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Yield curve interactions with the macroeconomic factors during global financial crisis among Asian markets

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ABSTRACT

This study examines the interaction between the yield curve movements and the macro economic factors among the nine Asian sovereign bond markets. The yield curve and macro-economic variables were jointly modelled in the dynamic Nelson Siegel model framework and are fitted in the vector auto regressive (VAR) process in a state space framework. The results indicate the existence of a bi-directional relationship between the yield curve and macro factors in the Asian economies. The study found that both the policy rate and the inflation rate influence the short end of the yield curve, reflecting an effective management of the monetary policy. While output growth strongly leads the long term rates in the region, steepening of the yield curve causes increase in Inflation. The depreciation of exchange rates led to increase the level factor in emerging economies and the increase in slope factor appreciated the exchange rates in developed Asian markets.

1. Introduction

Central banks set the short term interest rates on the basis of the expected future path of the economy, which in turn affects the long term rates (Orphanides & Wei, 2012). The goal of any central bank is to affect the long term rates in order to boost growth in the economy which would be achieved by affecting the yield curve. On the other hand, there is also an indirect feedback effect from long term rates to the macro economic factors (Nimark, 2008). The movement in the term structure signals the shift in the macro factors, inducing the central bank to alter the short term rates. Thus there exists complementary relationship between the yield curve and the state of the economy. This study aims to analyse the interactions between the yield curve and economic factors across nine Asian economies.

Literature on macro economy and yield curve has concentrated on the slope of the yield curve as the significant predictor of economic activity (Estrella & Hardouvelis, 1991), and the stance of the monetary policy (Evans & Marshall, 1998). Mishkin (1990) provided evidence that long term rates contain information about the future expected inflation. Alternatively, some recent studies jointly modelled the term structure with macro-economic factors in two different approaches. Ang and Piazzesi (2003) used an arbitrage free model, and Diebold, Rudebusch, and Aruoba (2006) used the Dynamic Nelson Siegel model. Both these models distilled the yield curve

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into a set of latent factors and modelled macro factors jointly with yield curve factors. The advantage is that these models allow the capturing of the bidirectional relationship between the yield curve and macro factors, and they help to assess the time varying relationships.

The1997 Asian Currency crisis brought an increased awareness and urgency in developing an efficient bond market to reduce external borrowings from other countries and to channelize the domestic savings to their long term investment needs in the region. Since then, various measures were taken to develop the bond markets. Globalisation of emerging markets coupled with domestic economic growth increased the capital inflows into these economies. The sudden rise in the capital flows increased challenges in the macro-economic management in the region (Pradhan et al., 2011). Given the significant growth in bond markets and capitals inflows in the region, it was necessary to examine how the bond markets respond to the macroeconomic surprises in the region.

This study has examined the interactions between the yield curve and the macroeconomic factors of Asian economies such as Japan, Hong Kong, Singapore Malaysia, Korea, India, China, Indonesia and Philippines for the period of January 2003 to December 2013. The zero coupon yields of Asian economies and macro factors were considered at monthly frequency from January 2003 to December 2013. The macro economic factors considered were monetary policy rate, inflation, output growth and exchange rate. The yield curve and macro-economic variables were modelled jointly in the Dynamic Nelson Siegel model frame work as in Diebold et al. (2006) and were fitted in a vector auto regressive (VAR) process in a state space framework.

The results of this study reflect the feedback effect between the yield curve and macroeconomic factors in the nine Asian economies. The term structure factors exhibited significant persistence among all the Asian economies. Increase in the policy and inflation rates affects the slope of the term structure while the output growth strongly leads the long term factor of the yield curve. The depreciation of exchange rates led to increase in the level factor in emerging economies, and increase in slope factor led to the appreciation of the exchange rates, confirming the uncovered interest rate parity.

The contribution of the study is three fold. Prior studies that examined the relationship between macro factors and yield curve were conducted mostly on developed economies, especially the US and some industrialized economies (Afonso & Martins, 2012). The literature on Asian economies is thin. In the literature on emerging economies, Mehl (2009) used the slope of the yield curve to predict inflation and economic activity. This paper contributes to literature by investigating the interactions between macro factors and the yield curve at various maturity spectrums among the Asian economies.

Second, though there is a large body of literature about the information content of the term structure, the focus was on the predictive ability of term spread to forecast macro-economic factors (Nimark, 2008). This paper on the other hand, focuses on how the shift in the term structure alters the macro factors, and how the shift in macro factors affects the term structure movements in Asia. The countries considered for this study demonstrated varied characteristics. While Korea (2001), Philippines (2002) and Indonesia (2005) adopted inflation targeting policies, Japan fought deflation in a lower interest rate environment. Singapore and Hong Kong strove for exchange rate stability, while the Indian and Chinese bond markets operated in a regulated market environment.

Third, the period of the study starting from January 2003 to December 2013was the crucial time in the development of Asian bond markets. This period also covers the economic drifts and turns caused by the 2007–2008 global financial crisis. The emerging markets received strong capital flows into the local currency bond market at the onset of the crisis, which led to volatility in asset prices and was quite a challenge to regulators in terms of macroeconomic management.

The rest of the paper is organised as follows: Section 2 presents stylized facts about Asian bond markets; Section 3 presents the theoretical background of yield curve and macro factors; Section 4 presents the model, Section 5 describes the data and presents the results, and Section 6 summarizes and concludes.

2. Stylized facts about Asian bond markets

The local currency bond market in Asia has developed rapidly in the past decade due to the increased financial openness in the region post the Asian Financial Crisis. In the year 2000, the total size of the Asian local currency Government bond market was USD 493 billion; by 2013, it had increased to USD 4560 billion(excluding Japan)[1] (source: Asian Bond online) indicating the rapid development of the bond market in the region.

Table 1 presents the comparative size of the local currency bond market denominated in USD billions for the years 2000 and 2013. In the Government bond market segment, the Japanese bond market is the largest in the region followed by China and South Korea. In the corporate bond market segment, China stands the largest among the Asian economies, followed by South Korea and Japan. India stands as the fourth largest bond market in the region. The development and growth of the bond market after the Asian financial crisis has been phenomenal in all the countries in the region.

The Asian countries considered in the study shared a regional resemblance, but exhibited heterogeneous monetary policy objectives. Japan was fighting deflation in a low interest rate environment, and was using various unconventional measures such as purchases of long term bonds, real estate funds and exchange traded funds to influence the economy. Emerging economies such as Korea, Indonesia, and Philippines were adopting inflation targeting regimes and used monetary policy rates to influence the inflation and the economy. Singapore was one major economy that used the exchange rate to manage inflation, as their economy is import driven. Moreover, their interest rates are largely determined by the US rates and investors' expectations of currency movements. (Source: Bloomberg report). Hong Kong adopted a linked exchange rate system with US dollars to maintain currency stability. Their exchange stability was maintained through the automatic interest rate mechanism (Source: Hong Kong Monetary Authority). The Indian economy effectively used

[1] The end of period exchange rate are taken from Bloomberg.

Table 1
Size of the Asian local currency bond market.

Countries	Size of Government Bond Market (USD Billions)		Size of corporate Bond Market (USD Billions)	
	Year: 2000	Year: 2013	Year: 2000	Year: 2013
Japan	3499	9203	1053	786
Singapore	25	150	19.6	94
Korea	82	626	0	1015
Hong Kong	14	108	46.58	86
Malaysia	36	182.4	33.02	130
Indonesia	47	90	2	18
China	199	3073	3.49	1612
Philippines	21	86	0.15	13
India	NA	679.8[a]	NA	273.03[a]

[a] Indian Government bond market data was obtained from CCIL and as on August 2016. Indian Corporate bond market data was obtained from SEBI. NA: not available. Source: Asian Development Bank (Asia bond online), SEBI- for corporate bond data, CCIL, RBI for Indian Government bond. The data is as on December 2000 and December 2015 respectively. The data for Korea bond markets is as on Jan 2000 and December 2015.

Repos (Repurchase agreements) and open market operations to promote liquidity and manage money supply in the economy.

3. Macroeconomic effect on the yield curve: theoretical motivation

The literature on relationship between yield curve and macro-economic factors has evolved into two different strands. One strand comprises of studies that have documented the information content in the yield curve as the predictor of economic activity. The other strand constitutes studies that have jointly modelled the behaviour of yield curve with the macro economic factors. Empirical evidence shows that the link between bond yields and macroeconomic factors is stronger.

