PUEY UNGPHAKORN INSTITUTE
FOR ECONOMIC RESEARCH

Economic Fundamentals and Spill-over among Asian Term Structures

by

Wachirawat Banchuen

January 2017

Discussion Paper

No. 52

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Wachirawat Banchuen

Bank of Thailand

Abstract

This paper estimates affine term structure models of government bonds in selected 5 emerging countries during 2002-2015 periods. It aims to study the relationship between sovereign bond markets and the real economy. The analysis confirms evidences earlier that macroeconomic variables help explaining yield curve and term premium dynamics. For short-term bonds, yield's responses to shocks are mostly carried by policy channel. For long-term bonds, responses are mostly from term premium. Furthermore, there are external factors that could generate yields co-movement in some emerging-economy countries. Our findings therefore suggest that portfolio diversification would benefit investors who allocate their assets globally. Central banks, however, have to face with difficulties in managing bond market as they have to oversee risk factors affecting investors' risk perception and causing cross-country spill-over effects.

Economic Fundamentals and Spill-over among Asian Term Structures

1. Introduction

Affine term structure model with no-arbitrage assumption is a popular model for pricing bond yields. Many studies have been using this type of model to study and forecast term structure of the sovereign bond markets in developed countries including the US, the UK, and EU countries. However, only a few, if any, have conducted research using this affine term structure model for emerging countries like Thailand, Indonesia, Malaysia, or even more developed country like Singapore and Korea. This paper aims to use this class of models to study some EM countries' term structures and shed lights to some implications regarding the relationship between real economic activity and sovereign bond markets for both investors and policy makers. The analysis confirms evidences found in sovereign bond markets in developed countries that macroeconomic variables help explaining yield curve and term premium dynamics, and there are external factors that could generate yields co-movement in some countries.

The affine no-arbitrage models with only yield curve factors, applied mostly in finance literatures, offer an extraordinary fitting performance, however, they offer little insight into the economic nature of each state variable. In economic literatures, macro models are usually employed to give good insights and explanation of each economic variable but offer poor fitting performance. To provide such good insight and decent fitting performance, this paper combines a conventional affine term structures model with macroeconomic variables, both domestically and externally. Furthermore, we also employ the unspanned macro factors technique that offers benefits over the spanned macro factors models. To name a few, our canonical model benefits from smaller dimension of the vector of risk factors and it also complies with the economic intuition that macro variable should offer some predictive power on bond yields but yield curve factors should not be able to replicate the portfolio of macro variables.

The estimation method employed in this paper is the regression-based, introduced by Adrian, Crump, and Moench (2013). This approach allows computationally fast estimation, but offers comparatively similar dynamics to those estimated by maximum likelihood (ML), which involves high-dimensional non-linear optimizations that has many local optima and undefined regions.

Our empirical results confirms evidences found in sovereign bond markets in developed countries that macroeconomic variables help explaining yield curve and term premium dynamics, and there are external factors that could generate yield co-movement in some emerging Asian countries. Based on our empirical results, there are 4 stylized facts that could be highlighted. First, a surprise positive shock in real activity, commodity price, and DM policy rate would result in an upward shift of yield curves, with the slope being 'bear flattened' in most cases. Second, the responses of yield curve's level factor are persistent and sometimes do not adjust back completely, reiterating the consequence of policy rate inertia. Third, the responses of short-term bonds are mostly from 'risk-neutral' channel (i.e. policy channel), which reflects the expected path of monetary policy. The responses of long-term bonds on the other hand are from 'term premium', which offers additional compensation to 'risk-averse' investors for holding longer-maturity bonds. Fourth, the external shocks like commodity price and DM policy rate could simultaneously affect investors' price of risk across countries, and thus induce co-movement in bond yields through term premium channel.

The paper is structure as the following. In section 2, a conventional ACM model used to price bond yields in each country is described. The close-form equations for pricing parameters, as well as the estimation procedures are also illustrated here. Section 3 describes both financial and economic data employed for each selected country, as well as the choice of sample period. The fitted yield curves are also outlined in this section. In section 4, we proceed to discussing empirical results from various shocks analysis, as well as identifying channels of the shock upon different parts of yield curves. Section 5 is the conclusion and some brief implications for both investors and policy makers.

2. The Model

In this section, the model of multiple term structures of interest rates across countries, each indexed by *i*, will be presented. We begin with the traditional model where all state variables are spanned in both pricing and historical measure. We then justify the reasons to extend the model to include unspanned macroeconomic variables.[1] As proposed by Joslin, Priebsch, and Singleton (2014) and Joslin, Singleton, and Zhu (2010), the state variables of each underlying economy should be divided into two groups, spanned and unspanned ones. Specifically, yield curve pricing factors X^s_t is spanned in both pricing and historical measure, while macro variables (X^u_t) are unspanned in the pricing measure.

2.1 State variables and excess returns in and ATSM

The expression for excess bond returns in an affine term structure model (ATSM) is derived following the exposition from Adrian et al. (2013) (ACM hence forth). The dynamics of a K×1 vector of state variables X_t is assumed to evolved according to Gaussian vector autoregression with 1 lag, VAR(1):

$$X_{t+1} = \mu + \Phi X_t + v_{t+1} \tag{1}$$

[1] ACM also discussed the methodology to extend the model to include the unspanned macroeconomic factors, however they did not justify the benefits of including unspanned factors, nor did they provide the results of the estimated model.

Where the shock v_{t+1} are assumed to follow Gaussian distribution with variance-covariance matrix $\sum$:

$$v_{T+1} \sim N(0, \Sigma) \tag{2}$$

We denote a zero-coupon bond price with maturity *n* at time *t* by $P_t^{(n)}$. The assumption of no-arbitrage implies the existence of pricing kernel M_t such that

$$P_t^n = E_t[M_{t+1} P_{t+1}^{n-1}] \tag{3}$$

The pricing kernel is assumed to be exponentially affine as:

$$M_{t+1} = exp\left[-r_t - \frac{1}{2}\lambda_t'\lambda_t - \lambda_t'\Sigma^{-1/2}v_{t+1}\right] \tag{4}$$

where $r_t = \ln P_t^{(1)}$ denotes the continuously compounded risk-free rate that is also assumed to be an affine function of:

$$r_t = \delta_0 + \delta_1' x_t \tag{5}$$

As suggested in Duffe (2002), market prices of risk (λ_t) are of the essentially affine form in the factors:

$$\lambda_t = \Sigma^{-1/2}(\lambda_0 + \lambda_1 X_t) \tag{6}$$

We define the log excess holding return of a bond maturing in n periods as:

$$rx_{t+1}^{n-1} = \ln P_{t+1}^{n-1} - \ln P_t^n - r_t \tag{7}$$

Using Eq. (4) and (7) in (3), ACM show that

$$1 = E_t\left[exp\left(rx_{t+1}^{n-1} - \frac{1}{2}\lambda_t'\lambda_t - \lambda_t'\Sigma^{-1/2}v_{t+1}\right)\right] \tag{8}$$

Under the assumption of joint normality of $\{rx_{t+1}^{n-1}, v_{t+1}\}$, ACM demonstrate further that,

$$E_t[rx_{t+1}^{n-1}] = Cov_t\left[rx_{t+1}^{n-1}, v_{t+1}'\Sigma^{-1/2}\lambda_t\right] - \frac{1}{2}Var_t[rx_{t+1}^{n-1}] \tag{9}$$

Denoting $\beta_t^{(n-1)\prime} = Cov_t[rx_{t+1}^{n-1}, v_{t+1}']\Sigma^{-1}$ and using Eq.(6) one can rewrite (9) as

$$E_t[rx_{t+1}^{n-1}] = \beta_t^{(n-1)\prime}[\lambda_0 + \lambda_1 X_t] - \frac{1}{2}Var_t[rx_{t+1}^{n-1}] \tag{10}$$

ACM use this relationship to decompose the unexpected excess return into a component that is correlated with v_{t+1} and another component that is conditionally orthogonal:

$$rx_{t+1}^{n-1} - E_t[rx_{t+1}^{n-1}] = \beta_t^{(n-1)\prime} v_{t+1} + e_{t+1}^{n-1} \tag{11}$$

Where e_{t+1}^{n-1} are conditionally independently and identically distributed (i.i.d.) with variance σ^2.

The return generating process for log excess holding period returns can be written as

$$rx_{t+1}^{n-1} = \beta^{(n-1)\prime}(\lambda_0 + \lambda_1 X_t) - \frac{1}{2}(\beta^{(n-1)\prime}\Sigma\beta^{(n-1)} + \sigma^2) + \beta^{(n-1)\prime}v_{t+1} + e_{t+1}^{n-1} \tag{12}$$

The first term on the right-hand side is the expected return of bond yields. While the second and third terms are the convexity adjustment and priced return innovation respectively. The last term on the right-hand side is the return pricing error. Stacking the system across n maturity and t time periods, ACM construct the expression such that

$$rx = \beta^{(n-1)\prime}(\lambda_0 i_t' + \lambda_1 X_-) - \frac{1}{2}(B * vec(\Sigma) + \sigma^2 i_N)i_T' + \beta' V + E \tag{13}$$

where rx is a N×T matrix of excess returns; $\beta = \left[\beta^{(1)}, \beta^{(2)}, \dots, \beta^{(n)}\right]$ is a K×N matrix of factor loadings, i_T and i_N are T×1 and N×1 vectors of ones; X_- is a K×T matrix of lagged pricing factors; B*= $\left[vec\left(\beta^{(1)}\beta^{(1)\prime}\right) \dots vec(\beta^{(2)}\beta^{(2)\prime})\right]'$ is a N×K^2 matrix; and V and E are matrices of dimensions K×T and N×T respectively

2.1 Estimation

For estimation, we follow ACM estimation technique which involves three-step linear regressions base on equation (13).

1. In the first step, we estimate the dynamic of state variables Eq.(1) by OLS to get Φ and $\hat{\Sigma}$. The estimation is calibrated as $\mu = 0$ to ensure that the factor means (principal component with mean zero) are equal to their sample averages. The underlying state variables are also decomposed into predicable component and an estimate of innovation $\widehat{v_t}$.
2. Next, regress excess returns on a constant, lagged pricing factors, and contemporaneous pricing factor innovations. In other words, the reduced form of Eq.13,
   $rx = ai_T' + \beta\hat{V} + cX_- + E$ is estimated in order to get $\hat{a}\ \hat{\beta}\ \hat{c}$ as well as $\sigma^2 = tr(\hat{E}\hat{E})/NT$ and construct B* from $\hat{\beta}$
3. Estimate the parameters of the price of risk via cross-sectional regression using Eq.(13) that $a = \beta'\lambda_0 - \frac{1}{2}(B * vec(\Sigma) + \sigma^2 i_N)$ and $c = \beta'\lambda_1$ ACM finally get the expression for the price of risk as:

$$\lambda_0 = \left(\hat{\beta}\widehat{\beta'}\right)^{-1}\hat{\beta}\left(\hat{a} + \frac{1}{2}\left(\hat{B} * vec\left(\hat{\Sigma}\right) + \sigma^2 i_N\right)\right) \tag{14}$$

$$\lambda_0 = \left(\hat{\beta}\widehat{\beta'}\right)^{-1}\hat{\beta}\hat{c} \tag{15}$$

2.2 Affine yields

Given the estimated model parameters above, one can generate a zero coupon yield curve. Under the assumptions made so far, ACM shows that bond prices are exponentially affine in the vector of state variables:

$$lnP_t^{(n)} = A_n + B'_n X_t + u_t^{(n)} \tag{16}$$

Substituting Eq.(16) into Eq.(7), they derive that

$$rx_{t+1}^{(n-1)} = A_{n-1} + B'_{n-1}X_{t+1} + u_{t+1}^{(n-1)} - A_n - B'_n X_t - u_t^{(n)} + A_1 + B'_1 X_t + u_t^{(1)} \tag{17}$$

After equating this expression for excess returns with the return generating expression in Eq.(12) and matching terms, they obtain the system of recursive linear restrictions for the bond pricing parameters:

$$A_n = A_{n-1} + B'_{n-1}(\mu - \lambda_0) + \tfrac{1}{2}(B'_{n-1}\Sigma B_{n-1} + \sigma^2) - \delta_0 \tag{18}$$

$$B'_n = B'_{n-1}(\Phi - \lambda_1) - \delta'_1 \tag{19}$$

$$A_1 = -\delta_0 \text{ , } B_1 = -\delta_1 \tag{20}$$

$$A_0 = 0 \text{ , } B'_0 = 0 \tag{21}$$

$$\beta^{(n)\prime} = B'_n \tag{22}$$

Following the definition of Dai and Singleton (2002), one can decompose an n-period bond yield into two parts namely the average expected short rate and the term premium

$$y_t^{(n)} = \tfrac{1}{n}\textstyle\sum_{i=0}^{n} E_t r_{t+i} + TP_t^{(n)} \tag{23}$$

The first term of the right-hand side of Eq.(23) is the average expected short rate over the next n periods, and the second term is the term premium. The expectation term can be computed as:

$$\frac{1}{n}\sum_{i=0}^{n} E_t r_{t+i} = -\frac{1}{n}[A_n^{RF} + B_n^{\prime RF} X_t]$$

where one parameters $A_n^{RF}$and B_n^{RF} can be derived by setting the price of risk parameters λ_0 and λ_1 in Eq.(18) and Eq.(19) to zero.

