in the Asia-Pacific sovereign bond yields at various maturity spectrums. The yield curves of Asia-Pacific economies are decomposed into three latent factors which are, level, slope and curvature using the dynamic Nelson Siegel model as proposed by (Diebold and Li, 2006). The level factor represents long-term yield rates, whereas the slope illustrates short-term yield rates and finally the curvature stands for medium-term yield rates. The dynamic interdependencies across those latent factors are captured by a TVP-VAR connectedness framework (Antonakakis and Gabauer, 2017). This TVP-VAR connectedness approach can be seen as an alternative to the popular rolling-window method of Diebold and Yılmaz (2014) which has been used widely to analyze propagation mechanism across variables over time. However, the time-varying structure of the parameters advances the initially introduced methodology substantially, since (i) there is no need to arbitrarily choose a rolling window-size, (ii) there is no loss of observations which in turn allows analyzing low-frequency data, and finally, (iii) the estimator is not as outlier-sensitive as the rolling-window VAR. Hence, choosing this procedures to analyze the interest rate dynamics seems to be appropriate. To the best of our knowledge, the investigation of various interest rate characteristics using this analytical structure is novel to the literature which in fact results in the support of already well-established linkages and in novel insights in the time-varying transmission mechanisms of the aforementioned linkages.

This study provides evidence that the level factor interconnectedness is relatively high compared to the interconnectedness of the slope and curvature factor whereas the medium-term factor exhibits the least linkages. Australia and Singapore are found to the dominant net transmitters of level factor and slope factor shocks. The trade linkages and similarities in financial characteristic indicate to be of major importance for the slope factor interconnectedness. Finally, results suggest that the influence of Japanese bond yields seems to be minimal in the Asia-Pacific sovereign bond markets.

The remainder of this study is organized as follows. Section 2 outlines the employed dataset and the applied statistical framework. Section 4 illustrates the empirical results of the yield curve transmission mechanisms, and finally, Section 5 concludes this study.

2 Methodology

2.1 Dynamic Nelson Siegel Model

The model introduced by Nelson and Siegel (1987) is expressed as a function that decomposes the large set of yields into small unobserved factors. These factors are capable of capturing the various shapes of the yield curve such as the level, slope and curvature. Central banks and practitioners increasingly using this model to estimate the cross-section of yields at a given point in time. The yield curve representation of the Dynamic Nelson Siegel model is given by VAR model in its state space form which can be written as follows:

$$
\begin{aligned}
\boldsymbol{z}_t(\boldsymbol{\tau}) &= \begin{pmatrix} 1 & \left(\frac{1-exp(-\lambda\tau_1)}{\lambda\tau_1}\right) & \left(\frac{1-exp(\lambda\tau_1)}{\lambda\tau_1} - exp(-\lambda\tau_1)\right) \\ 1 & \left(\frac{1-exp(-\lambda\tau_2)}{\lambda\tau_2}\right) & \left(\frac{1-exp(\lambda\tau_2)}{\lambda\tau_2} - exp(-\lambda\tau_2)\right) \\ \vdots & \vdots & \vdots \\ 1 & \left(\frac{1-exp(-\lambda\tau_m)}{\lambda\tau_m}\right) & \left(\frac{1-exp(\lambda\tau_m)}{\lambda\tau_m} - exp(-\lambda\tau_m)\right) \end{pmatrix} \boldsymbol{y}_t + \boldsymbol{u}_t \qquad \boldsymbol{u}_t \sim N(\boldsymbol{0}, \boldsymbol{R}) \\
\tilde{\boldsymbol{x}}_t &= \boldsymbol{\Gamma}\tilde{\boldsymbol{x}}_{t-1} + \boldsymbol{\eta}_t \qquad \boldsymbol{\eta}_t \sim N(\boldsymbol{0}, \boldsymbol{G})
\end{aligned}
$$

where $\boldsymbol{z}_t(\boldsymbol{\tau})$ and $\boldsymbol{u}_t$ represent $m \times 1$ dimensional vectors for yield rates with given maturities and error terms, respectively. The coefficient matrix in the measurement equation is following the structure introduced by Nelson and Siegel (1987). $\boldsymbol{x}_t = [L_t, S_t, C_t]$ is an 3×1 dimensional vector and comprises the yield rate shape parameters which are time varying-parameters. L_t stands for the level factor representing the long-term yield rates, S_t represents the slope factor representing the short-term yield rates and C_t is the curvature factor representing the medium-term yield rates. Continuing with the transition equation, $\tilde{\boldsymbol{x}}_t = \boldsymbol{x}_t - \bar{\boldsymbol{x}}_t$ is the demeaned time-varying shape parameter vector $\boldsymbol{x}_t$ where the 3×3 dimensional coefficient matrix $\boldsymbol{\Gamma}$ illustrates the dynamic relationship across the shape parameters. $\boldsymbol{\eta}_t$ is a 3×1 dimensional error vector which is assumed to be independent from $\boldsymbol{u}_t$. Furthermore, $\boldsymbol{G}$ is an $m \times m$ dimensional diagonal matrix and $\boldsymbol{R}$ is a 3×3 dimensional variance-covariance matrix, allowing the latent factors to be correlated.[1]