3.1. Information content in the yield curve

3.1.1. Yield curve and monetary policy

The term structure of interest rates contains useful information about the stance of monetary policy. The increase in central bank policy rate affects the short term rates and expected to increase the long term rates as per the expectations hypothesis and there by the aggregate demand. Monetary policy shocks primarily affect the short term rates and have a diminishing effect on the long term rates at future horizons due to the declining effect of the expected inflation (Evans & Marshall, 1998). However, long term rates' response is stronger for unanticipated changes and weaker for the anticipated changes (Berument & Froyen, 2009). The monetary policy authorities also use the information contained in the yield curve along with the macroeconomic indicators to infer the current state of the economy and alter the policy rates accordingly.

3.1.2. Yield curve and inflation

The generalized Fisher hypothesis states that the nominal interest rate is equal to the sum of the real interest rate, expected inflation and term premium (Chernov & Mueller, 2012). Hence, if the Fisher hypothesis holds valid and if the yield curve is normal, then the long term rates are expected to be greater than the short term rates. Thus, the steeping of the yield curve increases the term spread and in turn increases the inflation rate.

Only the long end of the yield curve contains information about the future path of inflation (Mishkin, 1990; Nagayasu, 2002). Shocks from inflation related indicators influence the level of the term structure and shocks from output related indicators influence the slope of the term structure (Lu & Wu, 2009). Inflation expectations shift the long term rates and determine the shape of the yield curve.

3.1.3. Yield curve and real economic activity

The shape of the yield curve changes across the business cycles (Ang, Piazzesi and Wei, 2006). There are three mechanisms to explain the relationship between the yield curve and economic activity. First, when the central banks increase the short term rates in order to bring down the inflation, long term rates increase less than the short term rates as the inflation is assumed to decline in the future. Then the yield curve gets flatter or inverted. An inverted yield curve indicates recession. Second, if the expectation hypothesis holds valid, then the long term rates represent the average of expected short term rates. In such cases, the increase in long term rates leads to a decline in the economic activity. Third, the agent savings perception is another channel to link the yield curve and economic activity. If the agents expect recession, they invest in long term bonds, and the additional demand pulls down the long term yield rates and reduces the term spread. Thus, the slope of the yield curve has been found to be a good predictor of recession and future consumption growth (Estrella & Hardouvelis, 1991; Harvey, 1988).

3.1.4. Yield curve and exchange rate

The uncovered interest rate parity states that the expected change in the exchange rate should be equal to the interest rate differentials. Svensson (2000) stated that exchange rate is the additional channel for transmission of monetary policy in open economies, where in, the exchange rate affects the price between the domestic and foreign goods, which in turn affects both the aggregate demand

and the inflation. Furthermore, the exchange rate captures the foreign rates and disturbances.

Chen and Tsang (2013) found that a one percent increase in the level or slope factor appreciated the exchange rate. The movement in the curvature factor was found to have smaller effect on the movement of exchange rates.

3.2. Yield curve: latent factors and macroeconomic variables

Bond market literature decomposes the yield curve into three factors: the level representing long term, the slope representing short term and the curvature representing the medium term factor. The level factor reflects the long-run inflation expectations; the slope captures the temporary business cycle movements in the economy and the curvature reflects the stance of the monetary policy (Dewachter and Lyrio, 2006). There exists a bi-directional relationship between the yield curve and macro-economic factors. The level factor raises the inflation; the increase in monetary policy rate raises the slope. (Diebold et al., 2006).

Increase in inflation expectations leads the yield rates and supply shocks in the UK bond market (Chadha & Waters, 2014). The level and slope are responsive to real economic activity and monetary policy shocks (Morales, 2010).

In Brazil, the exchange rate was found to be an important factor driving the yield curve movements (Matsumura & Moreira, 2011). The interaction between the yield curve and macroeconomic activity is unidirectional in China. They confirmed that adjustment in the yield curve does not significantly change the macroeconomic factors, but the changes in macroeconomic factors result in adjustments in the Chinese yield curve (Yan and Guo, 2015).

Prior studies clearly indicate the differences in the macro and yield curve interactions across the economies. A salient trait of the literature is that it focuses mainly on US and other developed markets and less on the emerging Asian markets. This study is a pioneering attempt to investigate the bi-directional relationship between macroeconomic factors and the term structure in the Asian markets.

4. Methodology

4.1. Dynamic Nelson Siegel model

Diebold and Li (2006) and Diebold et al. (2006) generalized the Nelson Siegel model in which yields are decomposed into three dynamic latent factors. This representation aggregates information from the array of zero coupon yields into three latent factors, and is written as:

$$y(\tau) = L_t + S_t\left(\frac{1-e^{-\lambda\tau}}{\lambda\tau}\right) + C_t\left(\frac{1-e^{-\lambda\tau}}{\lambda\tau} - e^{-\lambda\tau}\right). \tag{1}$$

where,$y(\tau)$ denotes of yield of maturity τ.L_t, S_t and C_t are the time varying latent factors of the yield curve. L_t represents the long term factor and it is labelled as Level. S_t represents the short term and is labelled as Slope. C_t represents the medium term and is referred as Curvature.

In this research study, Eqn (1) was used in the state-space form, where L_t,S_t and C_t follow a vector autoregressive process of order (1). The state-space form has two equations viz., measurement equation and transition equation. The measurement equation relates to the yields and the dynamics of latent factors, and is written as:

$$\begin{pmatrix} y_t(\tau_1) \\ y_t(\tau_2) \\ . \\ . \\ . \\ y_t(\tau_N) \end{pmatrix} = \begin{pmatrix} 1 & \left(\frac{1-e^{-\tau_1\ \lambda}}{\tau_1\ \lambda}\right) & \left(\frac{1-e^{-\tau_1\ \lambda}}{\tau_1\ \lambda} - e^{-\tau_1\lambda}\right) \\ 1 & \left(\frac{1-e^{-\tau_2\ \lambda}}{\tau_2\ \lambda}\right) & \left(\frac{1-e^{-\tau_2\lambda}}{\tau_2\ \lambda} - e^{-\tau_2\lambda}\right) \\ . & . & . \\ . & . & . \\ . & . & . \\ 1 & \left(\frac{1-e^{-\tau_n\lambda}}{\tau_2\ \lambda}\right) & \left(\frac{1-e^{-\tau_2\lambda}}{\tau_2\ \lambda} - e^{-\tau_2\lambda}\right) \end{pmatrix} \begin{pmatrix} L_t \\ S_t \\ C_t \end{pmatrix} + \begin{pmatrix} \varepsilon_t(\tau_1) \\ \varepsilon_t(\tau_2) \\ . \\ . \\ . \\ \varepsilon_t(\tau_N) \end{pmatrix} \tag{2}$$

The measurement equation is denoted in matrix notation as:

$$y_{t=}\Omega p_t + \varepsilon_t \tag{3}$$

where.y_t is n x 1 vector of observed yields

Ω is nx3 matrix of loading of latent factors
p_t is the 3 × 1 vector of latent factors and
ε_t is the nx1 matrix of error terms.

The transition equation governs the dynamics of latent factors and is written as:

$$\begin{pmatrix} L_t - \mu_l \\ S_t - \mu_s \\ C_t - \mu_C \end{pmatrix} = \begin{pmatrix} Q_{11} & Q_{12} & Q_{13} \\ Q_{21} & Q_{22} & Q_{23} \\ Q_{31} & Q_{32} & Q_{33} \end{pmatrix} \begin{pmatrix} L_{t-1} - \mu_l \\ S_{t-1} - \mu_s \\ C_{t-1} - \mu_C \end{pmatrix} + \begin{pmatrix} \upsilon_t(L) \\ \upsilon_t(S) \\ \upsilon_t(C) \end{pmatrix} \tag{4}$$

Eqn (4) is written in vector notation as:

$$(p_t - \mu) = Q(p_{t-1} - \mu) + \upsilon_t \tag{5}$$

where, p_t is the 3 × 1 vector of latent factors,

μ is 3 × 1 means of the latent factors,
Q is 3 × 3 matrix of VAR coefficients
υ_t is 3 × 1 matrix of disturbance term.

