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ORIGINAL PAPER

Yield curve in India and its interactions with the US bond market

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Abstract This paper examines the dynamics of the yield curve in India. The study decomposes the entire yield curve into three latent factors (viz. level, slope and curvature) for both the Indian and US sovereign bond markets using the dynamic Nelson Siegel model applying Kalman filter in state space framework. The extracted level factor represents long term, the slope represents short term and the curvature represents medium term interest rate factor. Using the extracted latent factors, the impact of the US yield curve interactions upon the Indian yield curve has been investigated. It provides a new dimension to the literature through investigating the influence of external factors (i.e. US contribution) on the emerging economy yield curve. It is found that the level and slope of the US market leads the long end of the Indian yield curve. The Indian slope was domestic in nature, but after the global financial crisis, linkages between the Indian slope and the US yield curve have increased. The results of this study would enable policy makers to understand the interactions between the domestic yield curve and US market and ensure monetary policy stabilisation. The linkages will also help the global investors in their asset allocation decisions.

Keywords Yield curve · Dynamic Nelson Siegel model · Global financial crisis

JEL Classification E430 · G12 · G15 · G010 · G2 · C58

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1 Introduction

Financial markets have witnessed high volatility in recent years; and increased volatility of interest rates causes concern to policy makers, investment professionals and financial economists. The relationship between the interest rates that differ only with maturity is known as the term structure of interest rates and is represented graphically by the yield curve (Mansur et al. 2005). A well-established yield curve allows for the inferring of expectations of inflation and economic activity. It synthesizes agents' perceptions about the future state of the economy (Matsumura and Moreira 2011), and plays a crucial role in conducting monetary policy, pricing of financial assets, managing financial risk and portfolio allocation.

The yield curve of a country is driven primarily by domestic factors. The existing yield curve literature is concentrated on the interaction effects with domestic factors using macro-economic variables (Diebold et al. 2006; Lange 2013; Kaya 2013; Morales 2010; Aguiar-Conraria et al. 2012; Matsumura and Moreira 2011). These papers have noted that macroeconomic factors had a significant impact on the level and slope of the yield curve. Kanjilal (2013) examined the linkages between the yield curve and the macroeconomic activity in India and found that changes in the monetary policy play an important role in driving the yield curve.

Financial liberalisation of many emerging markets resulted in increased correlation of the yield curve across the countries. Thus, the sovereign bond yields, which were known to be domestic in nature, particularly among emerging markets, are now being exposed to global linkages. Diebold et al. (2008) found that global factors play a significant role in the movements of the domestic yield curve of developed markets. The pace at which the recent financial crisis, which originated in developed financial markets and spread across all emerging markets, provides further evidence of global linkages. These evolving global interactions necessitate in exploring the global linkages among emerging markets domestic yield curve. This paper investigates to extend the previous research and offers new evidence about the interactions in the sovereign yield curve between the developed US market, and India, an emerging market.

Indian economy is considered as a bright spot in the global horizon. It is the fastest growing emerging economy in the world with the current GDP growth rate of 7.5 %. The rising conviction in the market performance has helped the economy to emerge as the favourite destination among the Foreign Portfolio Investors. The economic liberalization resulted in India easing rules for foreign investments in Indian government securities. The total foreign investment received in 2014 is Rs.2562.13 billion, of which Rs.159.156 billion is invested in Indian debt markets (Source: CDSL).[1] In the context of increasing capital flows from foreign investors in the Indian sovereign securities, it is essential to understand the dynamics of domestic yield curve interactions with global markets.

US being the largest economy in the world affect the rest of the economies through multiple trading and investment channels (Engsted and Tanggaard 2007). The shocks transmitted from the US economy are expected to significantly influence the assets of other economies (Singh et al. 2013). Moreover, the Federal Reserve Open Market Committee's (FOMC) announcement in September 2013 regarding tapering of the

[1] CDSL stands for Central Depositories (India) Ltd.

Quantitative Easing (QE) program has moved the stock and bond markets worldwide. Notably, the effect of that announcement impacted not just the US financial markets but also other developed and emerging markets (Berge and Cao 2013).