2.2 TVP-VAR Connectedness Approach

To investigation the transmission mechanism of yield curve characteristics, a TVP-VAR connectedness framework (Antonakakis and Gabauer, 2017) is applied. It extends the connectedness approach of Diebold and Yılmaz (2014) by a TVP-VAR structure (Koop and Korobilis, 2014) to overcome the burden of (i) an arbitrarily chosen rolling-window size, which causes highly volatile or flattened parameters, (ii) losing observations and (iii) outlier sensitivity (Antonakakis and Gabauer, 2017; Korobilis and Yilmaz, 2018). According to the Bayesian information criterion (BIC) a VAR lag length of order one should be used. Thus, employed TVP-VAR(1) can be written down mathematically as,

$$\boldsymbol{y}_t = \boldsymbol{\Phi}_t \boldsymbol{y}_{t-1} + \boldsymbol{\epsilon}_t \qquad \boldsymbol{\epsilon}_t | \boldsymbol{I}_{t-1} \sim N(\boldsymbol{0}, \boldsymbol{\Sigma}_t) \tag{1}$$

$$vec(\boldsymbol{\Phi}_t) = vec(\boldsymbol{\Phi}_{t-1}) + \boldsymbol{\xi}_t \qquad \boldsymbol{\xi}_t | \boldsymbol{I}_{t-1} \sim N(\boldsymbol{0}, \boldsymbol{\Xi}_t) \tag{2}$$

where $\boldsymbol{I}_{t-1}$ constitutes the information available until $t-1$, $\boldsymbol{y}_t$, $\boldsymbol{\epsilon}_t$ and $\boldsymbol{y}_{t-1}$ represent $m\times1$, $m\times1$ and $m \times 1$ vectors, respectively, and $\boldsymbol{\Phi}_t$ and $\boldsymbol{\Sigma}_t$ are $m \times m$ and $m \times m$ dimensional matrices, respectively. Furthermore, $vec(\boldsymbol{\Phi}_t)$ and $\boldsymbol{\xi}_t$ are $m^2 \times 1$ dimensional vectors and $\boldsymbol{\Xi}_t$ is an $m^2 \times m^2$ dimensional matrix.

Since the connectedness approach by Diebold and Yılmaz (2014) rests on the generalized forecast error variance decompositions (GFEVD) developed by Koop et al. (1996) and Pesaran and Shin (1998) the TVP-VAR has to be transformed to its vector moving average (VMA) representation by $\boldsymbol{y}_t = \sum_{i=1}^{p} \boldsymbol{\Phi}_{it} \boldsymbol{y}_{t-i} + \boldsymbol{\epsilon}_t = \sum_{i=0}^{\infty} \boldsymbol{\Lambda}_{it} \boldsymbol{\epsilon}_{t-i}$.

Afterwards, the (scaled) GFEVD ($\tilde{\psi}^g_{ij,t}(K)$) is computed which can be interpreted as the forecast error variance share one variable explains on others. These variance shares are normalised, so that each row sums up to one, meaning that all variables together explain 100% of

[1]Since the details of the Kalman Filter estimation procedure is beyond the scope of this study, interested readers are referred to (Diebold and Li, 2006)

variable's i forecast error variance. This is calculated as follows

$$\psi^{2,g}_{ij,t}(K) = \frac{\boldsymbol{\Sigma}^{-1}_{iit} \sum_{h=0}^{K-1} (\boldsymbol{e}'_i \boldsymbol{\Lambda}_{ht} \boldsymbol{e}_j)^2}{\sum_{h=0}^{K-1} (\boldsymbol{e}'_i \boldsymbol{\Lambda}_{ht} \boldsymbol{\Sigma}_t \boldsymbol{\Lambda}'_{ht} \boldsymbol{e}_i)} \tag{3}$$

$$\tilde{\psi}^{g}_{ij,t}(K) = \frac{\sum_{t=1}^{K-1} \psi^{2,g}_{ij,t}}{\sum_{j=1}^{m} \sum_{t=1}^{K-1} \psi^{2,g}_{ij,t}} \tag{4}$$

where $\sum_{j=1}^{m} \tilde{\psi}^{g}_{ij,t}(K) = 1$, $\sum_{i,j=1}^{m} \tilde{\psi}^{g}_{ij,t}(K) = m$ and $\boldsymbol{e}_i$ is a selection vector with a one on the ith position and zero others.

All relevant connectedness measures can be computed in five steps. First, we are interested in how much variable i transmits to all other variables j, (total directional connectedness TO others), which is defined as

$$C^{g}_{i\to j,t}(K) = \frac{\sum_{j=1, i\neq j}^{m} \tilde{\psi}^{g}_{ji,t}(K)}{\sum_{j=1}^{m} \tilde{\psi}^{g}_{ji,t}(K)} * 100 \tag{5}$$

Second, we want to know how much variable i receives from shocks in variables j (total directional connectedness FROM others), which is defined as

$$C^{g}_{i\leftarrow j,t}(K) = \frac{\sum_{j=1, i\neq j}^{m} \tilde{\psi}^{g}_{ij,t}(K)}{\sum_{i=1}^{m} \tilde{\psi}^{g}_{ij,t}(K)} * 100 \tag{6}$$

Finally, the subtraction of the total directional connectedness TO others by the total directional connectedness FROM others leaves us with the net total directional connectedness, which can be interpreted as the influence variable i has on the analyzed network.

$$C^{g}_{i,t} = C^{g}_{i\to j,t}(K) - C^{g}_{i\leftarrow j,t}(K) \tag{7}$$

If $C^{g}_{i,t} > 0 (C^{g}_{i,t} < 0)$, it means that variable i influences the network more (less) than being influenced by it. Alternatively, it provies information whether variable i is driving or driven by the network.