The Kalman filter was used to maximize the likelihood function which sequentially updates the transition and measurement equation until an optimal point is achieved. For the Kalman filter, it was assumed that the disturbance term of the transition equation and the measurement equation are orthogonal to each other and are uncorrelated with the latent factors.

$$\begin{pmatrix} \upsilon_t \\ \varepsilon_t \end{pmatrix} \sim WN\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} Z & 0 \\ 0 & K \end{pmatrix}\right] \tag{6}$$

The Z matrix is the variance covariance for the transition equation and K is the variance-covariance matrix for the measurement equation.

4.2. Macroeconomic factors and yield curve

The interaction between the macro factors and the yield curve was analysed by including the macroeconomic variables in the transition equation of state-space framework. The state vector P_t in the transition equation (5) included:

$$P_t = (L_t, S_t, C_t, outputgrowth, inflation, policyrate, exchangerate)$$

The transition equation including the macroeconomic variables is written as:

$$\begin{pmatrix} L_t - \mu_l \\ S_t - \mu_s \\ C_t - \mu_C \\ PR_t - \mu_{pr} \\ Output_t - \mu_{iip} \\ inf_t - \mu_{inf} \\ exch_t - \mu_{exc} \end{pmatrix} = \begin{pmatrix} Q_{11} & Q_{12} & Q_{13} & Q_{14} & Q_{15} & Q_{16} \\ Q_{21} & Q_{22} & Q_{23} & Q_{24} & Q_{25} & Q_{26} \\ Q_{31} & Q_{32} & Q_{33} & Q_{34} & Q_{35} & Q_{36} \\ Q_{41} & Q_{42} & Q_{43} & Q_{44} & Q_{45} & Q_{46} \\ Q_{51} & Q_{52} & Q_{53} & Q_{54} & Q_{55} & Q_{56} \\ Q_{61} & Q_{62} & Q_{63} & Q_{64} & Q_{65} & Q_{66} \\ Q_{71} & Q_{72} & Q_{73} & Q_{74} & Q_{75} & Q_{76} \end{pmatrix} \begin{pmatrix} L_{t-1} - \mu_l \\ S_{t-1} - \mu_s \\ C_{t-1} - \mu_c \\ PR_{t-1} - \mu_{pr} \\ output_{t-1} - \mu_{output} \\ Inf_{t-1} - \mu_{inf} \\ exch_{t-1} - \mu_{exch} \end{pmatrix} + \begin{pmatrix} \upsilon_t(L) \\ \upsilon_t(S) \\ \upsilon_t(C) \\ \upsilon_t(PR) \\ \upsilon_t(output) \\ \upsilon_t(inf) \\ \upsilon_t(exch) \end{pmatrix} \tag{7}$$

The matrix notation is denoted by:

$$(p\prime_t - \mu) = Q(p\prime_{t-1} - \mu) + \upsilon_t \tag{8}$$

where, Q is the (7 × 7) matrix containing the VAR coefficients of the latent and the macro economic factors, and μ is the mean of the state vector. The assumptions of υ_t, Z and K matrix remain the same as in the baseline model.

4.3. DATA

The monthly zero coupon yields of maturities 3, 6,12,24,36,48,60,72,84,96,108, and 120 months, for Asian economies such as Japan, Hong Kong, Korea, Singapore, Malaysia, India, China, Indonesia and Philippines, denominated in local currency terms were considered for the period of January 2003 to December 2013. The zero coupon yields were obtained from the Bloomberg database, except for India. Indian zero coupon yields were obtained from NSE India (National Stock Exchange) Archives.

Macroeconomic variables such as output growth, inflation, monetary policy rate and exchange rate with respect to US dollars of each country were considered at monthly frequency. The measurement details, and data sources of the macroeconomic factors are reported in Appendix 1. The descriptive statistics of macroeconomic factors for each of the nine countries is provided in Appendix 3.

Fig. 1 depicts the zero coupon yield curve of Asian economies. The yield curves were noted to be upward sloping across the countries, except for India and China, whose yield curves were downward sloping, both in 2012 and 2013 respectively. The inverted yield curve signals economic slowdown and impending recession.

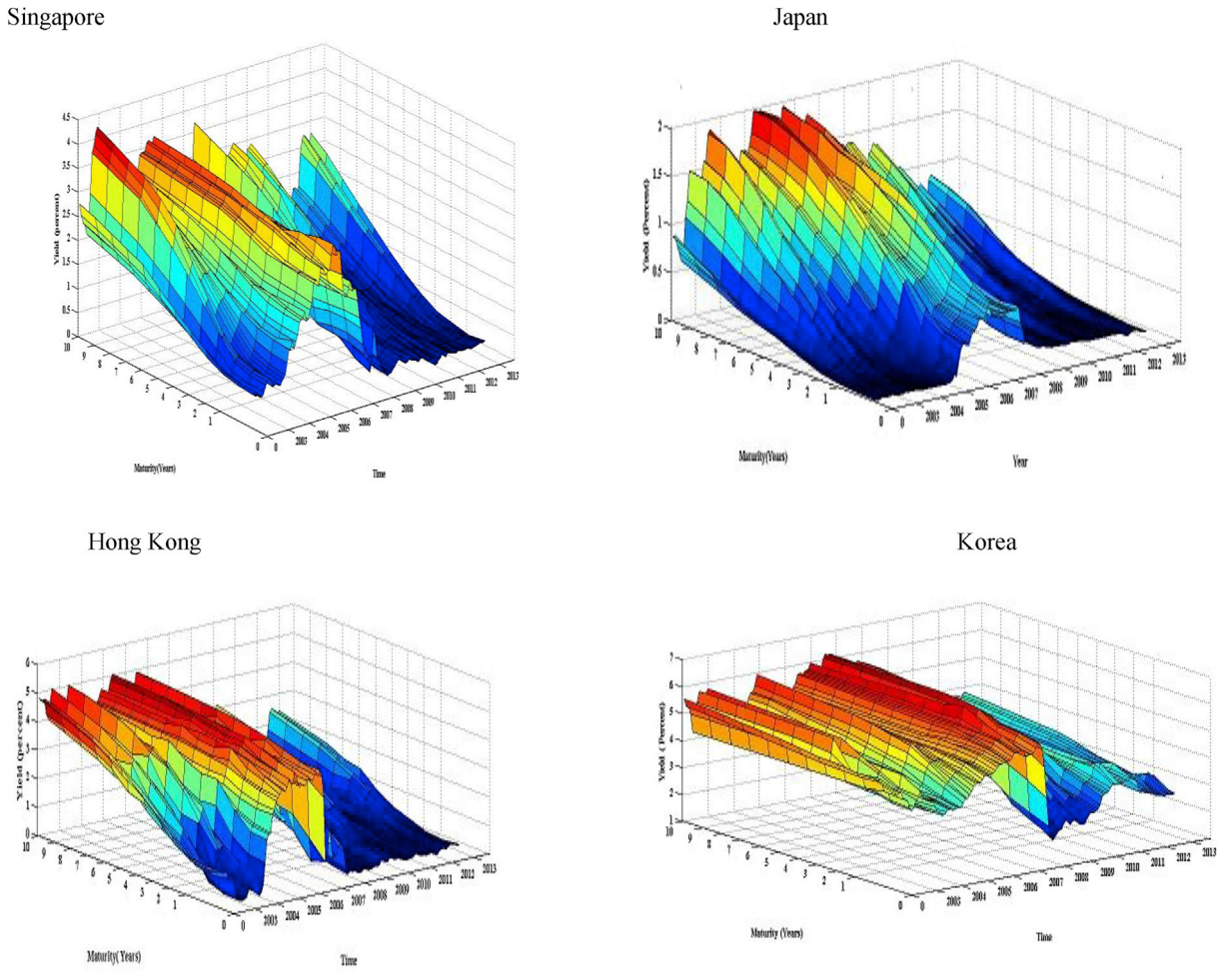


Fig. 1. An Overview of the Yield Curve in Asian Economies. Notes: Fig. 1 presents the yield curve of Asian countries from 2003 to 2013. The X axis represents the year, the Y axis represents Maturity in years and the Z axis represents the Yields in percent.

The Chinese yield curve exhibited inversion in 2012.[2] The spike in short term rates of China was first triggered when the China Ever Bright Bank failed to repay the overnight loan of RMB 6bn in the interbank markets. A severe liquidity squeeze was experienced in the Chinese interbank money market during this period. Along with this they also experienced a sharp decline in the exports. The regulators imposed tighter controls on capital flows, which led to further squeezing of the liquidity.