The increasing cross border relationship between India and the US, and the recent research evidence about the impact of global factors on the domestic yield curve motivates the present study. This paper analyses the unexplored dynamics of the Indian yield curve and the impact of the US yield movements on Indian sovereign yields.

This paper has investigated the dynamics of the Indian yield curve and its interactions with the US yields using zero coupon yields of India and the US at various maturity horizons for the time period of January 2003 to December 2013. The yield curve is quantified by applying Dynamic Nelson Siegel Model using Kalman filter as in Diebold et al. (2006) in which the latent factors of the model follow a Vector Autoregressive (VAR) process in a state-space framework. The Dynamic Nelson Siegel model decomposes the term structure of interest rates into three latent factors viz; level, slope and curvature. The level represents the long term interest factor, the slope represents the short term interest factor and the curvature represents the medium term interest factor. This study further extended the state-space representation of the yield curve by including the US latent factors to examine its interactions on the Indian yield curve. The transmission of US monetary policy shocks was analysed using variance decomposition. The US interaction on the Indian yield curve is also analysed by including the Indian macroeconomic variables and exchange rate in the model. Further, the impact of the global financial crisis upon the yield curve interactions was also analysed.

The results indicate that the lag terms of the level, slope and curvature of the yield curve, for both the Indian and US markets, have a significant influence on the respective latent factors, and cross factor interactions exist in both the markets. In India, the level leads the curvature, whereas in the US, the slope leads the curvature. The inference therefore is that the long term factor leads the medium term factor in emerging markets like India, while the short term factor leads the medium term factor in the US. The level and curvature factors in India are influenced by the US. The Indian slope factor is basically domestic in nature, but after the global crisis, linkages between the Indian slope factor and the US yield curve have increased.

The contribution of this study is three fold. First, it is the one of the very few studies that examines the impact of US yield curve movement on the Emerging Market yield curve. The interest rate is an important channel through which transmission happens to the other markets. Wongswan (2006) found that the US monetary policy announcements impact both the developed and emerging countries' equity markets. This study on linkages between the US and Indian yield curves facilitates to understand the co-movements of economic activity.

Second, from the modelling point of view, this study provides a new dimension to the literature by investigating the influence of external factors (i.e. US contribution) on the domestic yield curve in the state-space framework. Earlier, Lange (2014) used empirical proxies for the US latent factor to examine its influence on the Canadian yield curve. The current study extracts the latent factors from US zero coupon yields using the Kalman filter. These extracted factors were used to examine the influence of the US yield curve movement on the domestic yield curve.

Third, this paper also investigates the influence of the US yield curve on the Indian market during the global financial crisis, to provide a clear picture on the linkages between the two countries during the period of heightened market instability.

The rest of this paper is structured as follows: Section 2 discusses the Data and analytical model, Section 3 presents the empirical results and Section 4 presents the summary and policy implications.

2 Data and analytical model

2.1 Sovereign bonds

Sovereign bonds are the bonds issued by the Central Government of the country to fund the government's obligation. Sovereign yields serve as the benchmark rate to value the financial securities in an economy.

The Bond market in India is dominated by the sovereign bonds which are referred as Government securities. The Government securities constitutes of 78 % of securities traded in debt segment (Source: NSE). The Indian Government securities are issued by Reserve bank of India (Country's central bank) on behalf of the central government. Major participants are commercial banks, primary dealers and Institutional investors like insurance companies. Foreign institutional investors are allowed to invest and are active traders in this segment. The Reserve bank of India uses these government securities to actively manage the liquidity and money supply in the economy.

This study uses the zero coupon yield rates of sovereign bonds in India and the US to examine the yield curve interactions across them. Zero coupon yield rates were used to extract the latent factors using the Dynamic Nelson-Siegel model by applying the Kalman filter. The interactions between the Indian and US yield curves have been analyzed with the help of Vector Auto Regression (VAR) in the expanded state-space framework.

2.2 Dynamic Nelson Siegel model

Diebold et al. (2006) interpreted the Nelson Siegel representation in a dynamic form, in which L_t, S_t and C_t are time varying parameters.