Finally, the total connectedness index (TCI) can be constructed as follows,

$$C^{g}_{t}(K) = \frac{\sum_{i,j=1, i\neq j}^{m} \tilde{\psi}^{g}_{ij,t}(K)}{\sum_{i,j=1}^{m} \tilde{\psi}^{g}_{ij,t}(K)} * 100 = \frac{\sum_{i,j=1, i\neq j}^{m} \tilde{\psi}^{g}_{ij,t}(K)}{m} * 100. \tag{8}$$

A high TCI value indicates that the market is highly interrelated and risky.

3 Data and Summary Statistics

We compile a dataset of monthly sovereign zero coupon yield curve for Japan, Malaysia, Australia, Hong Kong, Singapore, China, South Korea, India and Indonesia over a period from January, 2013 to December, 2017. The data is obtained from Bloomberg and denominated in the local currency. Tweleve maturities are considered for each country which are, 3, 6, 12, 24, 26, 48, 60, 72, 84, 96, 108 and 120 months. The zero coupon yields based on different maturities are decomposed into three latent factors namely level, slope and curvature using the Dynamic Nelson Siegel (Diebold and Li, 2006).

Table 1 presents the summary statistics of all three factor across Asian economies. Of main importance is the fact that all series are stationary at the 1% significance level according to the ERS test (Stock et al., 1996). In addition, we see that most series are significantly autocorrelated and/or exhibit ARCH errors (Fisher and Gallagher, 2012) which means that estimating a VAR with a time-varying variance-covariance matrix is appropriate.

[Insert Table 1 around here]

4 Empirical Results

We start with Tables 2 to 4 which are summarizing the average connectedness measures in the level, slope and curvature factors. The level factor captures the behaviour of long-term yield rates. As per the expectations hypothesis, long-term rates are expectations of current and future short-term rates. Sutton (2000) find that deviations in the long-term rates as per the expectations hypothesis is because of the influence of international components in the long-end of the yield curve. Moreover, Driessen et al. (2003) identify that the level factor is also influenced by global shocks, whereas the steepness of the yield curve is driven by country-specific shocks. In addition, the long-term yield rates across countries are found to be highly correlated primarily because of the term-premia associated with it (Jotikasthira et al., 2015). Thus, it is expected that the dynamic total connectedness measures are likely to be higher in the level factor compared to those in the slope and curvature factor. On the other hand, the slope represents the monetary policy induced behavior of short-term rates used to manage economic growth and inflation. Thus, the slope of the yield curve is determined by domestic factors, with the co-movement of the slope reflecting the corresponding common movements in the economic fundamentals to which the central banks respond (Jotikasthira et al., 2015).

4.1 Linkages in the level factor

Table 2 presents the averaged dynamic connectedness measures in the level factor of Asia-Pacific economies. It is shown that the total connectedness index in the level factor across the Asia-Pacific economies is 36% indicating high interdependence in long-term interest rate spillovers. The net total connectedness measures shown in Figure 2 reveal that Malaysia is constantly the main net receiver of long-term interest rate shocks whereas Australis is constantly the main transmitter. Other important transmitters are Singapore, followed by Hong Kong, Japan and Indonesia, whereas the net receiving countries include China, India, and Korea.

This is due to the fact that in the last two decades, Asian economies have evolved as Australia's major trading partners which led to the fact that Australis was integrated in the Asia-Pacific regional bond market. This result is in line with Paramati et al. (2015), who find that the influence of Australia on Asian markets has significantly increased after the GFC, with the interdependence being driven by strong bilateral trade linkages in the region.

In more detail, the shocks of Australia are primarily transmitted to Hong Kong (23%), Korea (14.5%) and Singapore (12.1%). While, the shocks of Singapore are transmitted to Hong Kong (10.3%), Australia (10.3%) and Malaysia (8.3%). There exist a strong regional interconnectedness between the level factor of Australia, Hong Kong and Singapore. In this regard, note that, Chevallier et al. (2018) examine the stock market linkages between these countries, and the results of these authors also corroborated that interdependencies between Australia, Hong Kong and Singapore is high, manifesting into a strong regional cluster.

It is noteworthy to highlight that, the influence of Japan on the level factor of the Asia-Pacific economies is limited. This result is consistent with the findings of Tsukuda et al. (2017) and Chevallier et al. (2018) in terms of Japan's impact on bonds and stock markets of the Asia-Pacific region. Japan is undoubtedly the largest investor of foreign securities in the Eastern Asian region, however their investments are predominantly exposed to highly-rated US and European debt securities. This explains why Japan's exposure in the Asia-Pacific market is rather limited, and why the integration in the Asia-Pacific market is lower than it could be (Lee et al., 2013).

Furthermore, results indicate that the own-country impact is rather high in China (81.2%) and India(77.2%), which in turn is not surprising because, both China and India have strict restrictions in terms of capital flows into their sovereign bond markets. Foreign investment in the Indian bond market is restricted to USD 30 billion, which accounts for only 4% of the total sovereign debt market. Similiary foreign investments in the Chinese bond market account for only 3.61% of the total security market in the country.