Similarly, the Indian yield curve exhibited a downward sloping yield curve in 2013.[2] It was a deliberate attempt to defend the weak currency in the country. During this period Fed announced the tapering of QE (Quantitative Easing Program), which led to capital outflows from the emerging economies. As a result, Indian economy experienced depreciation of the Indian rupee. The Reserve Bank of India deliberately pushed the short term interest rates, thus making it expensive for the speculators to sell the rupee.

Fig. 1 clearly shows that at the onset of the 2007–2008 Global Financial Crisis, the short term yield rates in all Asian countries reduced. The central banks adopted accommodative monetary policies and lowered the rates to boost economic growth in the region. The short-term rates had decreased to less than one percent after 2008 in Singapore, Japan and Hong Kong.

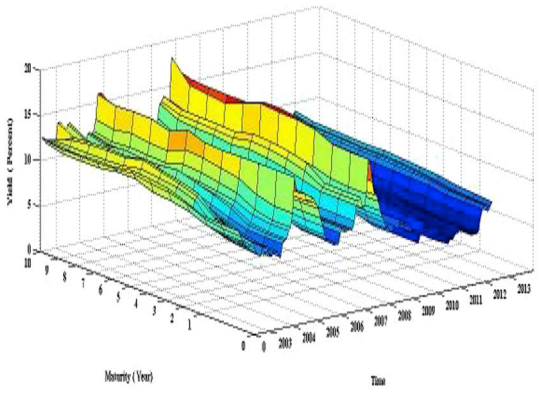
5. Empirical results

5.1. Estimation of term structure latent factors

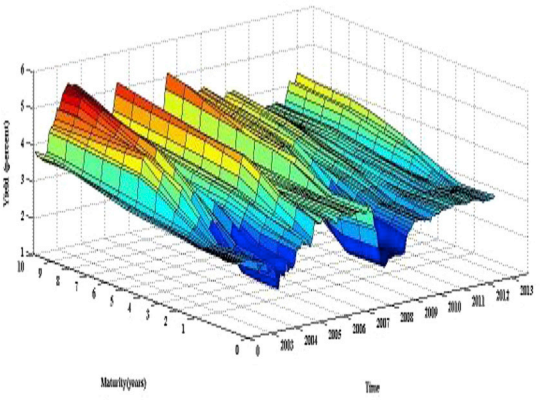
The term structure factors of the yield curve were extracted using the Dynamic Nelson Siegel model as in Eqn (1) and Eqn (2). The parameters of the latent factors $\theta(L_t, S_t, C_t, \lambda_t)$were estimated using OLS by initialising the λ value as 0.0609 following Diebold et al. (2006) for each country. Using the Kalman filter, maximisation, we find the value of λ_t which maximize the loading on C_t. Based on the

[2] Refer the yield curve figures of China and India in Fig. 1.

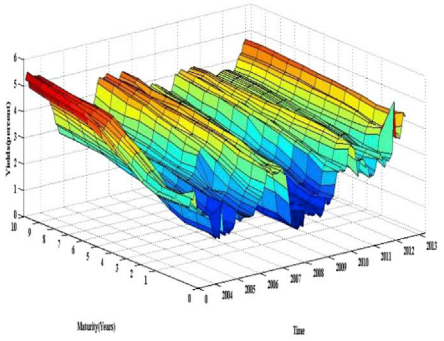
Malaysia



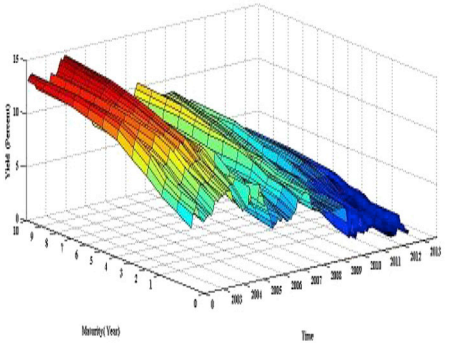
Indonesia



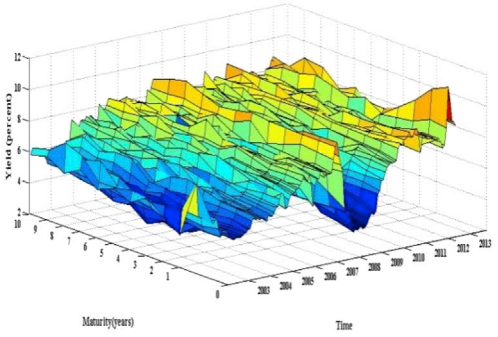
China



Philippines



India



Notes: Figure 1 presents the yield curve of Asian countries from 2003 to 2013. The X axis represents the year, the Y axis represents Maturity in years and the Z axis represents the Yields in percent

Fig. 1. (*continued*).

Table 2
Impact of Yield curve latent factors and Macro Factors on the Level.

Countries	L_{t-1}	S_{t-1}	C_{t-1}	$Policyrate_{t-1}$	Inf_{t-1}	$Output_{t-1}$	$Exchange_{t-1}$
$Japan_{Lt}$	0.92*** (0.14)	0.10 (0.27)	0.02 (0.01)	−0.23 (0.31)	0.002 (0.05)	−0.0006 (0.005)	0.003 (0.006)
$Hong\ Kong_{Lt}$	0.998*** (0.04)	0.11*** (0.03)	−0.016 (0.015)	−0.11*** (0.03)	−0.048*** (0.008)	0.001 (0.004)	−0.475 (0.62)
$Korea_{Lt}$	0.85*** (0.04)	−0.09* (0.03)	0.007 (0.05)	0.031 (0.024)	−0.017*** (0.000)	0.005*** (0.00)	0.0001 0.0008
$Singapore_{Lt}$	0.75*** (0.11)	−0.22** (0.12)	0.11*** (0.04)	0.014 (0.11)	−0.05*** (0.01)	0.005** (0.003)	−0.341 (0.339)
$Malaysia_{Lt}$	0.82*** (0.04)	−0.17** (0.08)	0.002 (0.07)	1.31*** (0.06)	0.028*** (0.08)	−0.017*** (0.001)	0.05 (0.04)
$India_{Lt}$	0.54*** (0.06)	0.11** (0.05)	0.26*** (0.03)	0.017 (0.016)	0.05*** (0.01)	0.004*** (0.001)	0.03*** (0.01)
$China_{Lt}$	0.94*** (0.03)	−0.02 (0.04)	0.037* (0.02)	−0.06** (0.03)	0.014 (0.01)	0.03** (0.01)	−0.004 (0.02)
$Indonesia_{Lt}$	0.986*** (0.07)	0.267** (0.09)	−0.02 (0.02)	0.216** (0.106)	−0.003 (0.10)	0.022 (0.01)	−1.42 (1.48)
$Philippines_{Lt}$	0.696*** (0.07)	0.353** (0.10)	0.769*** (0.16)	0.22*** (0.08)	0.05 (0.09)	0.03 (0.07)	0.142*** (0.07)

Notes: This Table presents the VAR estimates of individual country level factor with the lag of term structure latent and macro-economic factors. L_{t-1} represents lag of level factor, S_{t-1} represents lag of slope factor, C_{t-1} represents lag of curvature factor, $Policyrate_{t-1}$ represents the lag of policy rate, Inf_{t-1} represents the lag of inflation and $output_{t-1}$ represents lag of output growth and $Exchange_{t-1}$ represents the lag of exchange rate with respect to US dollars. The figures in the brackets represent the standard error. ***, ** and * shows the significance at 1%, 5% and 10% respectively.

value of λ_t, which maximize the loading on the C_t, the parameters L_t, S_t, $C_t$were estimated for each country.

The dynamic interaction between the latent factors and macro-economic variables was estimated as in Eqn (7). The yield macro model contains 7 variables with $P_t = (L_t, S_t, C_t, IIP$, inflation, policy rate, exchange rate), with one free parameter λ. A one step Kalman filter was used to maximize the likelihood function which maximises the loading C_t and updates measurement and transition equation until an optimality is reached. The likelihood function was maximized using the Marquart and Berndt-Hall-Hall-Hausman algorithm and a convergence criterion of 10^{-6}. The transition matrix Q contained (7 × 7) 49 parameters, (7 × 1) mean state vector contained 7 parameters, the Z matrix contained 7 variance terms and 15 covariance terms, and the K matrix contained the variance terms for each of the 12 maturities. This process was adopted for each country separately.