This affine term structure model assumes no-arbitrage opportunity in the system. In the other words, it is constructed base on expectation hypothesis that long term yield is acquired by compounding and roll-over the short term yields. Thus, if one adjusts the risk compensation that the agents require in order to hold long term bonds to be zero, i.e. set the price of risk parameter – lambda - to zero, the results could thus be interpreted as the expected monetary policy path, i.e. risk-neutral yields. It is the yields path that investors expect to receive without concerning the risk they have to bear when holding bonds with longer maturity. Thus, when investors expect monetary path to change drastically, it could be reflected in this channel. Theoretically, this channel should govern the term structure in the short tenor as yields in the short-end are typically anchored to the policy rate. So when there is a change in policy rate or a shift in expectation of monetary policy, risk-neutral yields are the first component to be adjusted.

Term premium, on the other hand, is the component that accounts for additional compensation that investors require in order to hold longer-maturity bonds. This is because the investors are actually risk-averse and they consider time-valuation of money when constructing their portfolios. So for them to relocate their wealth into longer maturity assets, the compensation must be higher compared to the shorter-maturity assets which are more liquid and associate with less risk.

Term premium could be influenced by various factors. One is the perceived riskiness of longer-term securities. When investors believe that there is high tendency for inflation risk, they would require higher premium as a cushion for their bond value against inflation. Moreover, term premium could also be perturbed by the change in demand for that specific type of securities. The market of the sovereign bonds is huge and in high demand, because of it being safe and liquid. So change in their demand and supply matters for their yields. Other than the domestic factors, external forces could also have an impact upon domestic yield curves as well. One is unconventional monetary policy from other central banks such as ECB and the ECB. The other factor is the impact from global commodity cycle. A fall in oil price reduces investors' perception of long-term inflation risk. Term premium in this case would fall as lower oil price also signals weakness in global economy. In the following section, we will study the impacts of these factors upon yield curves in more detail.

2.3 Affine Term Structure Model with Unspanned Macro Factors

Recent studies in this field have been expanding the model to include macroeconomic variables as state variables. Adding macro factors as another set of state variables gives various benefits to the term structure model. First and foremost, it would enable ones to study the impacts of the economic activity as well as the spill-over from real sector to bond markets. Second, as yield curves are often correlated with economic activity, the information contained in macro factors should therefore has predictive power for excess returns and risk premiums in bond markets over yield factors alone. Third, Joslin, Priebsch, and Singleton (2014), henceforth JPS, argued that enforcing macro "spanning" restriction like in the conventional model can lead to inaccurate model-implied risk premiums. Finally, as argued in Duffee (2010), having macro factors “unspanned” by yield curve factors will reduce the dimension of the risk factors (state variables) giving rise to better fitting performance by the model. The reason is that the first three principal components explain most of the variation in yields. This fact also motivates the small number of risk factors in the reduced form of affine term structure models.

Moreover, JPS (2014) have argued that macro factors could help explaining the movement in bond yields; however the reverse should not be trivial. Therefore, they proposed that macro variables should be included but unspanned by yield curve factors. In other words, those macro variables should help predicting bonds excess return, but at the same time, pure yield curve factors must not be able to form or replicate a portfolio of macro factors.

In order to model the term structure with unspanned macro factors, we follow the methodology proposed by JPS (2014). The idea is that the pricing kernel used for discounting cashflow is assumed to depend on a comprehensive set of factors (including macro factors), but bond yields is affined to a smaller set of portfolios of risk factors (only yield factors). This concept is applied to ACM model by setting macro factors such that they do not affect the dynamics of bonds under the pricing measure, but do affect them under historical measure.

The estimation then proceeds with slight modification of the three-step procedure explained earlier. The vector of pricing factors is partitioned as

$$\begin{bmatrix} X_t^s \\ X_t^u \end{bmatrix} = \mu + \Phi \begin{bmatrix} X_{t-1}^s \\ X_{t-1}^u \end{bmatrix} + \begin{bmatrix} v_t^s \\ v_t^u \end{bmatrix}$$

Where X_t^s is a vector of spanned factors with nonzero risk exposures and X_t^u is a vector of unspanned factors with zero risk exposures. The condition that yields do not load on the unspanned factors in the pricing measure (Q measure) requires that:

$$\delta_1 = [\delta'_{1,s} \quad 0']'$$

$$\Phi^Q = \Phi - \lambda_1 = \begin{bmatrix} \Phi_{ss}^Q & 0 \\ \Phi_{us}^Q & \Phi_{uu}^Q \end{bmatrix}$$

We also adopt the convention of setting $\Phi_{us}^Q = \Phi_{us}$ and $\Phi_{uu}^Q = \Phi_{uu}$ since they do not matter for bond pricing in the unspanned macro factors. Please refer to ACM for further details of how the model is extended to include unspanned macro factors for this regression-based estimation.

Although featuring the unspanned macro factor in this fashion gives various benefits to the model, it is worthwhile to note that there are some interpretation caveats in this type of model. One is that including macro factors as an addition variable over yield curve factors could perplex the interpretation of each factor. Some previous studies in economic journal such as Evans and Marshall (2001), and Abritti et al (2013) relate first principal component of yield curve, namely level factors, to real activity. Others relate the first two principal components, e.g. level and slope factor, to inflation expectation and central bank's policy response. Therefore, in this argument, adding another set of macro factor could confuse the interpretation between each factor. That is, the impact of the additional macro factors could overlap the economic impact embedded in the yield curve factors. We acknowledge this caveat and try to alleviate the problem by modeling macro factors to be unspanned and avoiding to incorporate inflation variable directly into the model. Further study on this issue is encouraged in order to find a better solution with higher delicacy.

3. Data

The aim of this paper is to study term structures of Thailand and its peer emerging market (EM) countries, namely Korea, Singapore, Malaysia, and Indonesia. The model of each selected country is estimated using month-end zero coupon yields of sovereign bonds. The following maturities: 3 months, 6 months, 1 year, 2 years, until 10 years can be downloaded readily via Bloomberg. Using cubic-spline method, we then interpolate these data to back out the cross section of yields for maturity $n = 3,4,\ldots,120$ months. The pricing factors used as state variables are the principal components extracted from these yields. Following the conventional conduct, we use the first three principal components of yield curve as pricing factors as they can explain over 99% of the sample variation in bond yields. We use excess return for $n=12, 24, 36,\ldots,120$ months, giving a cross-section $N=10$ maturities.

For the estimation of term structure models of each country, the choice of sample period is varying depending on the data available and the development of the bond market in each country. For Thailand, the sample is from January 2002 to December 2015. For Korea, the sample is from January 2004 to December 2015. For Singapore and Indonesia, the sample is from July 2005 to December 2015. And for Malaysia, the sample is from January 2007 to December 2015.

Another set of state variables are macro variables. Studies, such as Ang and Piazzesi (2003), Ludvigson and Ng (2009), have shown that adding macro economic factors help explaining the movement of yield curve and thus term premium. Other than improving fitting purpose, adding macro variables enable researchers to study the impact of the real economy upon financial sector, as well as the contagion effect across country. We divide macro variables into two groups. The first one is the domestic factor which represents the economic activity in each economy. The second group is the external factors, namely commodity price and policy rates in G4 countries.

To construct the domestic macro factor, we use the first principal component extracted from a set of real economic activity indicators. The choice of domestic macro factors varies across countries. Table 1 illustrates the selected variables to be extracted as a real economic activity in domestic market of each country.

For the commodity price index, we use the year-on-year growth of Bloomberg's composite global commodity price index. For the indicator of G4 monetary policy rates, we extract the first principal component of policy rates in the US, the UK, the EU, and Japan. All of the obtained state variables, i.e. yield factors and macro factors, are then normalized to have zero mean and one unit variance.

Lastly it should be noted again that price level indicators or inflation are not included in this model. This is done in order to avoid the multicollinearity problem that could potentially arises should the inflation variable is included. This is because, as discussed earlier, the first principal component of yield curve is usually referred to inflation.[2] It is also not surprising that yield curve levels are closely related to monetary instrument or policy rate, since it usually works as a response function to inflation and output. Scope of this paper does not include the study of interpretation of yield curve factors, however we acknowledge earlier findings and thus use it to avoid potential misspecification.

Figures 1 to 5 depict fitted yields and term structure decomposition of Thai, Korean, Singaporean, Malaysian, and Indonesian bonds respectively. Taking these results together, term structure model of Thai government bonds has the best fitting performance. Its root mean square error (RMSE) is around 0.1, while the average RMSE from other countries' term structure models is at around 0.25. Another observation that can be drawn from these figures is that risk-neutral components govern the short-term bonds variation, while term premium components govern the long-term variation. As illustrated in the lower-right bloc of Figure 1 and Figure 2, one could also observe that the downward trend of long-term yields in Thai and Korean bonds is attributed from a decrease in their long-term term premium. This result strengthens the argument that the recent downward trend in government bond yields, especially in the more developed financial markets, is a result of lower term premium required by investors.

4. Impulse Response Analysis

4.1 Real Activity Shocks

We first explore the impact of domestic economy upon bonds market. Conceptually, a higher growth in real economy means that investors would require higher compensation for holding bonds against rising

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[2] For further details of how the first principal component of yield curve (sometimes referred as a level factor) is related to inflation or expected inflation, please see Abbritti et al. (2013) and Hordahl et al. (2006)

inflation, thus economic growth should raises yields and drives down bond prices accordingly. Our empirical results support this notion well. Figure 6 plots the impulse response of bond yields to a 1 standard deviation shock to the real activity variable of each country. Except for Indonesia, an increase in domestic activity results in an upward shift in domestic yield curves. It is found that short-maturity bonds, which are affected more by policy rate change, receive more impacts from real activity shock than longer-maturity bonds. That is, the short-end of the curve increases more than the longer-end of the curve, making yield curves becomes 'bear flattening'. This complies with the fact that short-maturity bonds are more responsive to the economic news or shocks as it is easier for investors to adjust their position in this maturity class. In terms of magnitude, Korean yield curve has the largest response. This is in line with the fact that Korea is more domestic driven compared to Asian-safe heaven like Singapore and a more commodity-driven country like Malaysia.

Figure 7 plots the dynamic responses of the state variables to a positive real activity shock. For all the countries except Indonesia, we see that their responses of real activity variable die down quite fast, ranging from 5 to 10 months. However, the responses of the level factor tend to last longer and adjust back incompletely. The results comply with Evans and Marshall (2001), which also showed that macro factors have substantial and "persistent" effect on the level of the term structure. Previous evidence such as Rudebusch (2002b) and Clarida et al. (2000) suggested that change in monetary path tends to occur gradually. This also explains why the level factor, which typically exposed to policy rate, adjusts gradually and sometimes incompletely.

Intuitively, when there is a positive real activity shock to the economy, policy rate will respond in order to adjust the economy to its equilibrium. The first principal component of the yield curve - level factor- would adjust, in this case, higher. This eventually drives up the yield curve. In investors' perspective, a higher growth in the economy reflects that investors would require higher compensation for holding bonds against rising inflation. This force thus raises the required rate of return and thus driving up yield curve.

For Indonesia, the result is different as we see negative responds from real activity shock. The reason is that a change in domestic economic activity induces a change in bond flows which in turn affects yield curve. Figure 8a plots the bond flows (as a percentage of net assets) that come into the country with their yields. We use the country bond flows data from EPFR Global (www.epfr.com) which includes fund flows and country allocations from fund Managers, fund administrators, custodians, trust, advisors and fund companies.

We can inspect a negative relationship between bond flow and Indonesian yields with the correlation at around -0.40. Looking at the correlation between bond flows and economic activity variable in Figure 8b, we see a positive relationship. Figure 8c illustrates the evidence that bond flows have a negative correlation with yield curve's level factor. So the plausible explanation is that when there is a positive shock to real activity, foreign flows come into the country driving down their level factor and thus decreasing their yields.

Figure 9 illustrates the decomposition of the shock into risk-neutral and term premium channel. We can see that the shock operates through risk-neutral channel, i.e. policy channel, for the short-maturity bonds. This is because this channel is derived by compounding expected short rates into longer maturity yields. So when there is a shock that induce a change in policy rate expectation, this channel would incur a direct impact making short-term bonds the most affected. For long-maturity bonds, the shocks mostly operate through term premium channel, which reflects the investors' risk-aversion characteristic. Therefore, the finding that risk-neutral channel governs the movement in the short-end, while term premium channel governs the movement in the long-end of the curves is also applied for the emerging markets' sovereign bond yields.

4.2 External Shock

We can examine the dynamic response and co-movement of yields across countries using standardized external shocks, e.g. commodity price, and DM policy rates. The size of each respective shock is specified to be equal across different countries so that one could compare the impacts cross-sectionally.

Commodity Shock

We now turn to the first external shock, i.e. commodity price. Figure 10 plots the impulse response of yield curves to a unit shock in the global commodity price. One unit shock in commodity price causes yield curves of every country to shift upward. The curves are also bear-flatten for every country except for Singapore that has a parallel shift. Looking at the dynamics of the responses, we see that they peak at around a year after the shocks, and die down mostly in four years. Compared the responses across maturity, one can observe that short-maturity bonds are more affected by the shocks. For Thai sovereign bonds, the one-year bond has the response peaking at around 22 basis points, while the longer maturity bond, e.g. 10-years bond, has the response peaking at only 9 basis points.