Finally, when we look at the Malaysian level factor, it is found to be majorily influenced by Singapore. The geographical proximity and strong bilateral trade linkages between these countries are the most likely underlying reasons driving such a co-movement of the level factor. This result seems to reflect the findings of (Flavin et al., 2002) who have shown that geographical proximity, common border and bilateral trade linkages increases the cross-country asset market correlation.

[Insert Table 2 around here]

[Insert Figure 2 around here]

4.2 Linkages in the Slope factor

We continue to focus on the average dynamic connectedness values of the slope factor shown in Table 3. The results suggest that the total connectedness index in the slope factor is around 26%, and hence lower than the level counterpart as expected by economic theory. Again, we find Malaysia and Australia being one of the main net receiver and net transmitter, respectively. In addition, we find that Singapore and Indonesia are still net transmitters of short-term interest rate shocks and India stays a net receiver of short-term interest rate shocks. Contrary to our previous findings, the results suggest that even if Hong Kong and Japan are long-term shock transmitters they are on the receiving end when it comes to short-term interest rate shocks whereas empirical results suggest that China and Korea are driving short-term interest rates instead of being driven by them.

In addition, the intermarket linkage between Hong Kong and Singapore is found to be quite high in the slope factor. Hong Kong and Singapore are small open economies with scarce natural resources, however, they have developed into international trade centers in the Asia-Pacific region[2]. Moreover, Hong Kong constitutes about 12.3% of total Singaporean exports and ranks second among the top trading partners next to China (14.5%)[3]. Thus, the similar characteristics of the economies, coupled with trade linkages is likely to have led to the increased integration between the slope factor of the yield curves of Hong Kong and Singapore.

[2] See, www.scmp.com.
[3] www.worldstopexports.com.

At the same time, the Malaysian short-term factor is mainly influenced by Indonesia and vice versa. Malaysian and Indonesian economies share similar characteristics from ethnicity to the financial system. Both these economies follow an Islamic financial system and are dominant issuers of the Sukuk bonds in the world. Furthermore, investment by foreign investors in the sovereign bond market of these economies is high when compared to other Asia-Pacific economies. Thus, these two economies serve as an example, whereby the synchroncity of financial systems lead to increased integration at the short-end of the yield curve.

As discussed earlier, given that the slope of the yield curve reflects the domestic monetary policy stance, the convergence of monetary policy and business cycles of the economies are likely to lead to increased integration in slope (Kumar and Okimoto, 2011).

[Insert Table 3 around here]

In Figure 3, we present the dynamic net total directional connectedness for the Asia-Pacific region. Australia, Korea and Singapore are the dominant transmitter of shocks in the region whereas the Japanese slope factor has limited influence on the slope factor of other countries in the region. However, it is noteworthy that, Japan is strongly influenced by Singapore.

Additionally, own-country influence in the slope factor is highest in China (91.7%), followed by Indonesia (80.5%) and India (79.3%), indicating that these countries are more responsive to the domestic rather than external shocks. This finding suggests that these countries are relatively more isolated in the short-end of the yield curve. These results corroborates with (Tsukuda et al., 2017), who has shown that the Chinese and Indonesian bond markets are weakly integrated with the regional and global bond markets.

[Insert Figure 3 around here]

4.3 Linkages in the curvature factor

Finally, the curvature factor is capturing the humpedness of the yield curve, and represents medium-term yield movements. Earlier research conclude that movement in the middle-end of the yield curve does not have any significant influence due to the economic fundamentals (Diebold and Li, 2006; Dewachter and Lyrio, 2006). However, Mönch (2012) provide evidence that the curvature is informative in capturing the future movements of the yield curve. Hence, scurvature pillovers indicate the co-movements in expectations of future yield curves.

Table 4 documents averaged dynamic connectedness values of medium-term interest rate spillovers illustrated by the curvature factor of interest rates. It is found that linkages in the curvature are the lowest among all interest rate characteristics given that the total connectedness index is 18.6%. This result is consistent with the literature that suggests that the curvature is rather non-responsive to external shocks.

[Insert Table 4 around here]

Figure 4 presents the total directional connectedness in the curvature across the Asia-Pacific region. Hong Kong is found to be the dominant transmitter of shocks in curvature followed by Australia and Korea, with the influence of the Korean curvature factor found to be increasing in influence after the GFC.

The shock from Hong Kong is primarily transmitted to Singapore and Japan. In addition, bilateral linkages as, Hong Kong-Singapore and Malaysia-Indonesia are also found to be of importance in the curvature factor.

[Insert Figure 4 around here]

4.4 Dynamic Total Connectednesss

In Figure 1 represents dynamic total connectedness over the period 2003 to 2017 of all three interest rate characteristics. Results indicate that the dynamic total connectedness is time-varying in the long-term factor ranging from 35% to 45%. It is rather high in 2004, during the introduction of domestic bond market in the Asia-Pacific region, and then gradually started to increase during 2009 after the GFC.

In contrast, it seems that the dynamic total connectedness of the slope factor stays rather constant at around 25% after the GFC which would indicate that on average every short-term interest rate shock is influencing others by one-quarter of its magnitude whereas the rest (75%) is explained by its own lagged values. This indicates that monetary policy actions are not as independent as one might think and that short-term rates are highly influenced by other regional players. Even if this relation seems rather constant over time we can observe a more erratic behaviour during the GFC which could indicate the more independent monetary policy actions that were undertaken to mitigate the negative spillovers from the US housing market.