The Q matrix of transition equation in Eqn (7) captured the interactions between the latent and macro factors for each country of VAR order (1). The coefficients of the Q matrix obtained for each country was rearranged and reported for each factor in Tables 2–7, to comprehend the differences in the lead and lag relationship between the macro factors and the yield curve across the countries.

5.2. Interactions between macroeconomic factors and the level

Level represents the behaviour of long maturity yields, and indicates the long-run expectation of inflation. The long term rates have a direct impact on the investment and spending, which determines the aggregate demand in the economy (Miyajima, Mohanty, & Yetman, 2014, p. 478). Thus, level is the implicit target that central banks wish to influence to control inflation and promote economic growth (Bianchi, Mumtaz, & Surico, 2009).

Table 2 presents the effect of term structure latent and macroeconomic factors on the next period level factor. The level exhibited persistent and positive relationship with its own lag across all Asian countries. The domestic term structure slope increased the next period level factor in Hong Kong, India, Indonesia and Philippines and decreased the level in Korea, Singapore and Malaysia. The domestic curvature increased the next period level significantly in Singapore, India, China and Philippines.

A shock in the monetary policy rate on level factor has two different effects. First, if the expectation hypothesis holds valid then the increase in short term rate is expected to increase the long term rates through the monetary policy transmission mechanism. On other hand, if the monetary policy is credible, increase in the policy rate declines the expectation of future inflation and the expected long term rates. This study found that the increase in the monetary policy rate increases the level as proposed by the EH theory in Asian markets, except in case of China, Japan and Hong Kong. Yan and Guo (2015) reported that the Chinese monetary policy rate doesn't affect their yield curve because of the weak monetary policy transmission mechanism.

Japan has a different financial environment as compared to other Asian markets. The policy rate is zero lower bound (Dekle & Hamada, 2015). Since their short-term rates are lower, the Bank of Japan uses non-conventional monetary measures to stabilize the economy. Their measures include purchasing long term Japanese Government Bonds and increasing the base money (Abenomics Monetary Policy). Hence, the Japanese policy rate was not found to influence the level, and the direction of the relationship was negative, unlike in other economies. This result is in line with the findings of Kagraoka and Moussa (2013), who found that during the Quantitative Easing phase, the effect of policy rate increase declined the level.

Increase in inflation is expected to increase the long term bond yields. The results of this study reflect a mix of positive and negative influence that inflation has on the level factor of Asian countries. In emerging economies such as Malaysia and India inflation positively and significantly influenced the long term factor.

Inflation had a negative influence on the level factors of Korea, Hong Kong and Singapore. When an economy faces higher inflation, the Central banks adopt a contractionary monetary policy to lower the inflation, which in turn lowers the level factor (Diebold et al., 2006). The results of this study reflect the strength of the monetary policy in curbing inflation in these Asian countries.

For Korea, Singapore, India and China, increase in the output growth led to increase in the level. The higher output suggests economic growth and prosperity, thus increasing the level factor.

The depreciation of exchange rate with respect of US dollars positively increased the next period level factor in emerging economies such as India and Philippines, to attract foreign capital and strengthen their depreciating currency.

Table 3 presents the lead effect of the term structure level to the macro economic factors. A higher level indicates higher inflation,

Table 3
Lead effect of level on macro economic factors.

Countries	$Policyrate_t$	$Inflation_t$	$Output_t$	$Exchange_t$
$Japan_{Lt-1}$	0.18*** (0.04)	−0.991** (0.50)	2.051 (4.9)	−0.04 (0.78)
$Hong\ Kong_{Lt-1}$	0.19*** (0.02)	0.87*** (0.36)	0.14 (0.25)	−0.002 (0.001)
$Korea_{Lt-1}$	0.11*** (0.04)	0.10 (0.11)	0.35 (0.78)	−12.63 (10.5)
$Singapore_{Lt-1}$	0.68*** (0.09)	0.46*** 0.13	2.12 (2.17)	−0.011 (0.006)
$Malaysia_{Lt-1}$	0.20*** (0.06)	0.80*** (0.34)	−1.82 (2.02)	−0.46 (1.03)
$India_{Lt-1}$	0.48 (0.317)	0.56*** (0.19)	0.51 (0.65)	−0.02 (0.22)
$China_{Lt-1}$	−0.001 (0.02)	0.49*** (0.11)	−0.20 (0.11)	0.007 (0.004)
$Indonesia_{Lt-1}$	0.05*** (0.01)	0.17*** (0.04)	0.002 (0.25)	−0.008 (0.007)
$Philippines_{Lt-1}$	0.03*** (0.009)	0.12*** (0.02)	−0.03 (0.03)	−0.105 (0.65)

Notes: This Table reports effect of lag of level on the next period macro-economic factors. The figures in the brackets represent the standard error. ***, ** and * shows the significance at 1%, 5% and 10% respectively.

which causes raise in the policy rates. Thus, the level leads the policy rates. The results presented in Table 2 exhibit a statistically significant lead effect between the level and the policy rate. There exists a positive relationship between the level factor and the next period inflation, barring Japan. The inflation adjustment in Japan happens slowly, since the country experiences very low inflation over a long period of time. (Source: Brookings Press). Increase in the level factor led to appreciation of the exchange rates in the Asian economies, however it not found to be statistically significant.

Tables 2 and 3 clearly exhibit bi-directional effect between the long term and macro-economic factors across the Asian countries. The policy rate led the level in most of the Asian economies signifying the effective monetary policy transmission mechanism. Output growth led the long term factor. In developed Asian markets like Singapore and Hong Kong, inflation reduced level, whereas in the emerging Asian markets, inflation led level.

5.3. Interaction between slope and the macroeconomic factors

Slope of the yield curve is associated with the cyclical monetary response of the economy (Afonso and Martins, 2012). The tightening of monetary policy indicates higher short term rates which eventually increases the long term rates. Hence, the yield curve becomes flatter or inverted.[3] The flatter yield curve indicates economic slowdown. Thus, the slope of the yield curve plays a vital role in predicting recession. The slope is used by many studies as a significant predictor of inflation and economic activity.

Table 4 presents the results of the impact of macroeconomic factors on the next period slope of the yield curve. Increase in the level decreased the next period slope significantly in Japan, Korea and India. The lagged policy rate positively influenced the slope factor for all the Asian countries. This result indicates that increase in the policy rate is reflected in the short end of the yield curve. Further, the result is consistent with the general economic theory that the Central banks influence the policy rate through the short end of yield curve to stabilize the economy. Thus, the slope is considered as the indicator reflecting the current stance of the monetary policy.

The increase in inflation resulted in the Central bank increasing their policy rates. This led to increase in the slope of the yield curve. The result indicates the positive relationship between the slope and inflation in almost all the countries, except for Korea, Japan and Philippines. Japan and Philippines showed a positive relationship in the 2nd and 3rd lag, which is confirmed in the impulse response function.[4]

Central banks follow an accommodative monetary policy with lower interest rates to encourage GDP growth. Thus, it is expected that higher economic growth would result in higher slope in the next period (Lange, 2013). The result of the study also established this positive relationship between the slope and the lag of output in Hong Kong and Malaysia, except Indonesia. Djuranovik (2014) also found a negative relationship between the IIP and the next period slope factor in Indonesia. This was because of the nature of the Indonesian bond market. The size of the Indonesian bond market is 16% of the country's GDP, which is too small to influence the economic activity effectively, like in other countries.

The depreciation of exchange rate with respect to USD increased the next period slope significantly in Hong Kong, Korea and Philippines.

Table 5 presents the lead effect of term structure slope on the macroeconomic factors. Slope significantly led policy rates in all the Asian economies. It also led inflation, except in Japan and Hong Kong. Increase in the slope discourages output growth. This is consistent with the economic rationale that increases the short term rates, and reduces the expected output growth.

The increase in slope factor appreciated the exchange rate in Hong Kong, Singapore and Indonesia significantly. This result is in line with Chen and Tsang (2013) who found that rise in level and slope factor appreciated the currency in the United Kingdom, Canada, Japan and the United States.