Figure 10 also shows that Indonesian bonds have the largest response peaking at around 38 basis points for one-year bond and around 27 basis points for the 10-years bond. This reflects that commodity cycle matters a lot for the Indonesian bonds market. As Indonesia relies more on exporting commodity compared to peers, investors that has put their position on Indonesian sovereign bonds will adjust their portfolio following the change in trend of the commodity cycle. For a country like Singapore that its growth does not rely on commodity, the response is immaterialized. For Korean and Malaysian bonds, we see that the responses are mostly in the short-maturity bonds, ranging from 20 basis points in Malaysia to 28 basis points in Korea. For their long term bonds, the responses are insignificant.

We also observe some co-movement between the long-end yields of Thai bonds and Malaysian bonds. Particularly, after the shock for half a year, the responses of 10-year Thai bond and 10-year Malaysian bond are at around 10 basis points. We also see further that the responses come mostly through the term premium channel. This reflects that for the investors who allocate their funds globally, the external shock like commodity price do affect the price of risk that investors consider and thus the impact can spread across different countries through term premium required by investors. Therefore we tend to see the co-movement in the long-end yields through term premium channel. Figure 12 illustrates the decomposition of the shocks into each channel. The results confirm that the shock operates through term premium in the long-end yields. For the short-term yields, the shocks operate through risk-neutral or policy channel. This finding is similar to the result shown in the case of real activity shock.

One can observe that the response of yield curves dies down almost completely. This can be explained by looking at the dynamic of underlying factors. Figure 11 shows that a commodity shock increases the level factor in every country and it dies down at around 3-years time in most countries, while the response of the commodity factor itself dies down at around 2-years time. This is because investors interpret the shock as a temporary shock to the commodity cycle and so, over time, it will adjust back to the trend. Therefore, investors adjust their positions accordingly, which is reflected in the dynamic of the first principal component of yields or ‘level’ factor.

DM Monetary Shock

We now turn to the second external shock, the DM monetary policy rate. Figure 13 plots the impulse response of yield curves to a (normalized) unit shock in the DM policy rate. For Thailand, Korea, Malaysia, and Indonesia, a unit shock in policy rate causes their yield curves to shift up. However, the change in slope is varied across countries. It can be observed that, for Korea, short-maturity bonds are more responsive than long-maturity bonds, just like previous cases with real activity and commodity price shock. Compared among the five studied countries, the response is largest in Korea. For short-end yields, it peaks at around 150 basis points, one year and a half after the shock. For long-end bonds, it peaks at around 110 basis points after a year and a half as well. We can observe a similar result in Indonesian bonds, but the responses are homogeneous across maturities peaking at around 110 basis points. Only in Thailand that has larger responses in longer maturity bonds, which peak at around 55 basis points. For Malaysian bonds, we see only slight positive responses, particularly less than 10 basis points.

In term of co-movement of the bond yields across countries, we see that the 10-year Indonesian bonds have a co-move response with the 10-year Korean bonds, particularly 110 basis points at their peaks. This result, as shown in Figure 13 reaffirms a few things we have mentioned. First, the co-movement caused by external shocks typically appears through the adjustment of term premium in the long-end bonds, where investors re-evaluate the price of risks after the shock on external factors. Second, the magnitude of the co-movement in the long end is smaller than the individual responses that occurred through risk-neutral channel in the short-end.

For the countries with significant positive responses, namely Korea, Thailand, and Indonesia, we can observe that the responses of yields overshoot and do not die down completely. This is the consequence of the dynamic of underlying state variables, as shown in Figure 14. Looking at the dynamics of the DM interest rate itself, we see that the effect is apparently persistent as only 30% of the initial shock has faded over five years. Looking at the level factors response, its dynamic also corresponds with DM rate responses closely. That is, only 30-40% of the responses die down, causing the yield curve shift to persist. This is also an evidence that interest rate differential between countries does induce the dynamic of the level factors, which in turn affect the movement in yields.

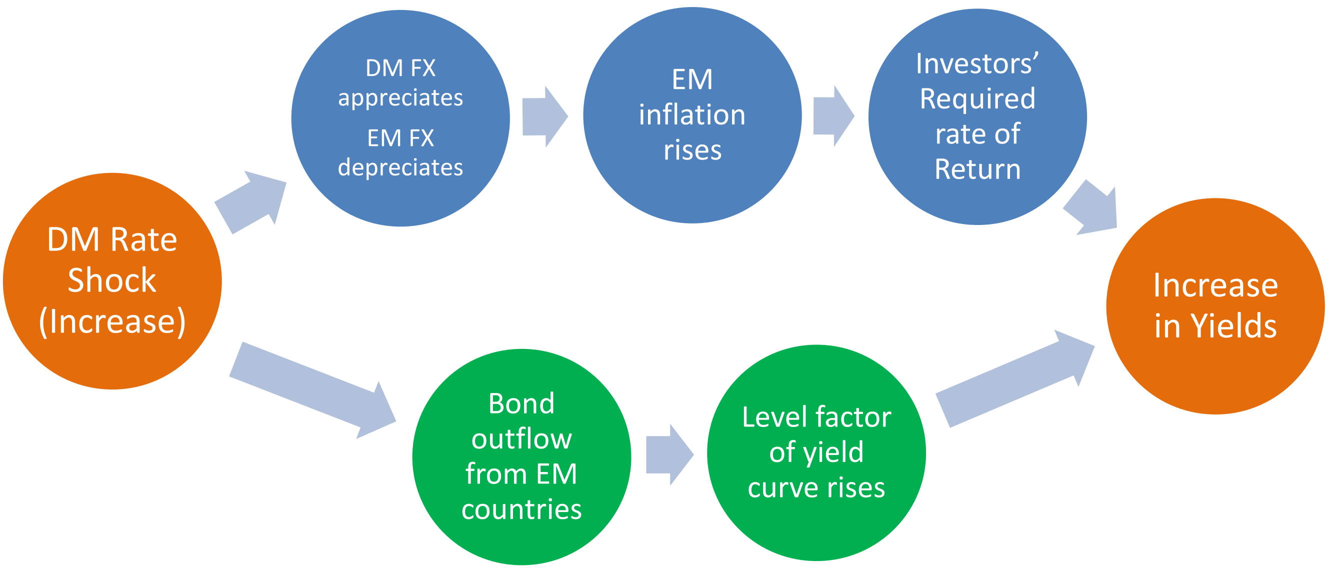


Chart 1: Impacts from DM interest rate shock

Broadly, a shock (an increase) in DM policy rate could affect the movement in EM yields in two channels. Referring to Chart 1 -which illustrates channels in which impacts from developed countries' policy rate shock goes through- the first channel is from inflationary pressure. A hike in DM policy rate would make their currency appreciated, resulting in a relative depreciation of EM currency. This effectively has an impact on relative inflation between DM and EM countries. Price level in EM countries will be higher as goods and services from DM countries are more expensive. This inflationary force would drive yield level in the EM countries as investors would require higher compensation for holding bonds in the time with rising inflation. We eventually see yields soaring up.

The second force relates the yield movement to the international flow between countries. An increase in DM policy rate could trigger an outflow from EM bond markets. This effectively influences the level factor of yield curve and thus driving up their yields. According to data from EPFR, Korea and Indonesia have the highest cumulative bond flow (in US$) among the five studied countries. The impulse response plotted in Figure 13 also shows that these two countries have the largest responses. Figure 16 plots the first principal component of Korean and Indonesian yield curves against the foreign flow into each country as a percentage of net assets. We find that there is a negative correlation between the PC1 and foreign flow, especially in the period of abrupt change in foreign flow as highlighted in the figure. This could provide an evidence for the hypothesis that foreign flow into the EM countries could have an impact for the movement in yield as well. However, we encourage for further study to explore the relationship between foreign flows and yield curves movement.

For Singapore, we see a negative response from yield curve. This is not surprising since Singapore does not share the same characteristics as the other EM countries. Unlike the other four EM countries, Singapore use exchange rate band as a monetary policy target instead of inflation rate. So when the DM policy rate such as the US fed fund rate is altered, Singapore tend to adjust their official rate in order to keep the exchange rate stable in the band. Therefore, the inflationary pressure channel does not operate here as the relative exchange rate does not change. Moreover, Singaporean bonds, which is considered to have low risk, do not offer high yields like other EM Asia bonds. Its characteristics is perceived more as a DM bonds in Asia. So when DM rate is increased investors do not withdraw their positions out of the country, but instead, there tends to be an inflow coming back to Singaporean bonds since the authority would increase their official rate following DM countries. As a result, we see the level factor dropping, making their yields decreased.

5. Conclusion and Implications

This paper applies the regression-based method, proposed by ACM (2013), for estimating affine term structure models. We study sovereign bonds issued by the government of Thailand, Korea, Singapore, Malaysia, and Indonesia during 2002-2015 period. We find that both yield curve factors (principal components) and macroeconomic variables help explaining the dynamics of yield curves. Except for Indonesia, all others yields have positive responses following the shock in domestic real activity. Conceptually, a better economic intuition should increase yield level. For the case of Indonesia, better economic condition could on the other way trigger foreign flow into their sovereign bond market causing yield curve to fall.

We have also examined the impact of external shocks upon domestic bond yields in each country. Most results comply with earlier finding in the US and the EU countries. Commodity shock causes yield curves of every country to shift upward, most of which is bear-flattened. The impact is largest in commodity-oriented country like Indonesia. For the country that does not rely on commodity like Singapore, the response is immaterial. In response to a normalized shock, there is also co-movement in yield between Thailand's and Malaysia's 10-year yields. This co-movement exists mostly through the term premium channel.

Another external shock that was examined is the change in policy rates in developed markets, namely G4 countries. We found that an increase in DM policy rate causes yield curves of every country, except for Singapore, to shift up. The largest response is in Korea while the smallest response is in Malaysia. In term of magnitude, this shock induces larger change compared to commodity shock. This is because it relates to two forces, which are (i) the additional compensation required by investors and (ii) the investment flow induced by change in relative interest rates between countries. For Singapore, we see negative responses because, unlike others, their monetary target is exchange rate band which would result in a rising domestic interest rate following DM rate hike. Lastly, we also find evidence of the positive co-movement in yield between Korea's and Indonesia's 10-year yields.

The evidences suggest that, following macroeconomic shock, the responses of yield curve's level factor are persistent and sometimes do not adjust back completely, reiterating the consequence of policy rate inertia. Moreover, the yield response of each tenor is carried upon different channels. For short-term bonds, responses are mostly carried by the risk-neutral channel. For long-term bonds, responses are mostly carried by the term premium channel. Risk-neutral channel reflects the expected future short rates that are priced by investors. This channel is derived by compounding short rates into longer maturity rates, using expectation hypothesis. The adjustment in this channel thus reflects investor's view upon future rates, taking into account the information today. The change in monetary policy usually has a direct impact in this channel as the short-end yield is typically anchored to the policy rate, therefore in some literature it is named as policy channel. The impact upon this channel is found to be relatively large; however, we do not find evidence of co-movement in yields through this channel.

Term premium channel, on the other hand, reflects the investors' risk perception in the system. When the external shock hits, there would be an adjustment in price of risk that could have an impact spilled across different countries simultaneously. As the external factors affect this "perception of risk", it could induce the co-movement in yields in some countries. Despite its spill-over effects, the magnitude of the impact is relatively small in this channel.

A few implications can be drawn from this study. For investors, our evidence of co-movement in some EM bond yields provides a proof that investors should diversify their portfolios to alleviate the impacts of the external shocks. Our suggestion would be to relocate the part of the funds to different asset class across the globe, such as investing in corporate bonds or equity, or bonds in Latin America countries.

Our empirical results also suggest that there would be challenges for the central banks of the open-economy countries to manage stability in their bond markets as they would have to face with difficulties in overseeing risk factors (both domestically and externally) that could affect investors' risk perception. Elevating complexity even further, those factors are likely to cause spill-over across countries, making yield curves in different markets to co-move. For instance, even though Thailand and Korea are not commodity-exporting countries, a shock in commodity price can still affect their bond yields and create the co-movement among their long-term yields.

For future studies, there are a few issues in this paper that could be analyzed and explore further. One is to study and solve the interpretation perplex between yield factors and macro factors. The other issue is to study deeper into the relationship between flows and dynamics of yield curves.

Reference

Abbritti, M., S. Dell'Erba, A. Moreno, and S. Sola (2013). Global Factors in the Term Structure of Interest Rates. IMF Working Papers 13/223, International Monetary Fund.

Adrian, T., R. K. Crump, and E. Moench (2013). Pricing the term structure with linear regressions. Journal of Financial Economics 110, 110.138.

Abbrahams M., T. Adrian, R. K. Crump, and E. Moench (2013). Decomposing Real and Nominal Yield Curves. Staff Report No. 570, Federal Reserve Bank of New York

Ang, A. and M. Piazzesi (2003). A no-arbitrage vector autoregression of term structure dynamics with macroeconomic and latent variables. Journal of Monetary Economics 50, 745.787.

Bauer, M. D., and G. D. Rudebusch (2014). Monetary policy expectations at the zero lower bound. Federal Reserve Bank of San Francisco Working Paper 2013-18.

Bauer, M. D., G. D. Rudebusch, and J. C. Wu (2012). Correcting estimation bias in dynamic term structure models. Journal of Business & Economic Statistics 30, 454.467.