Finally, the dynamic total connectedness measure of the curvature factor is analyzed which according to economic theory is rather non-responsive of external shocks. Hence, it can be seen as being influenced by country-specific economic indicators. We see that throughout the period of analysis, except for the small increase during the GFC, the trend seems to be decreasing indicating that curvature becomes more and more independent which is in-line with the assumption that it is non-responsive to external influence.

[Insert Figure 1 around here]

Thus, the total connectedness results for the three yield curve factors clearly indicate that the integration is high in level followed by the slope and curvature factors. This implies that in the long-run interest rates movements are closely interrelated that is essential for the refinancing scheme of governments and large institutions which in turn means that there is no free-lunch due to its high synchronization. Furthermore, the short-term interest rate movements seem to be rather constant over time illustrating a constant risk in the bond market which is of major importance for the refinancing scheme of firms. These results are in-line with economic theory since long-term financing involves more uncertainty than short-term financing. The short-lived erratic behaviour of the short-term interest rate interconnectedness during the GFC illustrates the negative spillover to the short-term financing scheme of banks and firms. Lastly, the dynamic connectedness of the curvature factor decreases over time which illustrates that the influence of external sources, even if already low, decreases even further. This could indicate that the negative US housing market spillover is nearly squeezed out of the Asia-Pacific bond market.

5 Concluding Remarks

This study investigates the time-varying interdependencies in the term structure of interest rates in Asia-Pacific countries across the maturity spectrum. First, the term structure of interest rates is decomposed into three latent factor using the Dynamic Nelson Siegel model (Diebold and Li, 2006). The three factors capture long-term, medium-term and short-term movements. Estimating the TVP-VAR connectedness approach (Antonakakis and Gabauer, 2017) shows the tranmission mechanisms of the latent factors.

The study find that interconnectedness is high in the level factor compared to the slope and curvature factors. The lowest interconnectedness in observed in the curvature factor. Australia and Singapore were dominant transmitter of shocks to the level and slope factor of Asia-Pacific economies term structure. The co-movement of slope factor between the countries are influenced by the trade linkages and similiar financial characteristics.

The results of the study helps the policy makers in understanding the degree of monetary policy independence in influencing the long-term rates. The interdependencies in sovereign bond yields in Asia-Pacific region clearly indicates that domestic term structure should be modelled in the international context where the foreign yield rates influence the domestic term structure especially at the short-term and long-term factor. This study also offers insights for effiecient portfolio diversification in the bond markets.

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Table 1: Summary Statistics

	Malaysia	Australia	HongKong	Singapore	China	Korea	India	Indonesia	Japan
					Level Factor				
ERS	-6.418***	-5.763***	-6.360***	-7.083***	-5.028***	-5.345***	-5.826***	-5.453***	-5.281***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$Q(10)$	50.866***	13.860	29.801***	68.849***	27.920***	11.921	20.423**	49.140***	108.736***
	(0.000)	(0.179)	(0.001)	(0.000)	(0.002)	(0.290)	(0.025)	(0.000)	(0.000)
$Q^2(10)$	17.223*	7.482	18.453**	33.923***	21.377**	51.063***	22.341**	27.155***	69.952***
	(0.070)	(0.679)	(0.048)	(0.000)	(0.019)	(0.000)	(0.013)	(0.002)	(0.000)
					Slope Factor				
ERS	-5.840***	-4.664***	-5.443***	-6.171***	-5.811***	-6.186***	-4.445***	-5.372***	-5.340***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$Q(10)$	35.690***	19.672**	20.292**	56.636***	30.187***	11.095	36.653***	9.956	94.629***
	(0.000)	(0.033)	(0.027)	(0.000)	(0.001)	(0.350)	(0.000)	(0.444)	(0.000)
$Q^2(10)$	30.035***	32.860***	24.380***	27.281***	16.818*	39.494***	25.894***	23.420***	63.147***
	(0.001)	(0.000)	(0.007)	(0.002)	(0.078)	(0.000)	(0.004)	(0.009)	(0.000)
					Curvature Factor				
ERS	-6.568***	-5.057***	-5.660***	-6.443***	-5.508***	-8.582***	-7.471***	-7.565***	-4.837***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$Q(10)$	67.294***	26.970***	33.146***	20.568**	29.084***	32.852***	40.637***	28.446***	126.521***
	(0.000)	(0.003)	(0.000)	(0.024)	(0.001)	(0.000)	(0.000)	(0.002)	(0.000)
$Q^2(10)$	22.463**	83.628***	25.851***	17.098*	7.476	58.214***	33.084***	10.593	118.805***
	(0.013)	(0.000)	(0.004)	(0.072)	(0.680)	(0.000)	(0.000)	(0.390)	(0.000)

Notes: ***,**,* denote significance at 1%, 5% and 10% significance level; ERS: Stock et al. (1996) unit-root test; Q(20) and $Q^2(20)$: Fisher and Gallagher (2012) weighted portmanteau test.