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

The loadings on L_t is constant and does not decay to zero representing the long term yields, hence, it is labelled as Level (L_t). The loading on S_t starts at 1 and decays monotonically to zero, representing the short term yields and labelled as Slope (S_t). The loading on C_t starts at zero, increases and decays to zero. It loads heavily in medium term yields and is labelled as Curvature.

If the dynamics of L_t, S_t and C_t follow a VAR process of the first order, the model immediately follows the state-space form. It comprises of two equations, namely, the measurement equation and the transition equation. The measurement equation which relates to the set of yields and the latent factors is:

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

The measurement equation written in vector notation is,

$$\mathrm{y_t} = \zeta g_t + \varepsilon_t \tag{3}$$

where y_t is a nx1 vector of observed yields (τ) at time t. ζ is the nx3 matrix of factor loadings, g_t is the 3x1 vector of latent factors and ε_t is a Nx1 vector of disturbance errors.

The transition equation relates to the dynamics of the latent factors as

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

The transition equation written in vector notation as

$$(g_t - \mu) = B(g_{t-1} - \mu) + \eta_t \tag{5}$$

where g_t is 3×1 latent factors, μ is 3×1 vector of means, B is 3×3 matrix of VAR coefficients and η_t is the 3×1 vector of disturbance errors.

The white noise of the transition and measurement equation should be orthogonal to each other and also to the initial state to obtain the linear least square optimality of the Kalman filter.

$$\begin{pmatrix} \eta_t \\ \varepsilon_t \end{pmatrix} \sim WN\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} P & 0 \\ 0 & H \end{pmatrix}\right] \tag{6}$$

The P matrix is the variance and covariance matrix of the transition equation. It is non-diagonal as the latent factors of the yield curve are correlated. The H matrix is the variance and covariance matrix of the measurement equation, which is diagonal, as the deviation of yields of various maturities is uncorrelated. The maximum likelihood function is estimated by the Kalman filter which updates the measurement and transition equation until an optimal point is achieved.

2.3 Dynamic interaction between US and Indian latent factors

The dynamic interaction between the US yield curve and the Indian yield curve was identified by including the US latent factors in the state space-equations.

$$(g'_t - \mu) = B(g'_{t-1} - \mu) + \eta_t \tag{7}$$

where $g' = (L_t, S_t, C_t, USL_t, USS_t, USC_t)$ is 6×1 matrix includes the Indian latent and the US latent factors, μ is 6×1 vector of means, B is 6×6 matrix of VAR coefficients and the dimensions of disturbance terms are increased accordingly. The assumptions made on the P and H matrices are similar to the baseline model.

2.4 India-US yield curve-macro model

India-US yield curve- macro model examines the US interactions on the Indian yield curve along with the macro factors and the exchange rate. The Indian macro factors considered are policy rate, inflation and Industrial production Index (IIP). The state space model of Eq. (7) is now replaced as

$$g' = (L_t,\ S_t,\ C_t,\ USL_t,\ USS_t,\ USC_t,\ policyrate_t,\ inflation_t,\ IIP_t,\ exchange_t)$$

The transition B matrix now contains the dimension of 10×1 VAR coefficients; μ is 10×1 vectors of means and transition covariance matrix P with 10 variance terms and 45 covariance terms. The assumptions made on P and H of the baseline model remains the same.

3 Empricial results

3.1 Summary statistics

The monthly zero coupon yields of maturities 3,6,12,24,36,48,60,72,84,96,108, and 120 months, spanning the timeframe from January 2003 to December 2013, for India and the US are considered. The US yields were obtained from the Bloomberg database, and the Indian zero coupon yields were obtained from the National Stock Exchange (NSE) data archives.

The Indian macro economic factors considered are call money rate as proxy for policy rate, Consumer price index to reflect domestic inflation level and Industrial production Index as proxy for economic activity along with the Rupee Dollar exchange rate. The data is sourced from database archive of Reserve Bank of India.