Clarida R., J. Gali, and M. Gertler. (2000). Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory. Quarterly Journal of Economics 115, 147.180.

Cochrane, J. H. and M. Piazessi (2005). Bond risk premia. American Economic Review 95, 138.160.

Coroneo L., D. Giannone, and M. Modugno (2013). Unspanned Macroeconomic Factors in the Yields Curve. Working Papers ECARES 07, Universite Libre de Bruxelles.

Disyatat, P., and P. Rungcharoenkitkul (2015). Monetary policy and financial spillovers: losing traction? BIS Working Papers 518

Dufee, G. R. (2002). Term premia and interest rate forecasts in affine models. Journal of Finance 57, 405.443.

Dufee, G. R. (2011). Information in (and not in) the term structure. Review of Financial Studies 24, 2895.2934.

Estrella, A. (2005). Why Does the Yield Curve Predict Output and Inflation? The Economic Journal 115, No. 505, 722.744.

Evans, C. L., and D. A. Marshall (2007). Economic determinants of the nominal treasury yield curve. Journal of Monetary Economics 54, 1986.2003.

Hamilton, J. D. and J. C. Wu (2012). Identifcation and estimation of a¢ ne term structure models. Journal of Econometrics 168, 315.331.

Hördahl, P., O. Tristani, and D. Vestin (2006). A joint econometric model of macro-economic and term structure dynamics, Journal of Econometrics 131, 405.444.

Joslin, S., M. A. Priebsch, and K. J. Singleton (2014). Risk premiums in dynamic term structure models with unspanned macro risks. Journal of Finance 69, 1197.1233.

Joslin, S., et al. (2013). Why Gaussian macro-finance term structure models are (nearly) unconstrained factor-VARs. Journal of Financial Economics 109, 604.622.

Joslin, S., K. J. Singleton, and H. Zhu (2011). A new perspective on Gaussian dynamic term structure models. Review of Financial Studies 24, 926.970.

Jotikasthira, C., A. Le, and C. Lundblad (2010). Why do term structures in different currencies co-move? Journal of Financial Economics 115 (1), 58.83.

Kozicki, S., and P.A. Tinsley (2001), Shifting Endpoints in the Term Structure of Interest Rates. Journal of Monetary Economics 47, 613.652.

Ludvigson, S.C., and S. Ng (2009). Macro factors in bond risk premia. Review of Financial Studies 22(12), 5027

Malik, S. and A. Meldrum (2014). Evaluating the robustness of UK term structure decompositions using linear regression methods. Journal of Banking and Finance 67, 85.102.

Moench, E. (2008). Forecasting the yield curve in a data-rich environment: A no-arbitrage factor- augmented VAR approach. Journal of Econometrics 146, 26.43.

Piazzesi, M. (2003). Handbook of Financial Econometrics, Volume 1, Chapter 12 Affine term structure models, pp. 691.758. Elsevier: Amsterdam, Netherlands.

Rudebusch, G. D. (2002b). Term Structure Evidence on Interest Rate Smoothing and Monetary Policy Inertia. Journal of Monetary Economics 49, 1161.1187.

Rudebusch G. D., and T. Wu (2008). A Macro-Finance Model of the Term Structure, Monetary Policy, and the Economy. The Economic Journal 118, 906.926.

Wright, J. H. (2011). Term premia and inflation uncertainty: empirical evidence from an international panel dataset. American Economic Review 101, 1514.1534

Table 1: Extracting Real Economic Activity factors

Country	Number of factors used for PCA	Economic Activity Variables
Thailand	4	MPI, Coincidence index, Retail Sales, Business sentiment index
Korea	5	Cap Utilization, IP, Construction Orders, Manu business Survey, Employment
Singapore	3	New order, PMI, Retail Sales
Indonesia	4	IP, Household Debt, Capital Adequacy ratio, NPL
Malaysia	3	Coincident economics indicator, Wage growth, Household credit

Note: this table lists the underlying economic factors that were used for extracting principal component, e.g. “Real Activity” factor, in each country