[3] According to Diebold and Li (2006) formulation, positive slope is related to the increase in the short term rates and small increase in long term rates (i.e. flattening of the yield curve).

[4] The generalized impulse response function was estimated to analysis the dynamic changes between the macro and term structure factors. The result of the impulse response function can be provided on request.

Table 4
Impact of Yield Curve latent factors and Macro Factors on Slope.

Countries	L_{t-1}	S_{t-1}	C_{t-1}	$Policyrate_{t-1}$	Inf_{t-1}	$Output_{t-1}$	$Exchange_{t-1}$
$Japan_{St}$	−0.47* (0.28)	0.50** (0.23)	0.003 (0.015)	0.58* (0.31)	−0.011 (0.05)	0.0019 (0.005)	−0.002 (0.006)
Hong $Kong_{st}$	−0.095 (0.079)	0.86*** (0.062)	0.04* (0.02)	0.010 (0.156)	0.017 (0.021)	0.022* (0.01)	3.42* (1.9)
$Korea_{St}$	−0.37*** (0.04)	0.56*** (0.05)	0.007 (0.02)	0.44*** (0.06)	−0.05 (0.18)	0.004 (0.01)	0.003* 0.002
$Singapore_{St}$	0.038 (0.08)	0.90*** (0.08)	−0.07** (0.04)	0.207*** (0.06)	0.039* 0.02	−0.004 (0.005)	0.446 (0.346)
$Malaysia_{St}$	0.29 (0.36)	0.78*** (0.08)	−0.015 (0.01)	0.109 (0.15)	0.045*** (0.013)	0.019*** (0.006)	0.02 (0.03)
$India_{St}$	−0.19*** (0.08)	0.82*** (0.11)	0.085** (0.04)	0.27 *** (0.11)	0.003 (0.08)	0.01 (0.01)	−0.03 (0.02)
$China_{St}$	0.05 (0.03)	0.89*** (0.05)	0.02 (0.03)	0.03 (0.04)	0.004 (0.014)	0.003 (0.018)	0.44 (1.04)
$Indonesia_{St}$	−0.08 (0.06)	0.66*** (0.08)	0.041** (0.02)	0.22** (0.09)	0.103 (0.102)	−0.03* (0.01)	0.63 (1.9)
$Philippines_{St}$	0.34*** (0.11)	0.67*** (0.13)	−0.005 (0.004)	0.41*** (0.13)	−0.07 (0.12)	0.11 (0.10)	0.45*** (0.10)

Notes: This Table presents the VAR estimates of individual country slope factor to the lag of yield curve and macro-economic factors. L_{t-1} represents lag of level factor, S_{t-1} represents lag of slope factor, C_{t-1} represents lag of curvature factor, $Policyrate_{t-1}$represents the lag of policy rate, Inf_{t-1} represents the lag of inflation, $output_{t-1}$ represents lag of output growth and $Exchange_{t-1}$ represents the lag of exchange rate with respect to US dollars. The figures in the brackets represent the standard error. ***, ** and * shows the significance at 1%, 5% and 10% respectively.

Table 5
Lead effect of slope on macro economic factors.

Countries	$Policyrate_t$	$Inflation_t$	$Output_t$	$Exchange_t$
$Japan_{St-1}$	0.17*** (0.04)	−0.983** (0.40)	1.74 (4.09)	0.499 (0.754)
Hong $Kong_{St-1}$	0.19*** (0.02)	−0.19* (0.10)	−0.014 (0.089)	−0.004*** (0.001)
$Korea_{St-1}$	0.07*** (0.03)	−0.05 (0.08)	−0.008 (1.4)	−8.88 (8.22
$Singapore_{St-1}$	0.622*** (0.08)	0.381*** (0.123)	2.02 (2.02)	−0.011* (0.006)
$Malaysia_{St-1}$	0.21*** (0.03)	0.277 (0.28)	−0.46* (1.68)	−0.388 (0.18)
$India_{St-1}$	0.55*** (0.10)	−0.15 (0.11)	−0.27 (0.27)	0.32*** (0.09)
$China_{St-1}$	−0.014 (0.03)	0.33** (0.15)	−0.56*** (0.13)	−0.00 (0.006)
$Indonesia_{St-1}$	0.077*** (0.01)	0.31*** (0.06)	0.038 (0.17)	−0.012*** (0.007)
$Philippines_{St-1}$	0.10*** (0.03)	0.54 *** (0.08)	−0.02 (0.03)	0.62** (0.18)

Notes: This Table reports effect of lag of slope on the macro economic factors. The figures in the bracket represent the standard error. ***, ** and * shows the significance at 1%, 5% and 10% respectively.

5.4. Interactions between curvature and the macroeconomic factors

Curvature represents the medium term yields and provides information about the economic growth (Kagraoka & Moussa, 2013). Diebold et al. (2006) found that in the US term structure, curvature lacks significant association with the macro economic factors. Similarly, Dewachter and Lyrio (2006) and Evans and Marshall (2007) concluded that curvature is unaffected by the macro factors in developed economies. However, recent studies such as Mönch (2012) found that curvature provides information about the future evolution of the yield curve. Møller (2014) used curvature to predict the GDP growth and suggested that curvature has more predictive power than the slope of the yield curve.

Table 6 presents the impact of macroeconomic factors on the next period curvature. Increase in the policy rate increased the curvature in Japan, China and Singapore significantly. It can be noted from Table 2 that the policy rate did not have any significant relationship with the level factor in Japan and China. These results highlight that the policy rate of Japan and China had greater influence on the curvature than on the respective level factors. The rise in inflation and Output growth is accompanied by increase in curvature significantly Malaysia and China.

Table 7 presents the bi-directional effect of curvature with the macroeconomic variables. Rise in the curvature reflects the hump

Table 6
Impact of Yield Curve latent factors along with Macro Factors on Curvature.

Countries	L_{t-1}	S_{t-1}	C_{t-1}	$Policyrate_{t-1}$	Inf_{t-1}	$Output_{t-1}$	$Exchange_{t-1}$
$Japan_{Ct}$	−1.5*** (0.52)	−1.44*** (0.50)	0.938*** (0.02)	1.60*** (0.58)	0.013 (0.09)	−0.006 (0.011)	0.008 (0.01)
Hong $Kong_{Ct}$	0.0003 (0.13)	0.047 (0.10)	0.93*** (0.03)	0.010 (0.015)	−0.015 (0.03)	0.026 (0.019)	1.94 (2.17)
$Korea_{Ct}$	0.57*** (0.20)	0.68*** (0.27)	0.92*** (0.18)	−0.59*** (0.70)	0.30 (0.26)	−0.00 (0.01)	−0.006 (0.004)
$Singapore_{Ct}$	0.122 (0.217)	0.242* (0.140)	0.58*** (0.06)	0.268*** (0.084)	0.126*** (0.03)	−0.020*** (0.006)	0.661 (0.564)
$Malaysia_{Ct}$	−0.49 (0.49)	0.039 (0.40)	0.856*** (0.04)	−0.608 (0.42)	0.168*** (0.05)	0.052*** (0.019)	−0.10 (0.09)
$India_{Ct}$	0.18 (0.29)	−0.058 (0.08)	0.75*** (0.07)	0.09 (0.06)	0.16 (0.10)	−0.01 (0.01)	−0.05** (0.02)
$China_{Ct}$	0.12 (0.09)	0.423*** (0.116)	0.715*** (0.05)	0.49** (0.26)	0.08** (0.05)	0.187*** (0.04)	−0.12* (0.06)
$Indonesia_{Ct}$	0.02 (0.12)	−0.18 (0.16)	0.94*** (0.03)	0.18 (0.19)	−0.061 (0.03)	−0.199 (0.19)	−0.92 (4.55)
$Philippines_{Ct}$	−0.39 (0.64)	−0.039 (0.38)	0.81*** (0.04)	−0.87 (0.75)	0.30 (0.31)	−0.22 (0.24)	−0.576 (0.29)

Notes: This Table presents the VAR estimates of individual country slope factor to the lag of yield curve and macro-economic factors. L_{t-1} represents lag of level factor, S_{t-1} represents lag of slope factor, C_{t-1} represents lag of curvature factor, $Policyrate_{t-1}$represents the lag of policy rate, Inf_{t-1} represents the lag of inflation, $output_{t-1}$ represents lag of output growth and $Exchange_{t-1}$ represents the lag of exchange rate with respect to US dollars. The figures in the brackets represent the standard error. ***, ** and * shows the significance at 1%, 5% and 10% respectively.