Table 2: Level Factor Connectedness Table

	Malaysia	Australia	HongKong	Singapore	China	Korea	India	Indonesia	Japan	FROM
Malaysia	60.0	6.2	3.0	8.3	3.6	4.4	5.2	6.1	3.3	40.0
Australia	3.2	45.3	20.3	10.3	0.4	11.2	2.2	1.5	5.6	54.7
HongKong	1.1	23.0	47.4	10.3	1.7	9.3	1.4	0.8	4.9	52.6
Singapore	3.2	12.1	12.2	55.1	0.5	5.2	1.8	2.2	7.5	44.9
China	3.4	2.6	1.9	1.0	81.2	1.2	2.3	3.7	2.7	18.8
Korea	3.6	14.5	10.0	7.7	0.6	56.9	1.1	4.6	1.0	43.1
India	5.8	3.9	4.0	3.5	0.9	1.2	77.2	2.9	0.5	22.8
Indonesia	2.4	2.8	1.9	3.0	3.0	6.3	2.7	77.3	0.5	22.7
Japan	1.8	8.2	2.5	6.5	2.5	1.0	0.5	1.6	75.6	24.4
Contribution TO others	24.6	73.4	55.8	50.4	13.2	39.9	17.4	23.4	26.0	323.9
Contribution including own	84.5	118.7	103.2	105.6	94.3	96.8	94.6	100.7	101.5	TCI
Net spillovers	-15.5	18.7	3.2	5.6	-5.7	-3.2	-5.4	0.7	1.5	36.0

Notes: Values reported are variance decompositions based on a 30-months-ahead forecasts.
In both periods, a TVP-VAR lag length of order 1 is selected by the BIC.

Table 3: Slope Factor Connectedness Table

	Malaysia	Australia	HongKong	Singapore	China	Korea	India	Indonesia	Japan	FROM
Malaysia	62.3	2.1	1.7	4.7	1.3	10.2	1.1	13.6	3.0	37.7
Australia	1.8	72.8	8.5	9.1	0.7	4.0	0.4	1.1	1.6	27.2
HongKong	1.7	7.5	67.1	15.7	0.6	3.0	1.1	0.9	2.3	32.9
Singapore	1.5	7.0	12.3	61.0	0.6	7.4	1.2	0.9	8.0	39.0
China	0.7	1.0	1.2	0.3	91.7	1.3	2.6	0.9	0.5	8.3
Korea	7.2	4.8	1.5	4.2	2.0	73.8	1.3	4.2	1.0	26.2
India	2.5	8.4	1.8	1.0	3.1	1.2	79.3	0.5	2.2	20.7
Indonesia	9.3	0.9	2.6	1.0	0.8	4.3	0.2	80.5	0.4	19.5
Japan	1.5	2.5	1.8	7.4	0.4	2.1	4.2	2.4	77.8	22.2
Contribution TO others	26.2	34.2	31.3	43.5	9.4	33.3	12.2	24.6	19.0	233.8
Contribution including own	88.4	107.0	98.5	104.5	101.1	107.2	91.5	105.1	96.8	TCI
Net spillovers	-11.6	7.0	-1.5	4.5	1.1	7.2	-8.5	5.1	-3.2	26.0

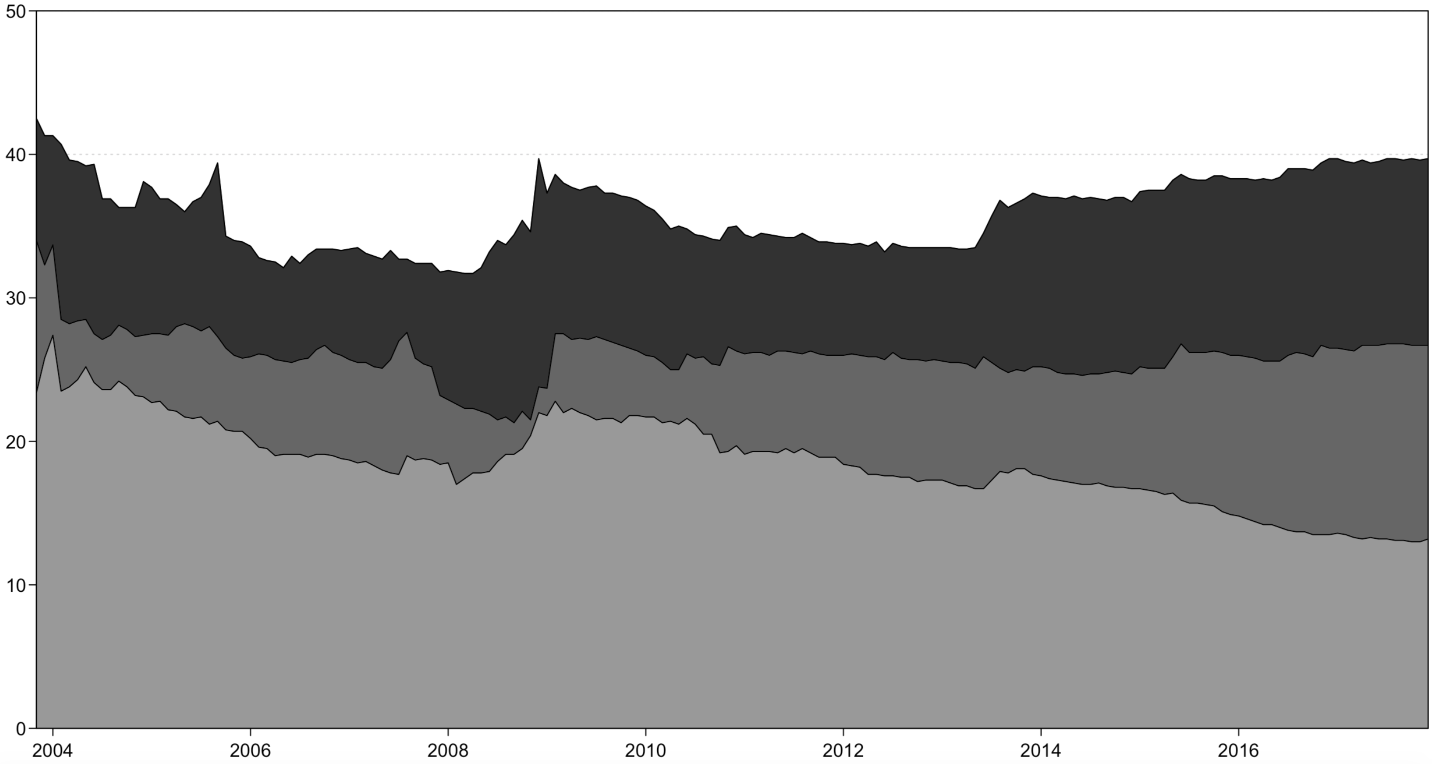
Notes: Values reported are variance decompositions based on a 30-months-ahead forecasts.
In both periods, a TVP-VAR lag length of order 1 is selected by the BIC.