Figure 1: Fitted Yield & Term Structure Decomposition: Thailand

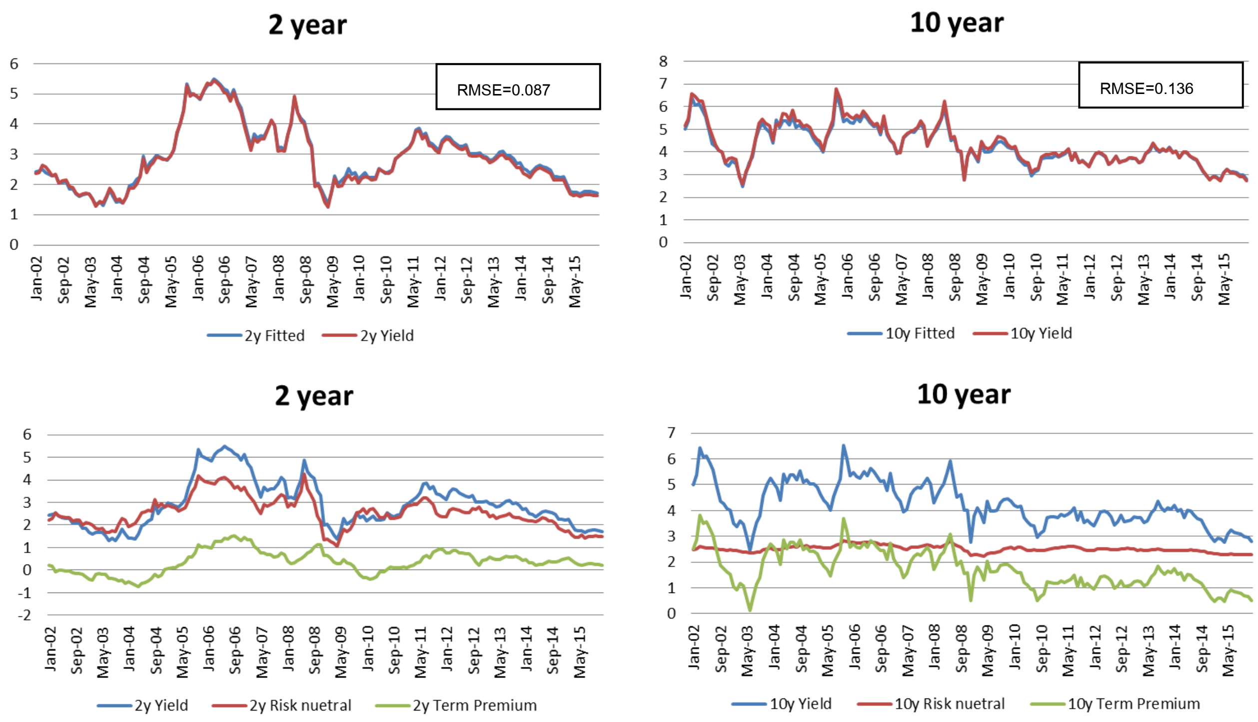


Figure 2: Fitted Yield & Term Structure Decomposition: Korea

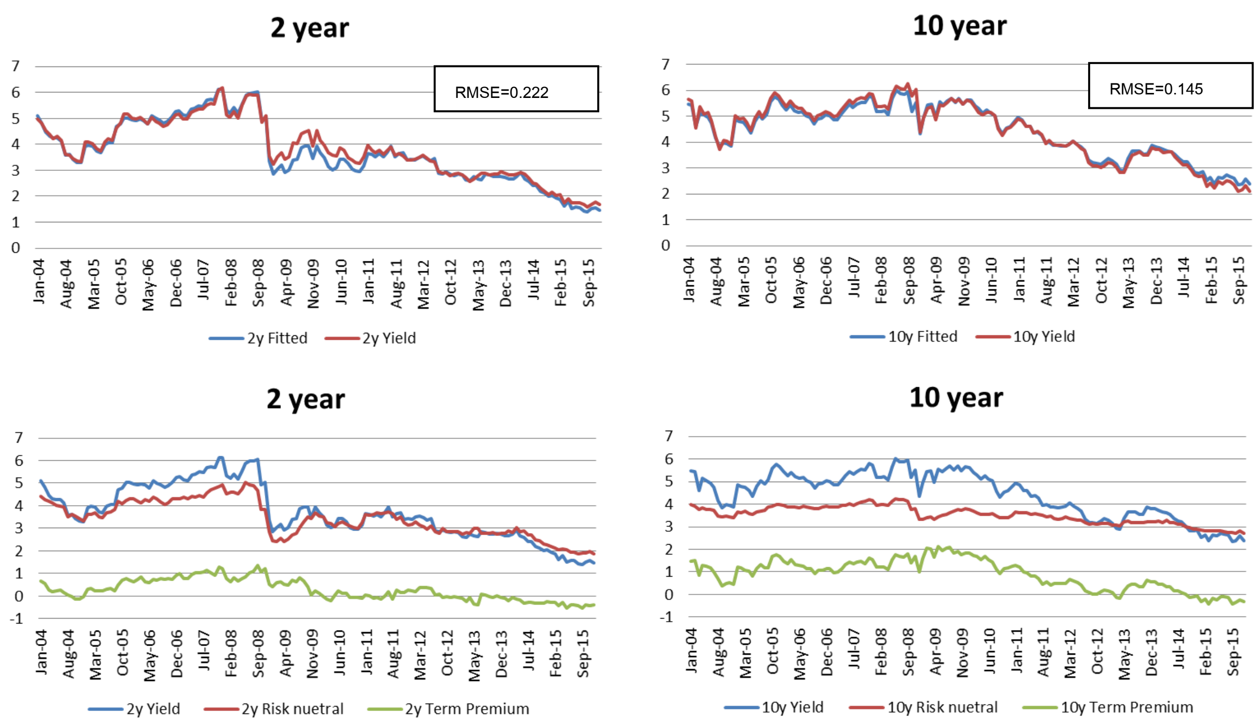


Figure 3: Fitted Yield & Term Structure Decomposition: Singapore

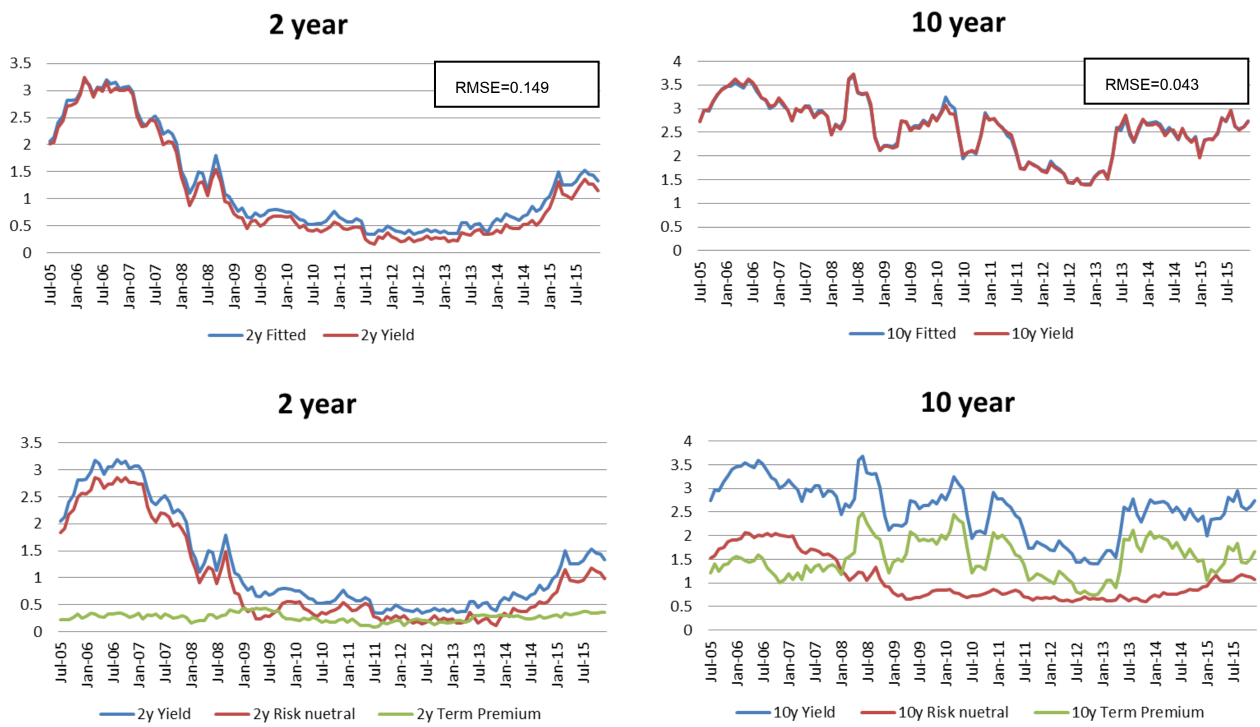


Figure 4: Fitted Yield & Term Structure Decomposition: Malaysia

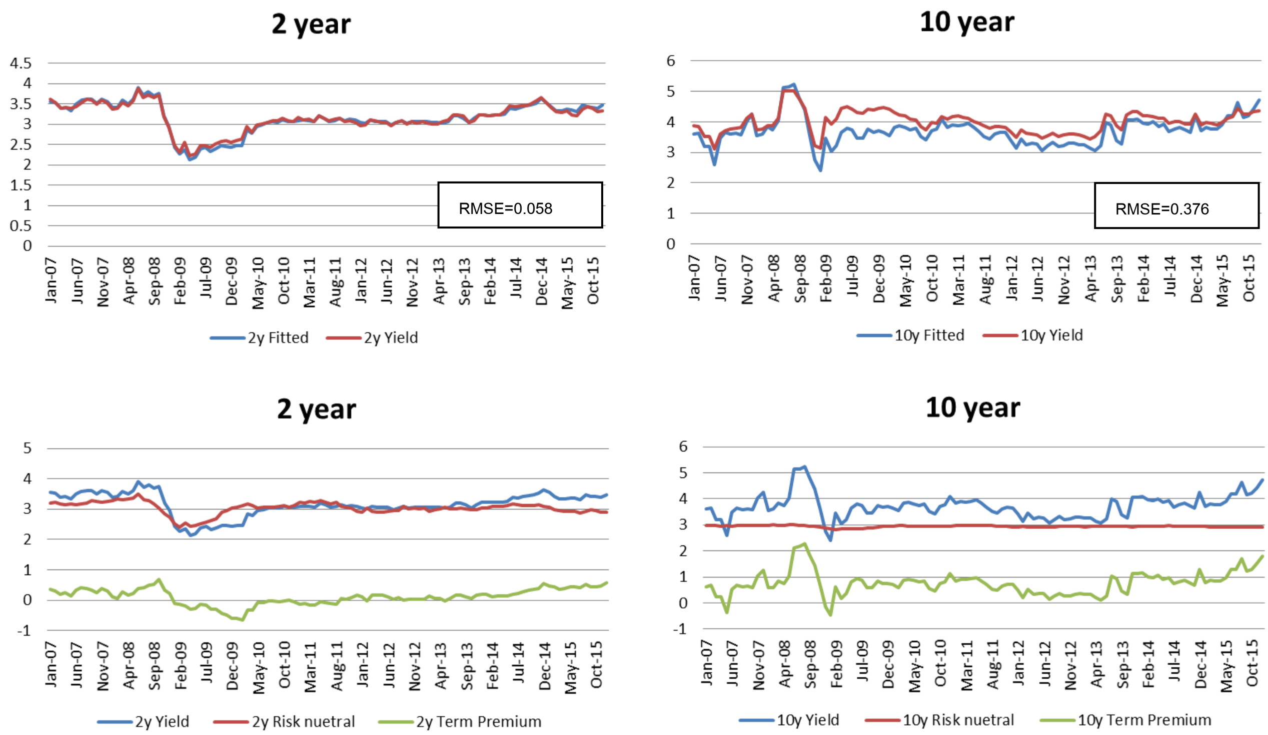


Figure 5: Fitted Yield & Term Structure Decomposition: Indonesia

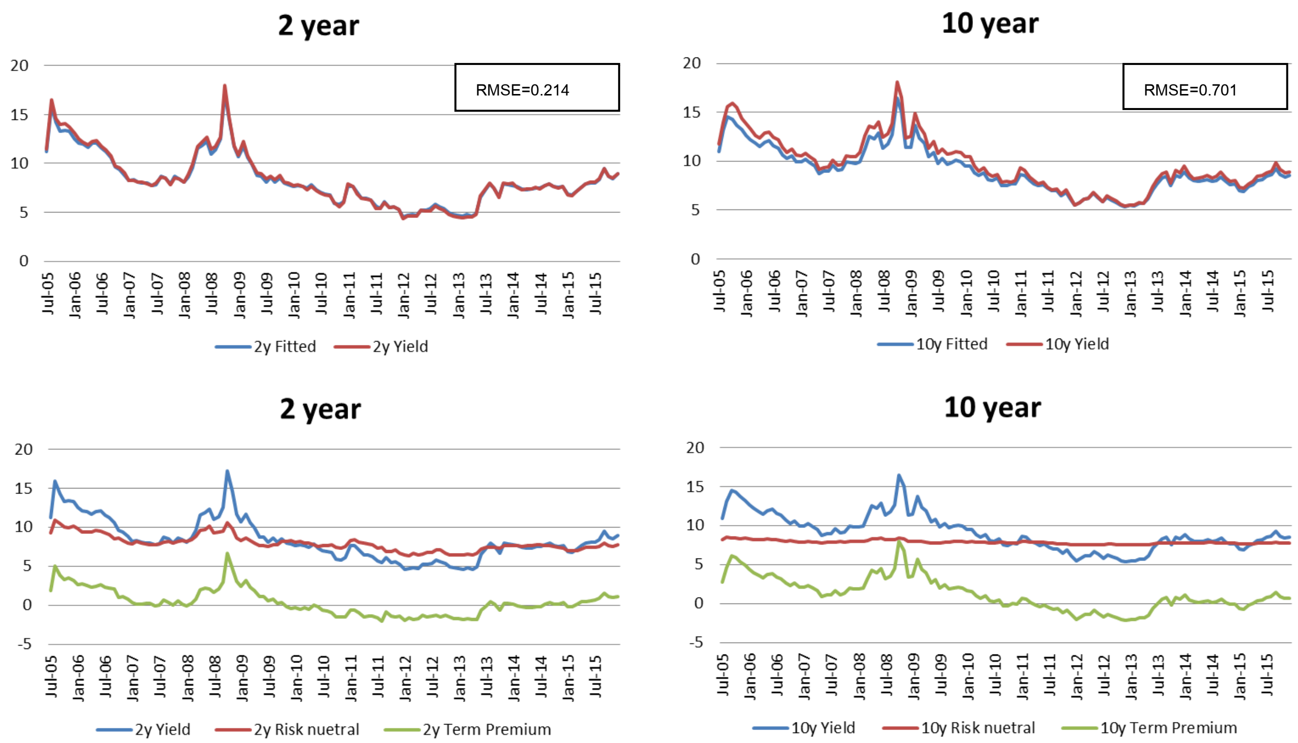
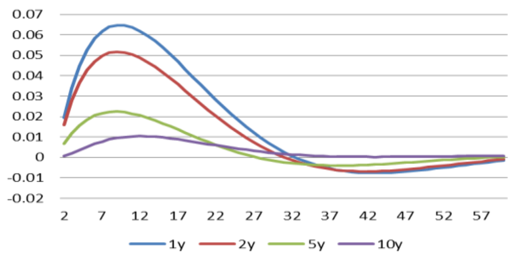
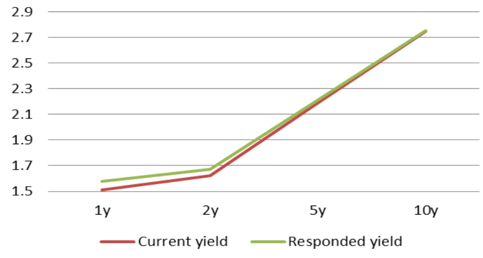
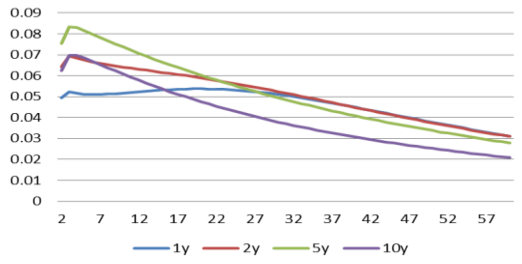
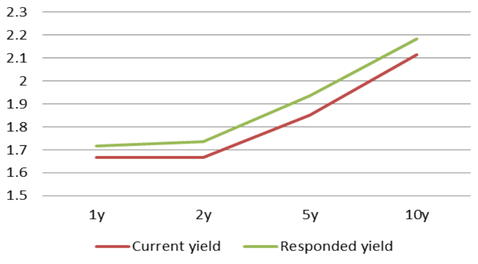
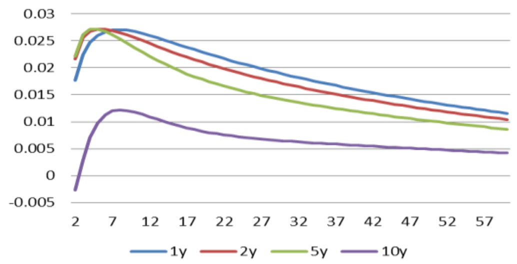
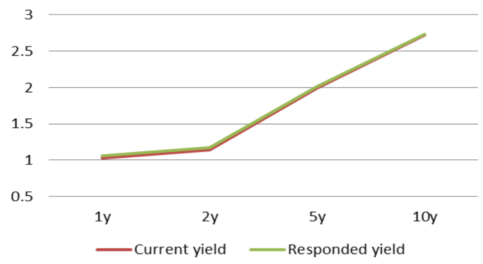
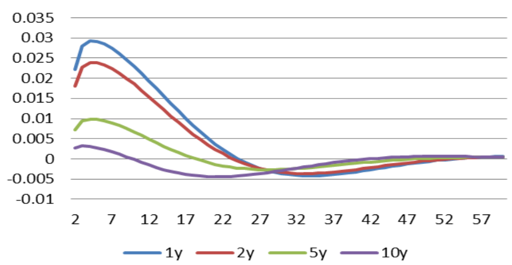
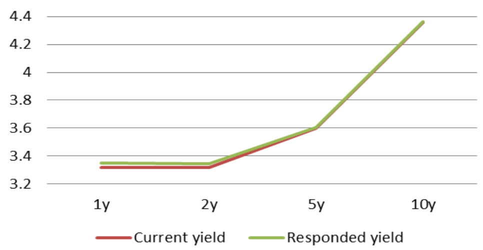
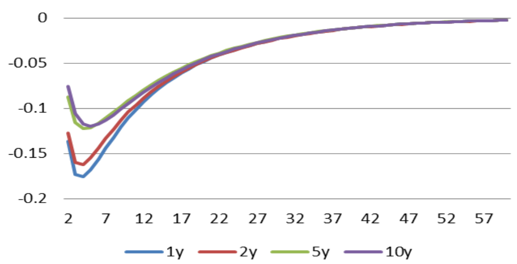
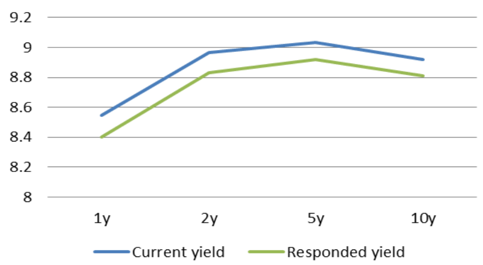
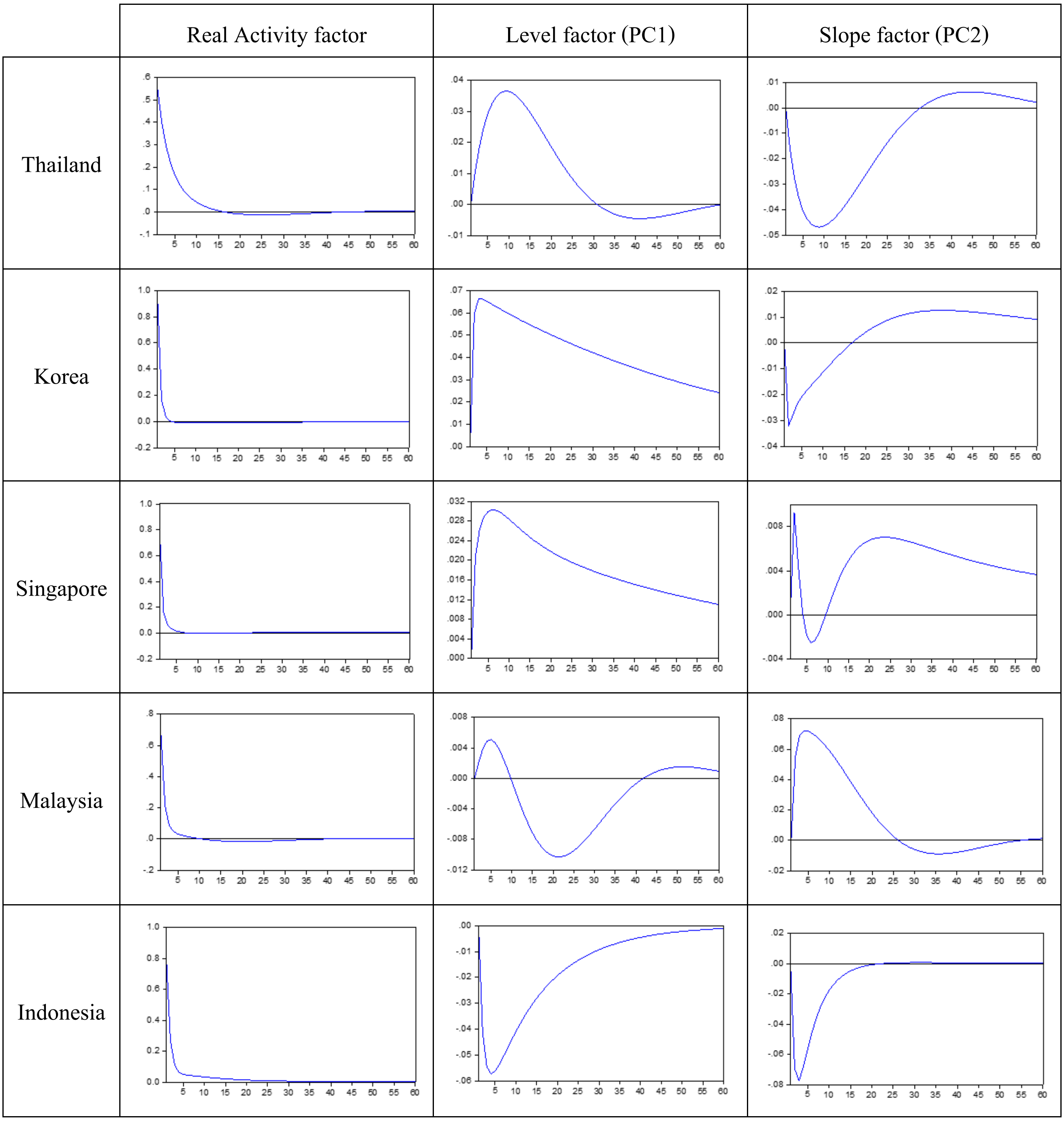


Figure 6: Real Activity Shock: Yields Impulse Response

	Yield Impulse Responses	Yield Curve Change
Thailand		
Korea		
Singapore		
Malaysia		
Indonesia		

Note: Figures on the left column illustrate the impulse response of yields for maturity of 1,2, 5, and 10 years. Figures on the right column illustrate the change in shape of yield curves following the shock. The x-axis corresponds to maturities; the y-axis corresponds to yields in percentage point. The ‘responded yields’ is taken from the period with the largest responds.