Table 7
Lead effect of curvature on macro economic factors.

Countries	Policy rate$_t$	Inflation $_t$	Output$_t$	Exchange$_t$
Japan $_{Ct-1}$	0.009*** (0.002)	0.007 (0.03)	0.012 (0.23)	−0.13 (0.20)
Hong Kong$_{Ct-1}$	0.03*** (0.00)	−0.07* (0.04)	−0.10** (0.04)	−0.0005 (0.000)
Korea $_{Ct-1}$	0.05*** (0.01)	−0.003 (0.03)	1.31*** (0.54)	−4.06 (5.39)
Singapore$_{Ct-1}$	0.12*** (0.03)	−0.09* (0.05)	−1.97*** (0.75)	0.002 (0.002)
Malaysia$_{Ct-1}$	0.026*** (0.004)	0.072** (0.03)	−0.38* (0.20)	−0.23* (0.17)
India$_{Ct-1}$	0.12 (0.09)	0.07 (0.10)	−0.21 (0.35)	0.10 (0.13)
China$_{Ct-1}$	0.019 (0.017)	0.05 (0.07)	0.21*** (0.07)	0.001 (0.003)
Indonesia$_{Ct-1}$	−0.0023 (0.004)	−0.023 (0.01)	0.002 (0.07)	−0.004** (0.002)
Philippines$_{Ct-1}$	0.000 (0.000)	0.005* (0.004)	0.002 (0.02)	0.0006 (0.004)

Notes: The Table reports the effect of the curvature on the next period macro-economic factors. Policyrate represents the next period policy rate, Inf$_{t+1}$ represents the next period inflation and output$_{t+1}$ represents next period output growth. The figures in the brackets represent the standard error. ***, ** and * shows the significance at 1%, 5% and 10% respectively.

shape in the yield curve. Markets witness hump shape when the short term rates rise while simultaneously the long term rates fall. This implies a flattening of yield curve and an indication of upcoming recession. Thus, the increase in curvature leads to increase in the policy rate. The results reflect this expectation. Curvature leads the policy rate significantly for most of the Asian countries. The increase in curvature led to appreciation of exchange rates in Malaysia and Indonesia significantly.

The increased curvature resulted in rise in inflation for Asian economies, but declined significantly for Singapore and Hong Kong. The results exhibited significant negative relationship between the output growth and the curvature in Hong Kong, Singapore and Malaysia.

5.5. Test for yield and macro interactions

The presence of a bi-directional relationship between the yield curve latent factors and macro-economic factors of each individual Asian country considered in the study was examined using the Wald test.

The coefficient matrix Q and the covariance matrix Z in Eqn (4) and Eqn (8) were used to assess the strength of the bi-directional relationship between the yield curve and the macroeconomic factors for each country. The coefficient Q matrix was partitioned into (2 × 2) blocks:

$$Q = \begin{pmatrix} Q_1 & Q_2 \\ Q_3 & Q_4 \end{pmatrix} \tag{9}$$

where,Q_1 represents the interaction between the yield curve factors, Q_2 represents the interaction between the contemporaneous values of yield curve factors and the lags of macro factors, and Q_3 represents the interactions between the lag of yield curve factors and contemporaneous values of macro factors and Q_4 represents the interaction between the macro factors.

Similarly, the covariance matrix Z was partitioned as:

$$Z = \begin{pmatrix} Z_1 & Z_2 \\ Z_3 & Z_4 \end{pmatrix} \tag{10}$$

where, Z_1 represents the covariance of yield curve factors, Z_2 and Z_3 represents the covariance of the yield curve and macro factors and Z_4 represents the covariance of the macro factors for each country.

Table 8
Test of Bi-directional interaction between the yield and macro factors.

Hypothesis	No Bidirectional relationship between the yield curve and macro factors $Q_2 = 0$, $Q_3 = 0$ and $Z_2 = 0$	No Yield to macro Interactions. $Q_3 = 0$ and $Z_2 = 0$	No macro to Yield interactions $Q_2 = 0$
Number of restrictions	36	24	12
Japan	3177 (0.00)	2655 (0.00)	65.00 (0.00)
Hong Kong	843.89 (0.000)	336.04 (0.000)	39.82 (0.000)
Korea	639.13 (0.000)	296.29 (0.000)	57.36 (0.000)
Singapore	1610.8 (0.000)	1440.7 (0.000)	78.24 (0.000)
Malaysia	356.28 (0.000)	278.91 (0.000)	53.19 (0.000)
India	259.72 (0.000)	131.35 (0.00)	35.59 (0.000)
China	215.59 (0.000)	113.78 (0.000)	44.86 (0.000)
Indonesia	305.03 (0.000)	249.49 (0.000)	22.51 (0.00)
Philippines	757.08 (0.000)	325.25 (0.000)	68.32 (0.000)

Notes' The P- values are represented in parenthesis. The Wald test is reported with chi square test statistic with number of restrictions as degree of freedom.

Table 8 reports the Wald statistics with various restrictions in the interactions between the yield curve and the macroeconomic factors. This test indicated the statistical evidence for the bi-directional link between the yield curve and macro factors for each country.

The results shown in Table 8 indicate the rejection of the null hypothesis suggesting that in the Asian economies, there exists a strong bi-directional relationship between the yield curve and macro factors.

6. Summary and conclusion

This paper examined the interaction between the yield curve and the macro-economic factors among Asia countries such as Japan, Hong Kong, Singapore, Malaysia, South Korea, India, China, Indonesia and Philippines. The macro economic factors considered were policy rate, inflation and output growth. The yield curve and macro-economic factors were modelled jointly, applying the Dynamic Nelson Siegel model, using the Kalman filter as in Diebold et al. (2006).

The results indicate that own factor dynamics persist across the term structure of all the Asian economies. The curvature in each country leads the domestic level across these Asian economies. It infers that, in Asia, the medium term rates drive the long term rates.

There exists a bi-directional feedback between the yield curve and the macroeconomic factors across all the Asian countries. The policy rates lead the long-term factor, indicating the effective monetary policy transmission mechanism in a majority of Asian economies. Level leads the inflation, which demonstrates that the inflation is strongly anchored by the long term factor. Increase in the policy rate and inflation affects the slope of the term structure while the output growth strongly leads the long-term factor of the yield curve. The depreciation of exchange rates led to increase of the level factor in emerging economies and the increase in slope factor appreciated the exchange rates in developed Asian markets such as Hong Kong and Singapore. These results provide evidence of effective management of monetary policy among Asian economies even during the crisis period.

Literature on the relationship between the macro and yield curve factors in the developed markets found that curvature lacks the significant link with the macro factors. However, curvature leads the policy rate in most of the Asian economies and it also impacts the inflation, output growth and exchange rates in few economies.

The recent global financial crisis has induced the Central banks such as Fed, Bank of England and Bank of Japan to overnight slash the interest rates to zero. The zero interest rate in many economies has persuaded the Central bank to experiment with other tools such as quantitative easing to boost the economy. Thus, as the scope of future study, it would be interesting to examine the impact of quantitative easing on the yield curve.