Table 4: Curvature Factor Connectedness Table

	Malaysia	Australia	HongKong	Singapore	China	Korea	India	Indonesia	Japan	FROM
Malaysia	78.7	0.9	2.7	3.8	2.2	2.7	1.6	6.7	0.8	21.3
Australia	1.8	87.1	2.7	1.3	1.1	1.4	3.1	0.7	0.9	12.9
HongKong	1.9	2.5	75.3	3.6	1.3	1.5	1.6	3.8	8.4	24.7
Singapore	3.5	2.9	4.9	78.1	0.8	6.0	1.7	1.0	1.2	21.9
China	1.4	1.8	0.9	1.3	88.5	2.1	2.3	0.5	1.3	11.5
Korea	2.9	1.5	3.9	1.1	0.7	81.7	0.2	5.6	2.4	18.3
India	1.2	3.2	2.1	2.4	2.5	0.2	85.5	0.5	2.4	14.5
Indonesia	6.9	1.4	4.6	1.2	0.5	3.1	0.3	81.5	0.5	18.5
Japan	2.5	2.7	8.9	3.7	1.2	2.5	2.0	0.4	76.2	23.8
Contribution TO others	22.2	16.9	30.7	18.3	10.2	19.5	12.8	19.1	17.8	167.4
Contribution including own	100.9	104.0	105.9	96.4	98.7	101.2	98.3	100.6	94.0	TCI
Net spillovers	0.9	4.0	5.9	-3.6	-1.3	1.2	-1.7	0.6	-6.0	18.6

Notes: Values reported are variance decompositions based on a 30-months-ahead forecasts.
In both periods, a TVP-VAR lag length of order 1 is selected by the BIC.

Figure 1: Level Factor Dynamic Total Connectedness



Notes: The light-grey shaded area illustrates the dynamic total connectedness of the curvature factor, the dark-grey shaded area shows dynamic total connectedness of the slope factor and the black area represents the dynamic total connectedness of the level factor.