Figure 7: Real Activity Shock: State Variables Responds



Note: Each sub-figure illustrates the impulse responds of the selected state variables following the real activity shock in each country. Column on the left is the response of real activity factor. Column in the center is the response of level factor. And column on the right is the response of slope factor.

Figure 8a: Indonesian Sovereign Yields and Bond Flows

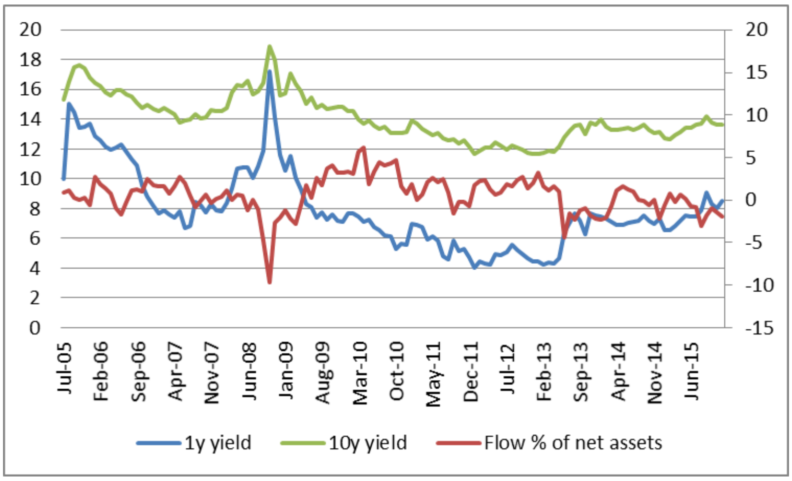


Figure 8b: Indonesian Real Economic Factor and Bond Flows

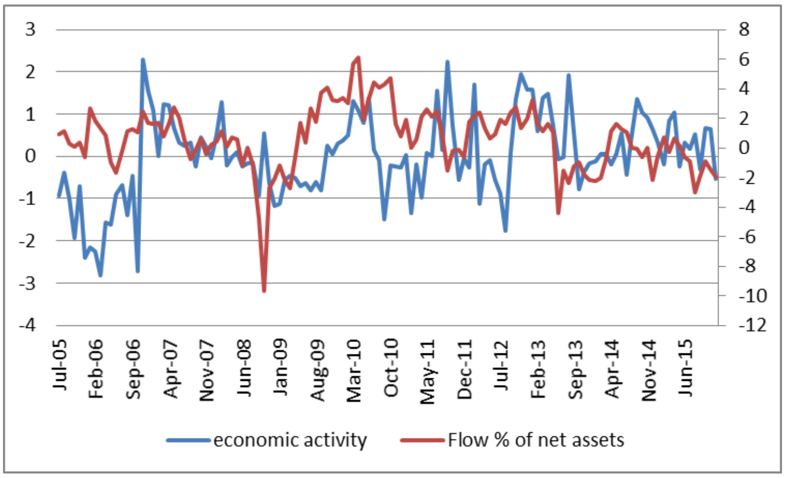


Figure 8c: Indonesian Yield's Level Factor and Bond Flows

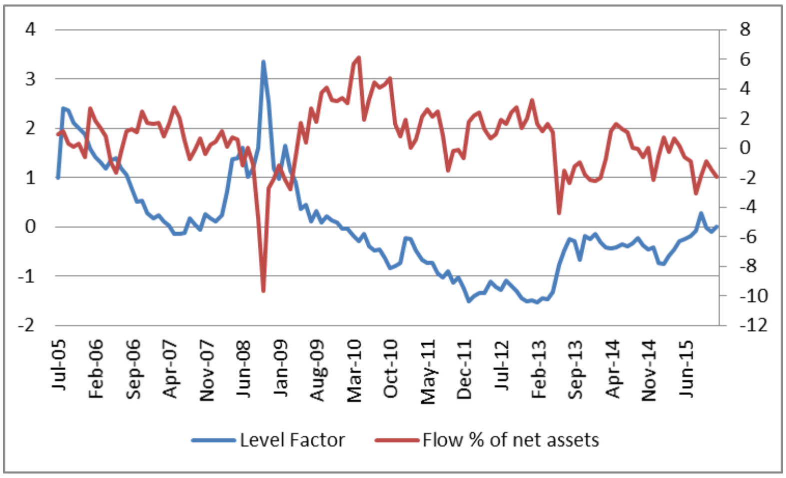


Figure 9: Real Activity Shock: Responds Decomposition

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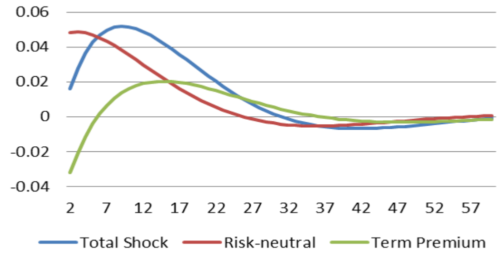
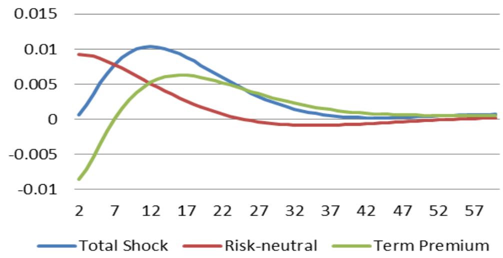
<tr><td>Thailand</td><td>
</td><td>
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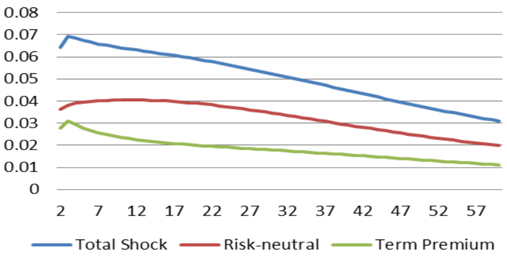
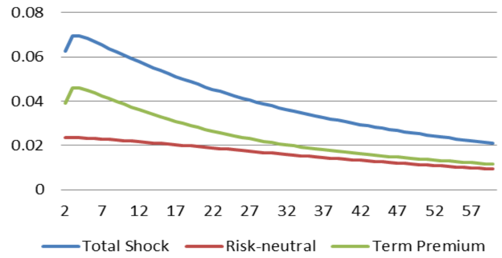
<tr><td>Korea</td><td>
</td><td>
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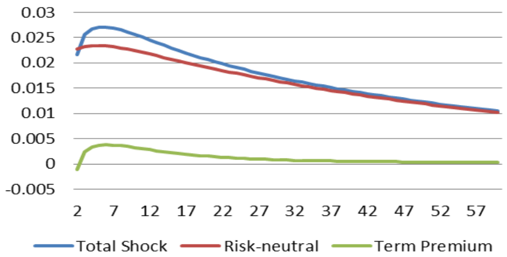
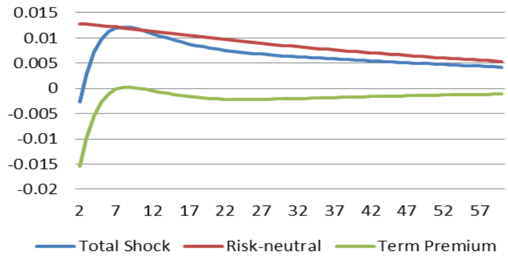
<tr><td>Singapore</td><td>
</td><td>
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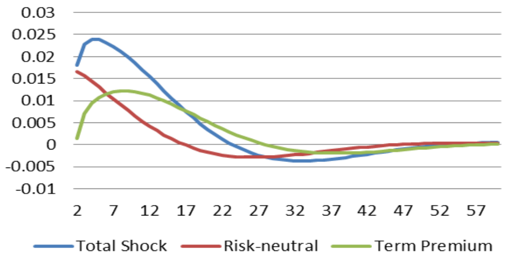
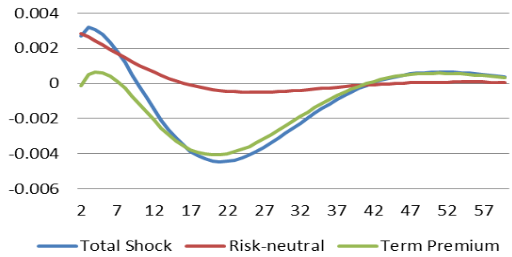
<tr><td>Malaysia</td><td>
</td><td>
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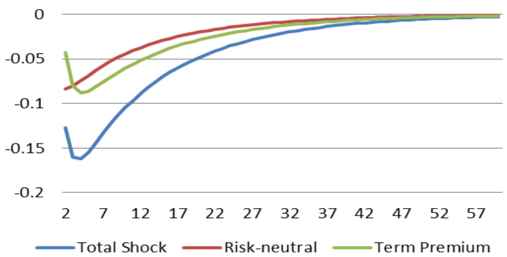
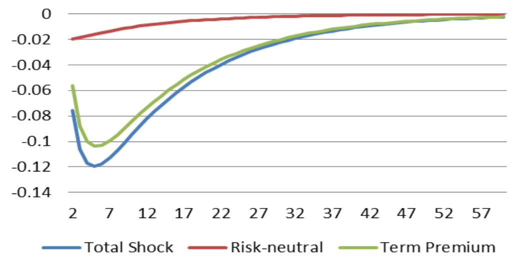
<tr><td>Indonesia</td><td>
</td><td>
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Note: Each figure illustrates the channel decomposition of the response, following the real activity shock. Red line is the impact incurred in risk-neutral channel. Green line is the impact incurred in term premium channel. Blue line is the sum of impact in both channels.

Figure 10: Commodity Price Shock: Yields Impulse Response

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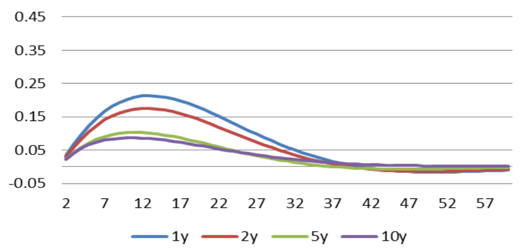

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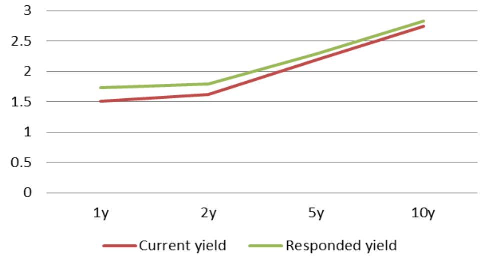

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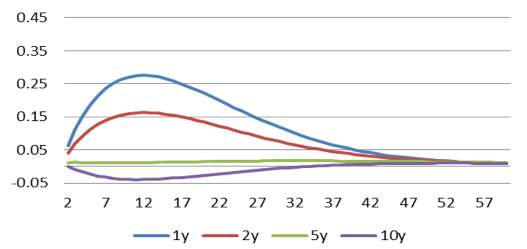

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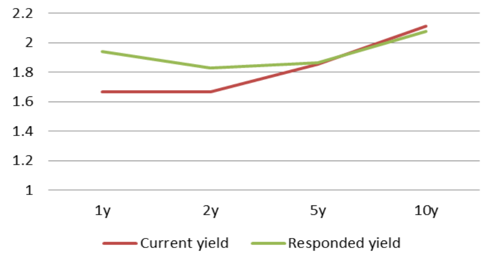

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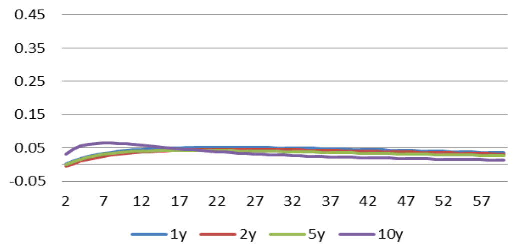

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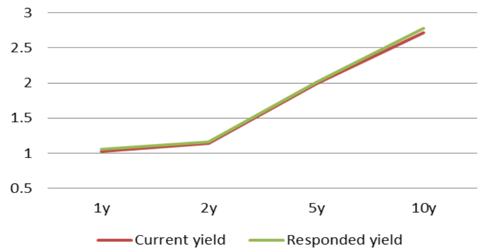