Appendix 1. Data sources and descriptions

Country	Macro-economic variables	Source
Japan	Industrial production index Inflation Policy rate (Short term overnight uncollateralised call rates) Exchange Rate	Bank of Japan website- Bank of Japan time series data search https://www.stat-search.boj.or.jp/index_en.html
Singapore	Industrial Production Index Inflation (CPI) Policy rate Exchange rate	Department of Statistics of Singapore (http://www.singstat.gov.sg/)
Hong Kong	Inflation (CPI) Policy rate GDP Exchange rate	Bloomberg
Korea	Industrial Production Index Inflation (CPI) Policy rate (uncollateralised call rates) Exchange rate	Bank of Korea, Economic statistics system http://ecos.bok.or.kr/EIndex_en.jsp
Malaysia	Industrial Production Index Inflation Policy rate Exchange rate	Bloomberg
India	Industrial Production Index Inflation(CPI) Policy rate (Call Money Rate) Exchange rate	Reserve bank of India website- Database of Indian economy http://dbie.rbi.org.in/DBIE/dbie.rbi?site=home
China	Inflation(CPI) Policy Rate GDP Exchange rate	Bloomberg
Indonesia	Industrial Production Index Inflation (CPI) Policy Rate Exchange rate	Bloomberg and Bank Indonesia http://www.bi.go.id/en/Default.aspx

(*continued on next page*)

(*continued*)

Country	Macro-economic variables	Source
Philippines	Inflation (CPI) Policy Rate Capacity Utilization Exchange rate	Bloomberg

Appendix 2. Descriptive statistics of extracted latent factors using Dynamic Nelson Siegel model

	Mean	Std. Dev	Minimum	Maximum	Jarque-Bera t- statistics	P values	ρ (1)	ADF t- statistics	P values
Japan									
Level	3.20	0.70	1.72	5.22	2.97	0.23	0.93	−1.68	0.44
Slope	−3.01	0.79	−5.22	−1.69	7.12	0.03**	0.95	−1.52	0.52
Curvature	−2.94	1.27	−5.15	−0.09	7.57	0.02**	0.96	−2.31	0.17
Hong Kong									
Level	3.93	1.41	0.87	6.73	1.49	0.47	0.96	−2.53	0.11
Slope	−2.88	1.72	−6.67	−0.38	7.76	0.02**	0.96	−1.92	0.32
Curvature	−2.13	2.11	−6.20	1.65	7.96	0.02**	0.93	−2.14	0.23
Singapore									
Level	4.35	0.93	2.97	6.72	10.42	0.01	0.92	−3.48	0.00***
Slope	−3.27	1.51	−6.03	−0.01	5.34	0.07*	0.96	−2.14	0.23
Curvature	−3.69	2.05	−7.66	0.07	5.80	0.06*	0.96	−1.35	0.60
Malaysia									
Level	4.77	0.66	3.50	6.84	9.50	0.01***	0.90	−3.83	0.00***
Slope	−1.94	1.06	−4.47	−0.15	10.92	0.00***	0.95	−2.59	0.09**
Curvature	−1.78	0.90	−4.33	0.48	0.47	0.79	0.83	−2.33	0.16
Korea									
Level	5.10	0.85	3.12	6.44	14.41	0.00***	0.94	−1.77	0.39
Slope	−1.28	1.31	−4.98	3.23	17.69	0.00***	0.85	−3.20	0.02**
Curvature	−0.98	1.14	−6.47	3.82	150.07	0.00***	0.59	−5.41	0.00***
India									
Level	7.69	0.63	6.04	8.79	18.55	0.00***	0.94	−2.73	0.07*
Slope	−1.54	1.68	−5.31	2.80	5.68	0.06*	0.96	−1.86	0.35
Curvature	−0.27	1.75	−9.23	3.90	120.21	0.00***	0.78	−3.33	0.01***
China									
Level	4.31	0.79	3.17	6.69	35.69	0.00***	0.93	−3.05	0.03**
Slope	−1.82	0.86	−3.60	0.08	4.44	0.11	0.92	−2.47	0.13
Curvature	−2.42	1.35	−6.02	−0.29	17.83	0.00***	0.92	−3.18	0.02**
Indonesia									
Level	11.86	3.04	6.26	20.17	1.57	0.454	0.91	−2.04	0.26
Slope	−19.52	6.78	−35.45	−10.5	10.33	0.00***	0.96	−2.18	0.21
Curvature	−11.08	4.40	−20.5	−4.75	12.31	0.00***	0.33	−2.01	0.27
Philippines									
Level	9.61	3.14	3.16	15.36	4.73	0.09*	0.96	−1.47	0.54
Slope	−5.34	1.63	−9.17	−2.04	6.26	0.04***	0.91	−3.05	0.03***
Curvature	0.304	3.82	−8.04	6.83	7.01	0.03**	0.92	−2.86	0.05**

Notes: This table provides the descriptive of the latent factors extracted from Dynamic Nelson Siegel model applying Kalman filter. Augmented Dickey fuller (ADF) test is used to check the stationarity of the series. Jarque-Bera tests the normality of the series. Rejection of null hypothesis at 1%, 5% and 10% levels are denoted by ***, ** and * respectively. ρ (t) denotes sample autocorrelation at displacement t.

Appendix 3. Descriptive statistics of macroeconomic factors

	Mean	Std. Dev	Minimum	Maximum	Jarque-Bera t- statistics	P values	ADF t- statistics	P values
Japan								
Policy Rate	0.13	0.17	0.00	0.52	46.45	0.00	−1.79	0.379
Inflation	−0.008	0.29	0.00	−0.90	0.69	0.70	−9.15	0.00**
IIP	0.04	2.54	−16.46	6.85	1363	0.000	−8.85	0.00***
Exchange Rate	100.91	14.05	76.72	122.64	10.12	0.006	−1.376	0.592
Hong Kong								
Policy Rate	0.95	1.07	0.11	3.39	32.99	0.00	−1.80	0.37
Inflation	2.08	2.47	−4.00	7.90	2.10	0.34	−1.83	0.361
GDP(annual growth rate)	4.45	3.57	12.1	−7.80	30.93	0.00	−3.44	0.011***

(*continued on next page*)

(*continued*)

	Mean	Std. Dev	Minimum	Maximum	Jarque-Bera t- statistics	P values	ADF t- statistics	P values
Exchange Rate	7.77	0.02	7.7	7.8	10.16	0.006	−2.96	0.04**
Singapore								
Policy Rate	0.85	1.07	0.01	3.56	30.12	0.00***	−0.900	0.78
Inflation	1.95	1.50	−1.40	6.50	44.91	0.00***	−4.73	0.00***
IIP	79.19	17.27	48.73	113.	7.7	0.02	1.22	0.66
Exchange Rate	1.47	0.17	1.20	1.77	10.70	0.004	−1.15	0.69
Malaysia								
Policy Rate	2.90	0.43	2.00	3.52	3.24	0.19	−2.17	0.21
Inflation	2.35	1.72	−2.40	8.50	95.74	0.00	−3.33	0.015**
IIP	0.65	3.96	−14.4	12.20	12.37	0.002	−8.11	0.00***
Exchange Rate	4.2	0.2	3.8	4.6	2.78	0.24	−2.18	0.213
Korea								
Policy Rate	3.38	0.97	1.45	5.14	5.23	0.07	−1.97	0.29
Inflation	94.4	8.94	79.68	108.1	10.09	0.006	−0.33	0.91
IIP	86.81	16.67	55.30	113	8.75	0.01	−1.02	0.74
Exchange Rate	1100.9	114.02	914.8	1119.98	5.27	0.07	−2.36	0.152
India								
Policy Rate	6.84	1.11	4.75	9.00	6.49	0.03	−1.51	0.52
Inflation (CPI Index value)	128.10	26.23	91.1	181.5	10.69	0.00	1.28	0.99
IIP growth rate	6.76	5.6	−7.20	20	0.13	0.93	−2.08	0.25
Exchange Rate	47.18	5.10	39.3	63.75	51.75	0.00	−0.33	0.92
China								
Policy Rate	6.01	0.65	5.31	7.47	14.42	0.00	−2.18	0.21
Inflation	3.12	2.27	−1.8	8.70	0.55	0.75	−2.54	0.10
GDP (annual GDP growth rate)	9.48	1.58	5.42	12.70	3.57	0.16	−2.72	0.07
Exchange Rate	7.12	0.75	6.07	8.27	11.36	0.003	−0.76	0.82
Indonesia								
Policy Rate	7.88	1.85	5.75	12.75	30.48	0.00	−2.42	0.13
Inflation growth rate	0.59	0.90	0.45	8.70	133	0.00	−9.27	0.000
IIP growth rate	0.41	4.85	−19.63	16.45	106	0.00	−4.57	0.00
Exchange Rate	9379.89	774.41	8239.05	12006.19	79.49	0.00	−0.778	0.82
Philippines								
Policy Rate	5.48	1.48	3.50	7.50	14.91	0.00	−0.411	0.90
Inflation	4.46	1.98	1.70	10.50	23.18	0.00	−2.79	0.06
Capacity utilization	81.04	1.79	80.4	83.6	5.46	0.06	−2.52	0.11
Exchange Rate	48.00	5.19	40.67	56.34	12.28	0.002	−1.37	0.59

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