Figure 2: Level Factor Net Total Directional Connectedness

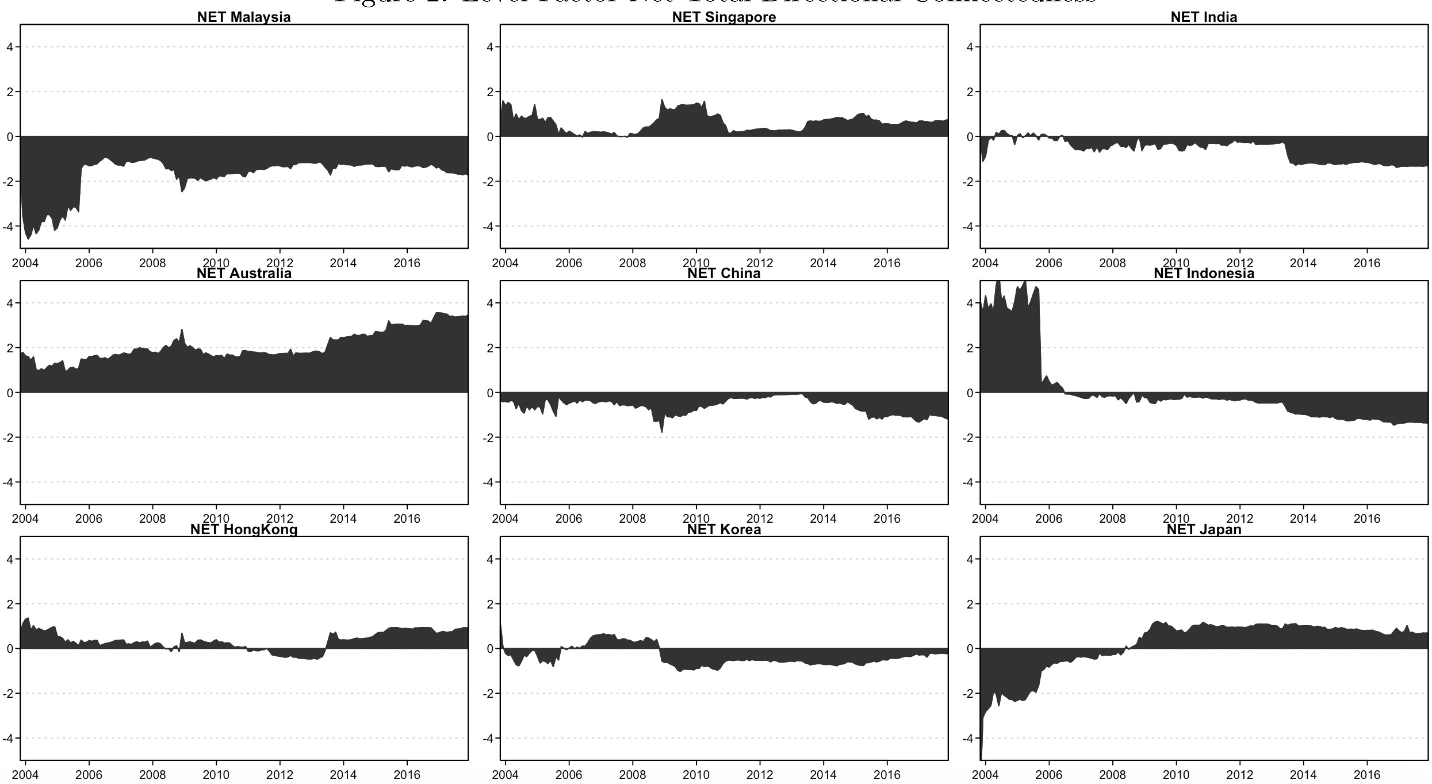


Figure 3: Slope Factor Net Total Directional Connectedness

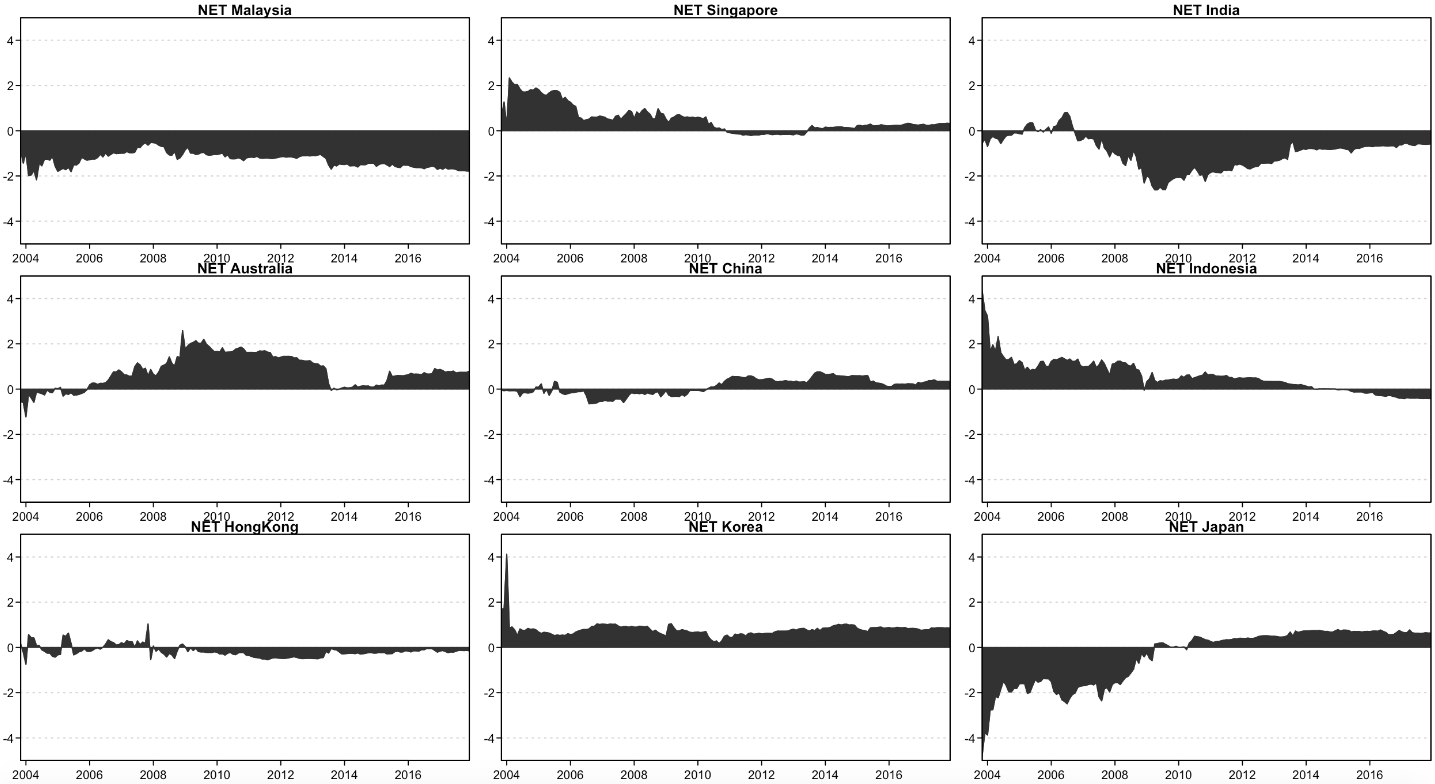


Figure 4: Curvature Factor Net Total Directional Connectedness