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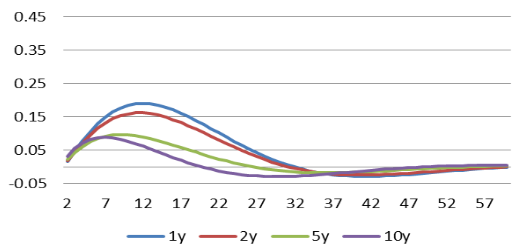

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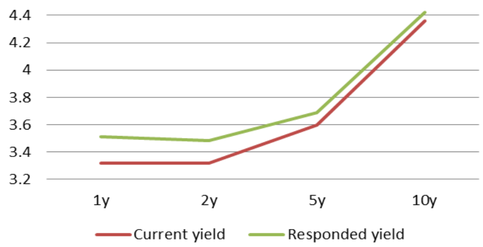

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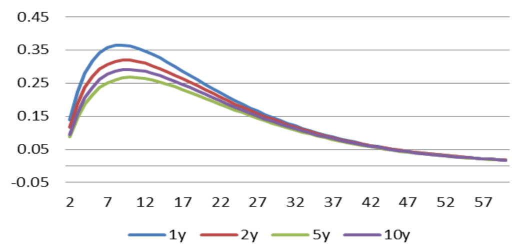

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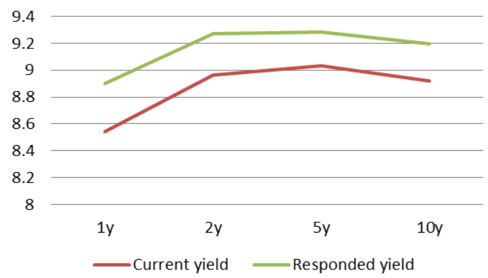
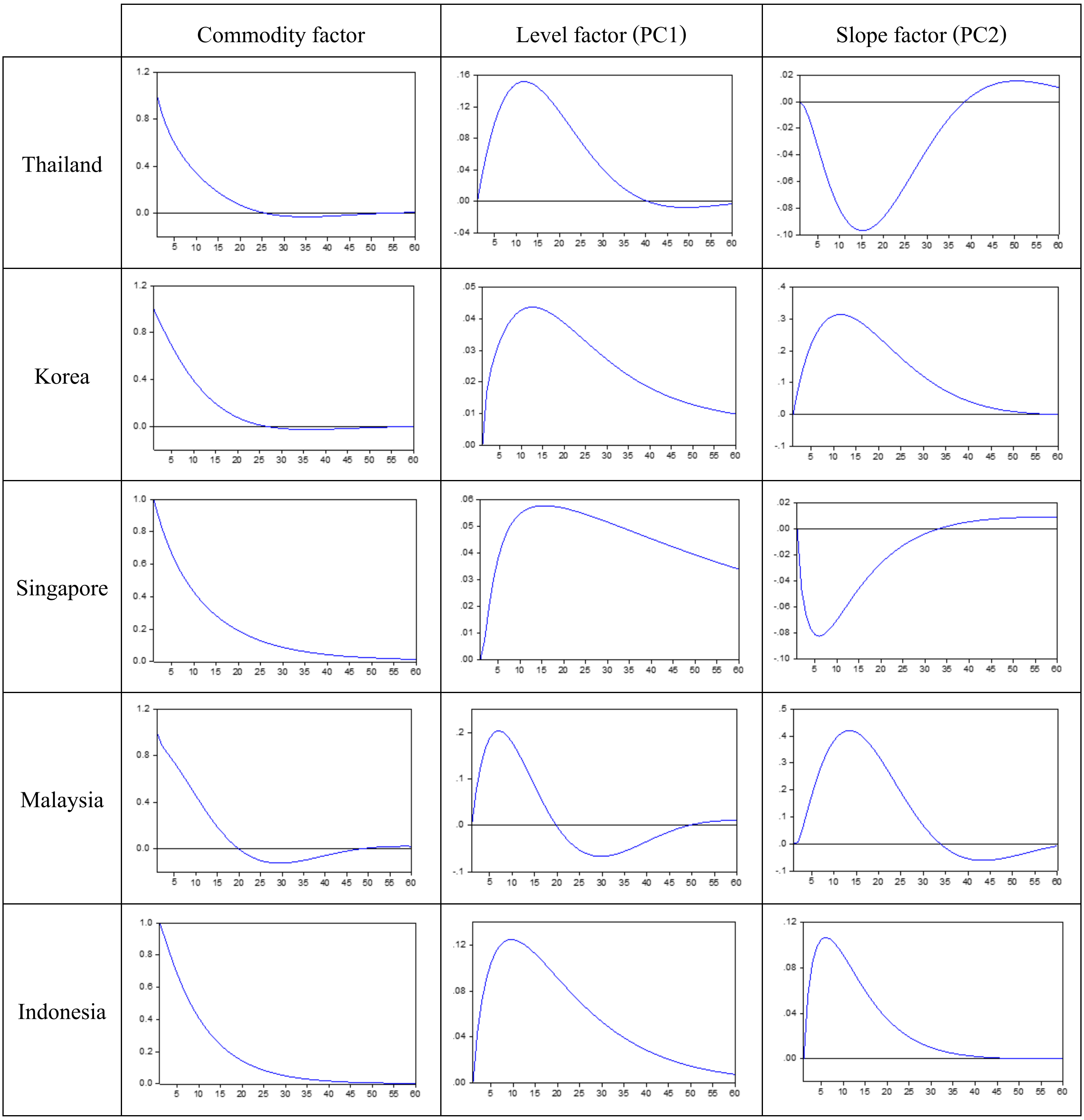


</td></tr>
</table>

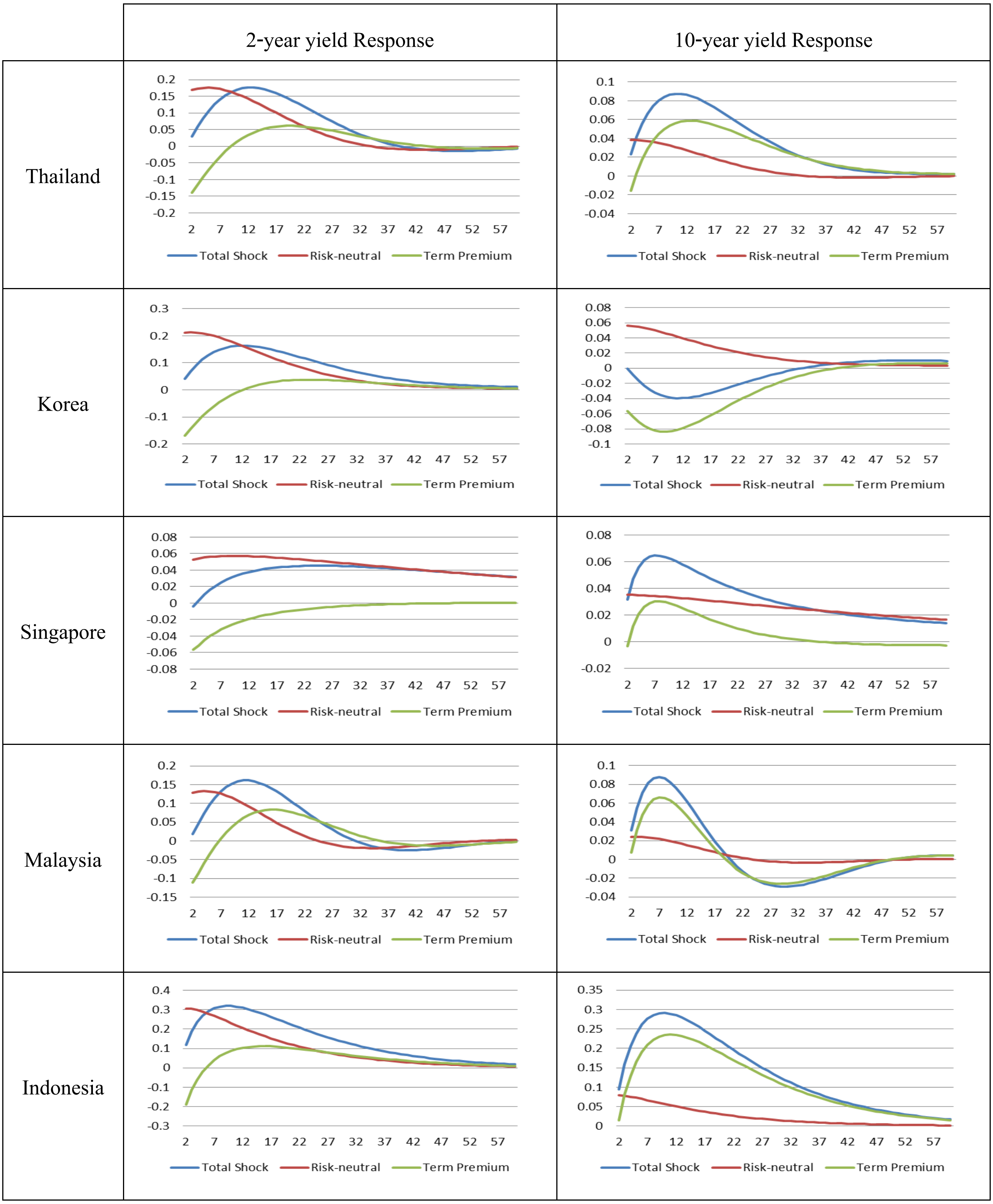
Note: Figures on the left column illustrate the impulse response of yields (maturity of 1,2, 5, and 10 years) to a unit shock in commodity price. Figures on the right column illustrate the change in shape of yield curves following the shock. The x-axis corresponds to maturities; the y-axis corresponds to yields in percentage point. The 'responded yields' is taken from the period with the largest responds.

Figure 11: Commodity Price Shock: State Variables Responds



Note: Each sub-figure illustrates the impulse responds of the selected state variables following the commodity shock in each country. Column on the left is the response of commodity factor. Column in the center is the response of level factor. And column on the right is the response of slope factor.

Figure 12: Commodity Price Shock: Responds Decomposition



Note: Each figure illustrates the channel decomposition of the response, following the commodity price shock. Red line is the impact incurred in risk-neutral channel. Green line is the impact incurred in term premium channel. Blue line is the sum of impact in both channels.