Table 1 reports the descriptive statistics of zero coupon yields of various maturities. The yield curves of US were found to be upward sloping. Volatility was higher for smaller maturities and came down with the increase in the maturity period. A strong autocorrelation was found with the preceding month yield rates. The US yield rates were highly persistent with the average first order autocorrelation of 0.98. The Indian

Table 1 Descriptive statistics of the Indian and US zero coupon yields

Maturity	Mean	Std. Deviation	Minimum	Maximum	ρ (1)	ρ (12)
India						
3 months	6.26	1.72	3.07	11.09	0.95	0.30
6 months	6.37	1.69	1.06	10.59	0.89	0.25
1 year	6.37	1.50	3.57	9.49	0.94	0.31
2 year	5.38	1.65	1.43	8.98	0.77	0.36
3 year	6.14	1.36	2.93	8.92	0.85	0.39
4 Year	6.52	1.22	3.32	9.07	0.84	0.39
5 Year	6.84	1.11	3.84	8.85	0.88	0.41
6 year	6.96	1.05	4.06	8.71	0.82	0.38
7 year	7.15	1.00	4.52	9.20	0.88	0.40
8 year	7.28	1.00	4.70	9.58	0.88	0.42
9 year	7.31	1.01	4.71	9.33	0.91	0.38
10 year	7.27	0.93	4.89	8.92	0.88	0.36
US						
3 months	1.53	1.78	0.01	5.16	0.99	0.69
6 months	2.14	1.83	0.35	5.58	0.99	0.71
1 year	2.37	1.70	0.58	5.66	0.99	0.71
2 year	1.99	1.66	0.21	5.18	0.99	0.75
3 year	2.24	1.55	0.33	5.15	0.99	0.75
4 Year	2.51	1.44	0.48	5.14	0.98	0.76
5 Year	2.78	1.34	0.66	5.11	0.98	0.74
6 year	2.98	1.25	0.81	5.14	0.98	0.72
7 year	3.19	1.16	1.00	5.15	0.97	0.69
8 year	3.35	1.11	1.19	5.16	0.97	0.68
9 year	3.52	1.05	1.39	5.17	0.97	0.70
10 year	3.68	1.00	1.56	5.19	0.97	0.65

This table reports the descriptive statistics of the zero coupon yields for India and US. All yields are monthly, 2003:01 – 2013:12

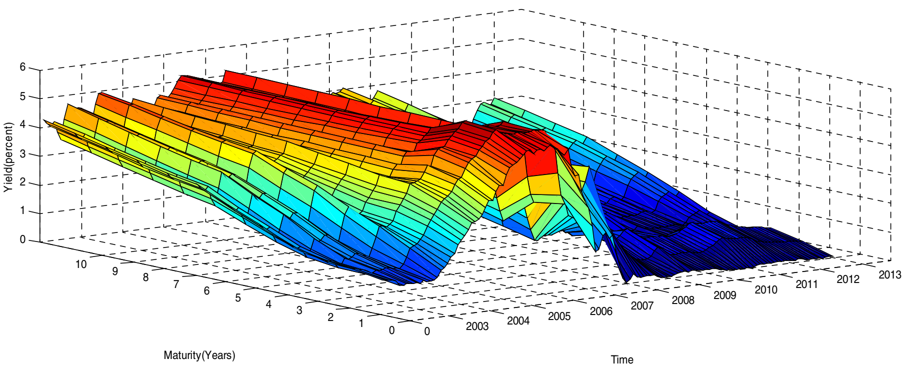
ρ (t) denotes sample autocorrelation at displacement t

yields are less persistent in relation to the US yields, with the average first order autocorrelation of 0.87.

The dynamics of the US yield curve has been captured in Fig. 1. Due to the global financial crisis the US yield curve witnessed a declining trend in 2007. Significantly, the US short term rates reached near zero during 2011–2013.

Figure 2 depicts the time varying yield curve in India. It was noted that the short term rates were higher than the long term rates in 2013 indicating an inverted yield curve. It was the period when the US Fed had announced the tapering of the QE (Quantitative Easing) program in 2013. During this period, the Indian rupee depreciated by 20 % and the Reserve Bank of India hiked the short term rates to curb the rupee fall and to tighten the liquidity in the economy. During that period the Reserve Bank of India had also initiated various other measures -it actively participated in open market

US Yield Curve across time



Notes: Figure 1 present the monthly zero coupon yields of various maturities for US and India for the period January 2003 to December 2013

Fig. 1 US Yield Curve across time

sale of bonds; the amount that banks could borrow from overnight markets was capped, and foreign direct investments were liberalized in certain sectors. All these measures restored the upward sloping yield curve in early 2014.