Figure 13: DM Policy Rate Shock: Yields Impulse Response

<table>
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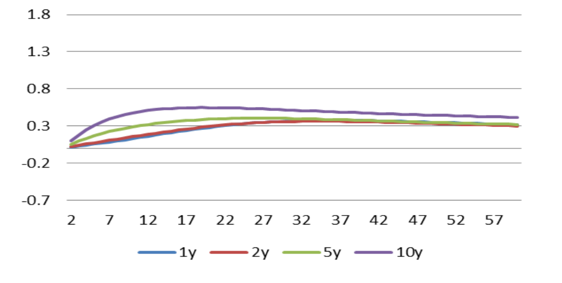
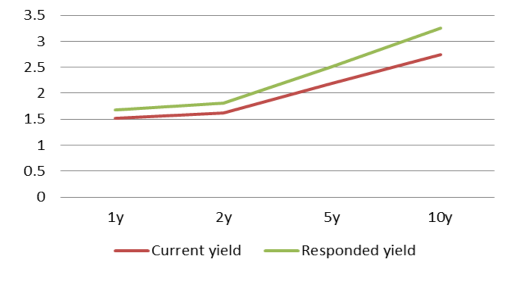
<tr><td>Thailand</td><td>
</td><td>
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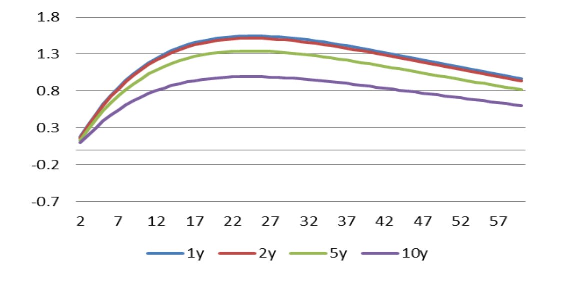
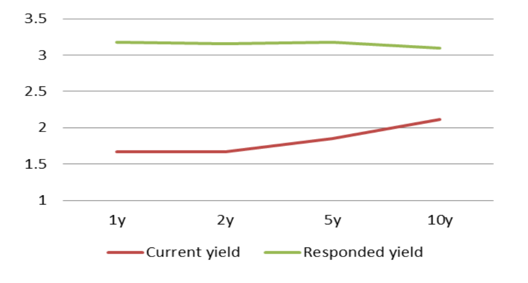
<tr><td>Korea</td><td>
</td><td>
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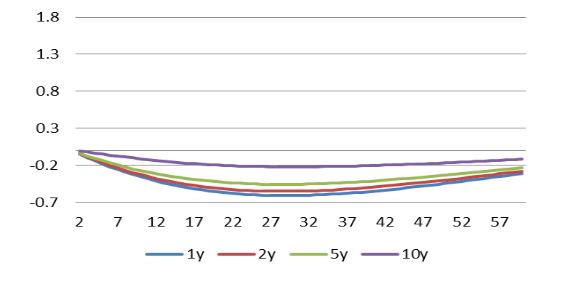
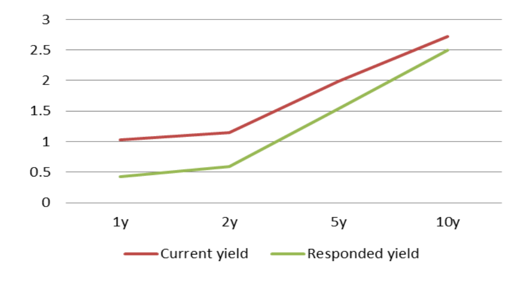
<tr><td>Singapore</td><td>
</td><td>
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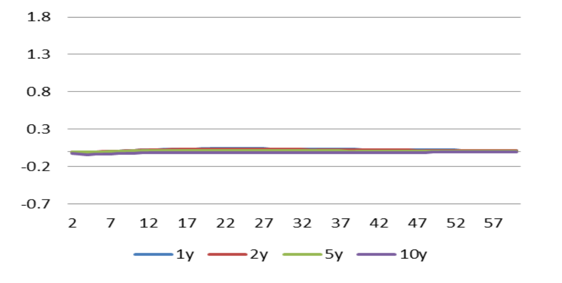
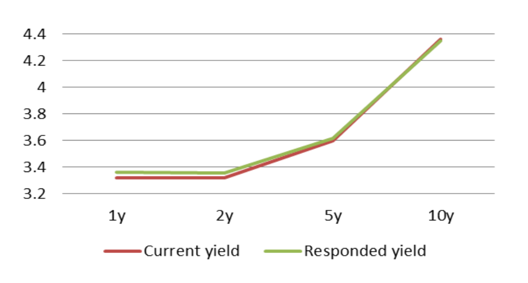
<tr><td>Malaysia</td><td>
</td><td>
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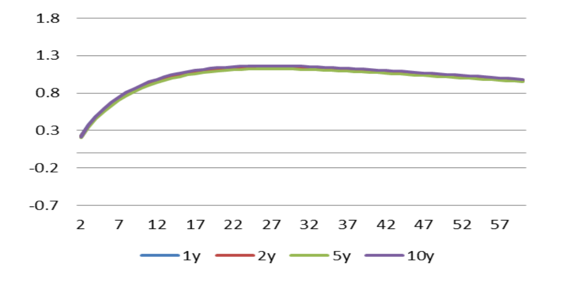
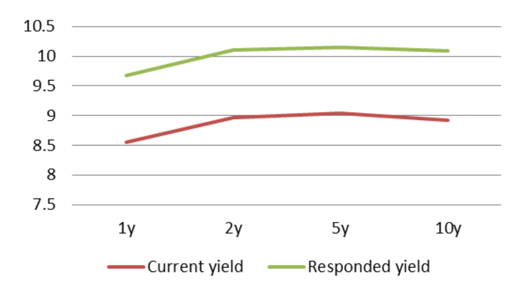
<tr><td>Indonesia</td><td>
</td><td>
</td></tr>
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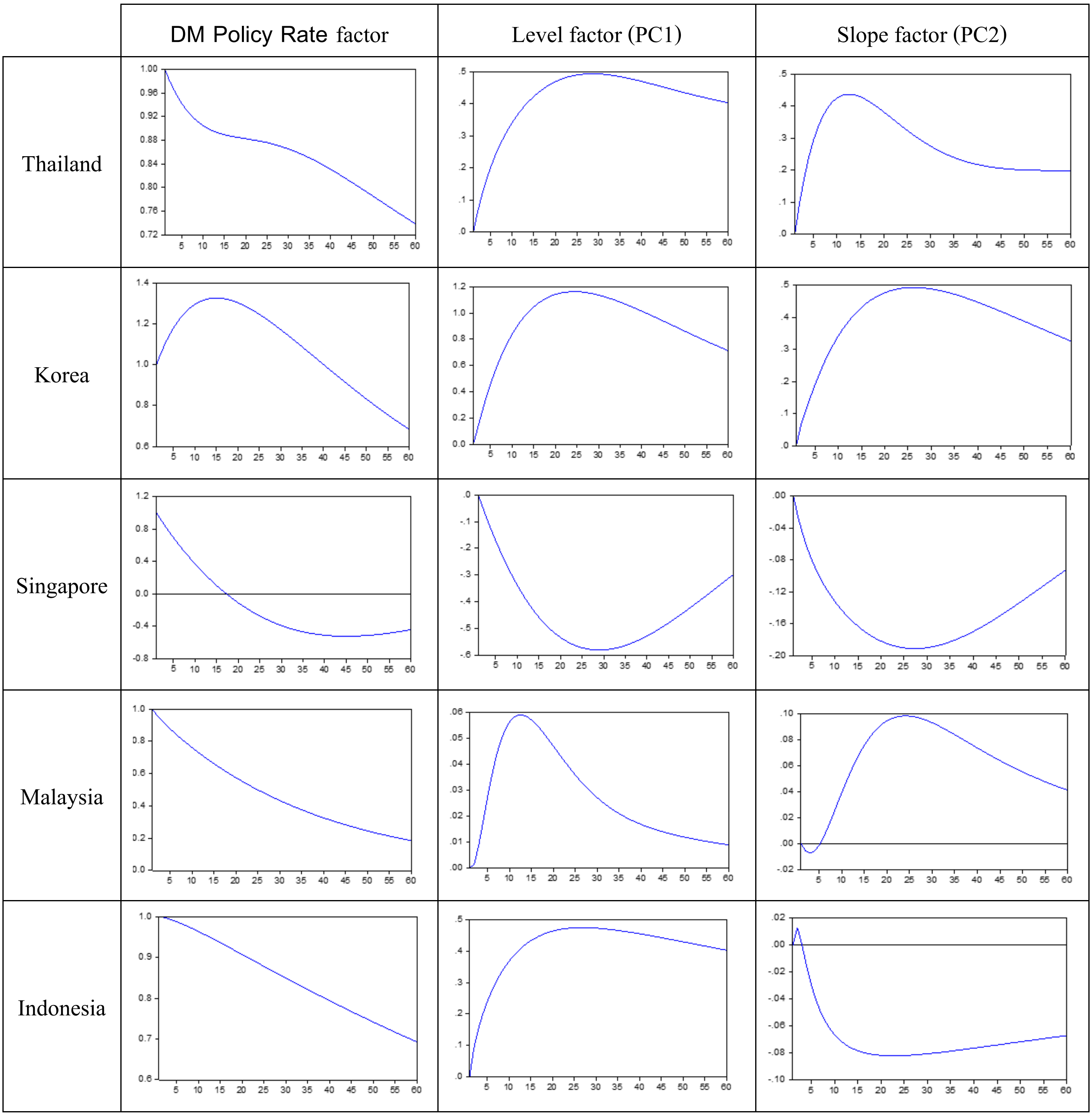
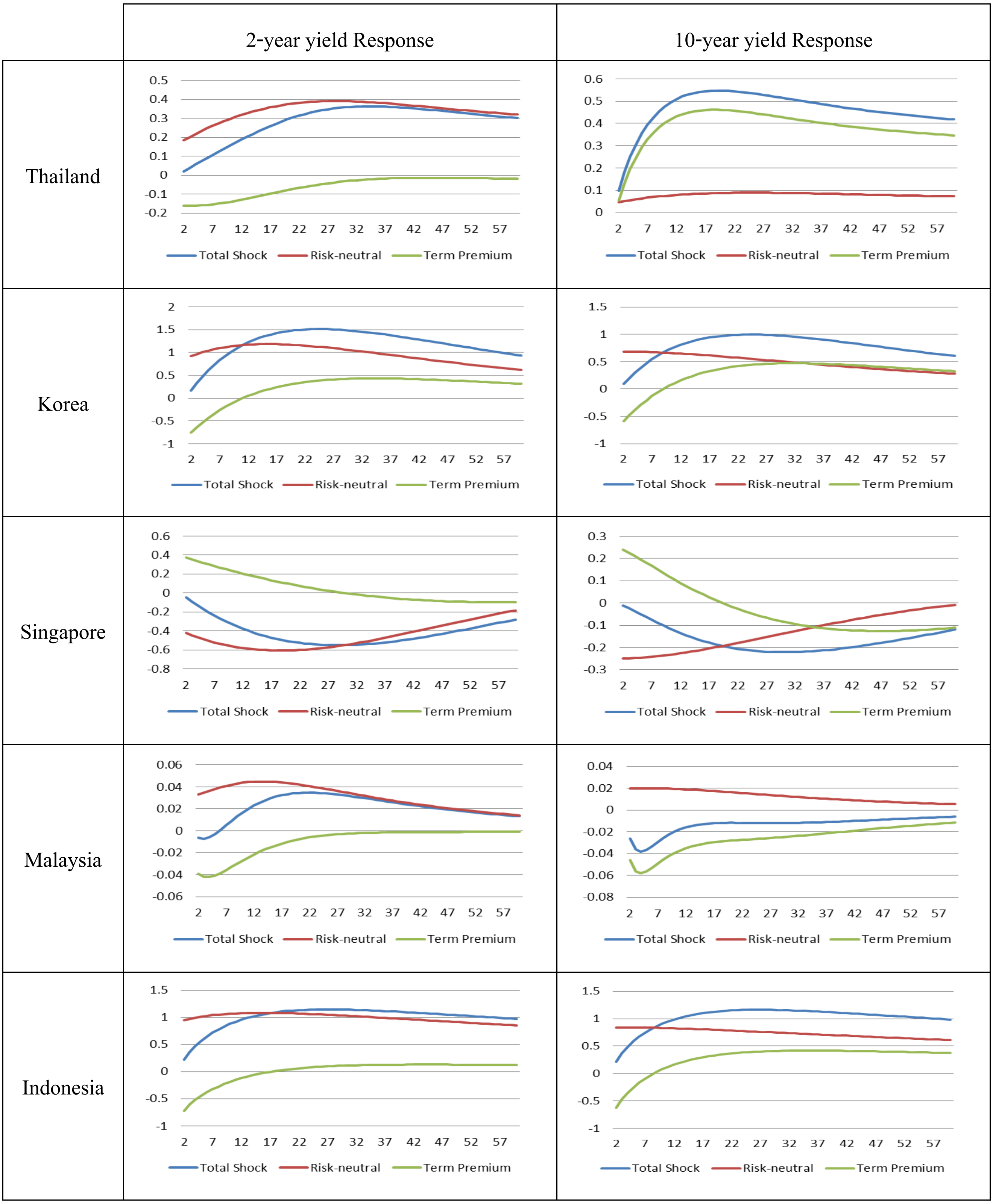
Note: Figures on the left column illustrate the impulse response of yields (maturity of 1,2, 5, and 10 years) to a unit shock in DM policy rate. Figures on the right column illustrate the change in shape of yield curves following the shock. The x-axis corresponds to maturities; the y-axis corresponds to yields in percentage point. The 'responded yields' is taken from the period with the largest responds.

Figure 14: DM Policy Rate Shock: State Variables Responds



Note: Each sub-figure illustrates the impulse responds of the selected state variables following the DM policy rate shock in each country. Column on the left is the response of DM policy rate factor. Column in the center is the response of level factor. And column on the right is the response of slope factor.

Figure 15: DM Policy Rate Shock: Responds Decomposition



Note: Each figure illustrates the channel decomposition of the response, following the DM policy rate shock. Red line is the impact incurred in risk-neutral channel. Green line is the impact incurred in term premium channel. Blue line is the sum of impact in both channels.

Figure 16a: Bond Flow and the First PC of Korean Sovereign Yields

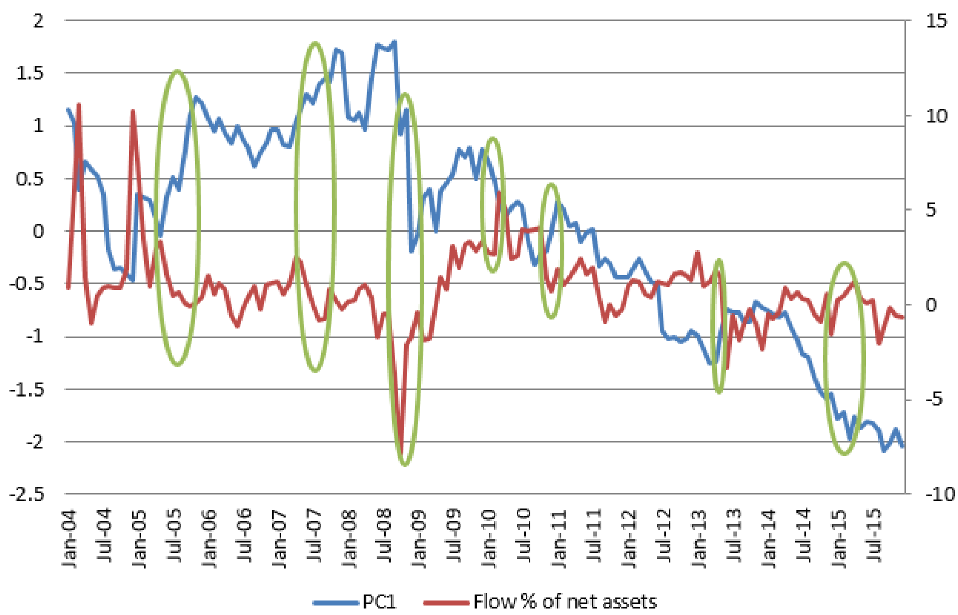


Figure 16b: Bond Flow and the First PC of Indonesian Sovereign Yields