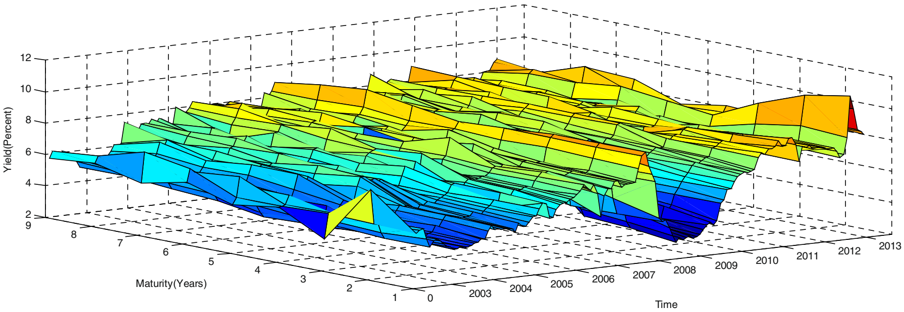
3.2 Estimation of latent factors

For the purpose of this study, yield rates were decomposed into three latent factors to comprehend their inter-linkages. The Dynamic Nelson-Siegel model was used to extract the latent factors. The state-space form of the model contains the VAR (1) transition equation summarizing the dynamic latent state variables and the measurement equation relating the observed yields with the state vector. 12 maturities have been considered and therefore vector y_t and ε_t contain 12 rows. The (3×3) transition matrix B contains 9 parameters, (3×1) mean state vector μ contains 3 parameters, and the measurement matrix contains one free parameter λ. The parameter λ was freely estimated along with the loading matrix as in Diebold et al. (2006).[2] The disturbance term of the transition equation Q matrix contains 3 disturbance variance terms, one for each latent factor and 3 covariance terms. The disturbance term of measurement equation H matrix contains 12 free parameters, one disturbance term for each of the yields. Therefore, 31 parameters were required to be estimated by numerical optimization using the Kalman filter. The likelihood was maximized by iterating the Berndt-Hall-Hall-Hausman algorithms with convergence criterion of 10^{-6}.

Table 2 presents the descriptive statistics of latent factors extracted using the Dynamic Nelson-Siegel Model applying the Kalman filter. The level represents the long term factor and signifies the bond market's perception on long term inflation. Increase in the long term factor reflects the increase in the future perceived inflation (Diebold et al. 2006). The average level in India was higher than that of US. The volatility of the level was less when compared to the slope and the curvature factor for both the countries. This indicates that the volatility of long term rates is lower than that of the short term rates. The same was further confirmed by higher persistence with the

[2] Initially λ is set at 0.0609 as in Diebold and Li (2006)

Indian Yield Curve across time



Notes: Figure 2 present the monthly zero coupon yields of various maturities for US and India for the period January 2003 to December 2013

Fig. 2 Indian Yield Curve across time

first order auto correlation in level for India as well as for the US. The extracted level values were compared with the generally estimated empirical proxy for level factor for the period January 2003 to December 2013. The empirical proxy was computed as the average of short, medium and long term yield rates. Following Diebold et al. (2006), short term was considered as 3 months and long term as 120 months.

$$\text{Empirical proxy for level} = ((y_t(3) + y_t(60) + y_t(120))/3)$$

Figure 3 graphs the extracted level factor and the empirical proxy for both the countries. It was noted that extracted values co-moved with the empirical proxy for India. Both the countries exhibited a marginal divergence during the global financial crisis (2008).

The slope represents the behaviour of short term yields. The changes in the monetary policy have a direct impact on the short term yield rates, which in turn affects the long term rates. Thus, slope is viewed as the monetary policy indicator. It helps in predicting the growth of the country (Mehl 2009). The slope is interpreted as the difference between the short and long term interest rates. The average slope was negative for both the countries, indicating upward sloping yield curves. It infers that the long term rates were higher than the short term interest rates. The volatility of the slope was higher, indicating that the volatility of the short term interest rates were higher than the long term interest rates. The slope showed higher persistence compared to the other latent factors with first order autocorrelation of 0.96 for India and 0.97 for the US.

Figure 4 graphs the estimated slope with the empirical proxy, which was measured as the difference between short term and long term yield rates.

$$\text{Empirical proxy for slope} = (y_t(3) - y_t(120)).$$

The extracted slope exactly co-moved with the empirical counterpart both for India and the US.

The curvature captures the behaviour of medium term yield rates. It is related to real interest rate movements and is not linked with the macroeconomic factors of the economy (Hoffmaister et al. 2009). The average curvature factor for India was −0.27 and for the US it was −2.95. The curvature exhibited lower persistence for both the countries.

$$\text{Empirical proxy of curvature factor} = 2{*}(y_t(60) - y_t(3) - y_t(120)).$$

Table 2 Descriptive statistics of latent factors extracted using the Dynamic Nelson Siegel model

	Mean	Std. Dev	Minimum	Maximum	ρ (1)
India					
Level	7.69	0.63	6.04	8.79	0.94
Slope	−1.54	1.68	−5.31	2.80	0.96
Curvature	−0.27	1.75	−9.23	3.90	0.78
US					
Level	5.31	0.71	3.67	6.74	0.93
Slope	−3.76	2.23	−7.00	0.29	0.97
Curvature	−2.95	1.96	−7.99	0.06	0.92

This table reports the latent factors for each country extracted from Dynamic Nelson Siegel Model using the Kalman filter for the sample period January 2003 to December 2013.ρ (t) denotes sample autocorrelation at displacement t

Figure 5 graphs the extracted curvature values with the empirical proxy. It was found that the extracted factors co-moved exactly with the empirical proxies.

A comparison of Figs. 6, 7, and 8 reflected the direction of co-movement between the extracted latent factors. While both the countries moved in same direction for slope and curvature, significant difference was exhibited in the level factor.

3.3 Yield curve in India

The model captures the impact of the latent factors on the domestic yield curve. VAR (1) of the transition equation estimates the dynamics of the latent factors. Table 3 presents the estimation results of B matrix as in Eq. (4) for India.

The B matrix of the transition equation indicated higher persistence across all the three latent factors, with statistically significant coefficients loaded on their own lag values. The cross factor dynamics appeared important for level and curvature factors. The Indian level affected its own lag and positively affected the lag of the curvature. The slope was independent and not influenced by the level and curvature factors. The slope

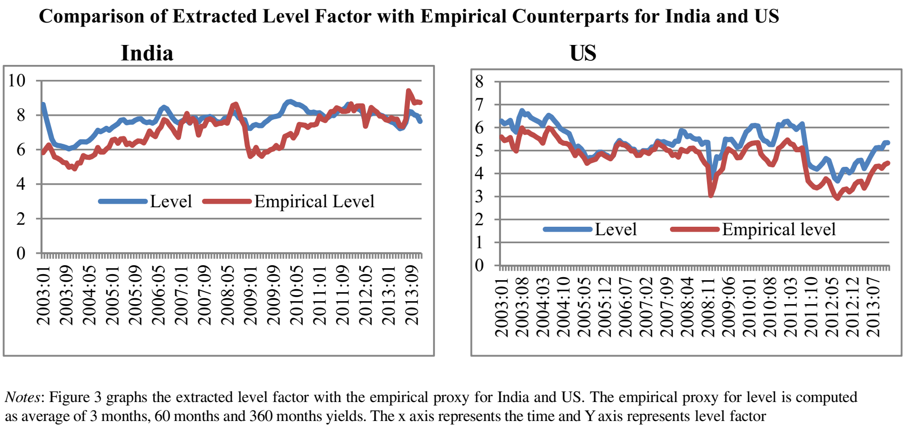
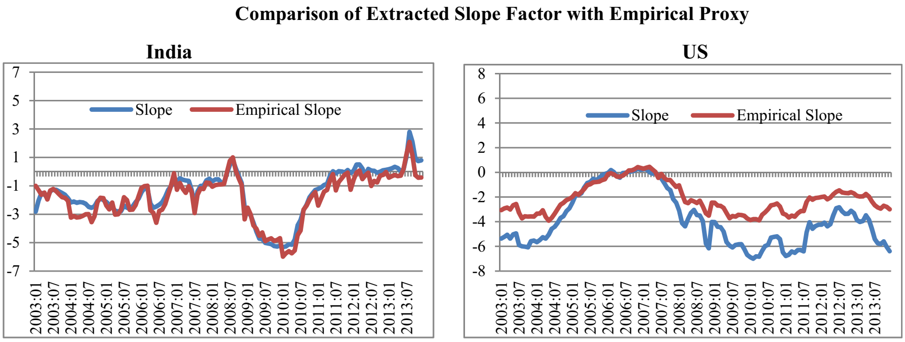


Fig. 3 Comparison of Extracted Level Factor with Empirical Counterparts for India and US



Notes: Figure 4 graphs the extracted slope factor with the empirical proxy for India and US. The empirical proxy for slope is computed as difference between the short term and the long term yields (Yield of 3 months minus the yield of 360 months). The x axis represents the time and Y axis represents the short term factor

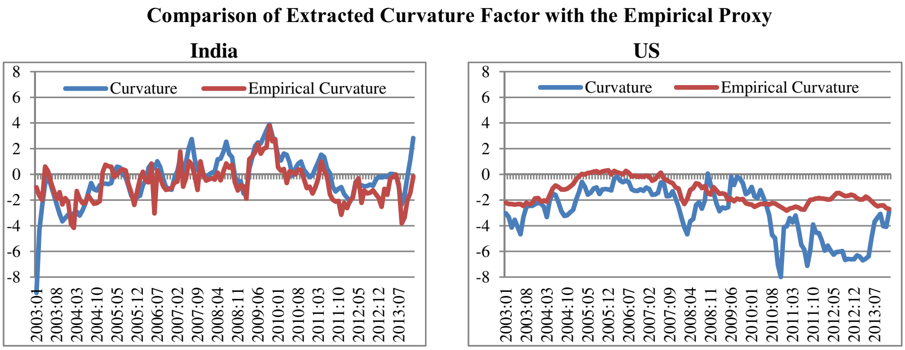
Fig. 4 Comparison of Extracted Slope Factor with Empirical Proxy

reacted to the monetary policy changes. The mean values of latent factors obtained in the VAR analysis synchronized with those of descriptive statistics reported in Table 1.

Table 4 presents the variance and covariance P matrix for a yields only model. The diagonal elements of the P matrix indicate the transition shock volatility. The estimated matrix suggested that level was the least volatile and the curvature factor was the most volatile component in the Indian term structure. This result was coherent with the results of (Djuranovik 2014). The off diagonal elements were not found to be significant. This led to the inference that there was no covariance between the volatility of level, slope and curvature factors. This also indicated that the latent factor volatility is not influenced by the cross factors.

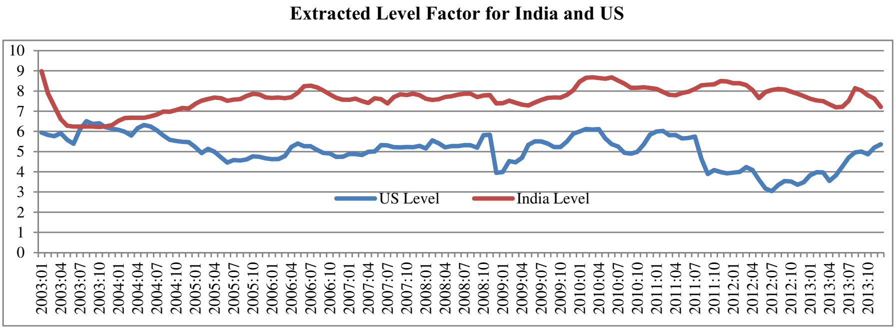
3.4 India-US yield curve interactions

The yield curve of a country is driven by both country specific and global factors (Diebold et al. 2008; Bae and Kim 2011; Jaramillo and Weber 2013). The US monetary policy changes are closely tracked by the countries across the world. The shocks transmitted from the US economy to other economies are expected to have a significant



Notes: Figure 5 graphs the extracted curvature factor with the empirical proxy for India and US. The empirical proxy for curvature is computed as 2*(y_t (60_{months}) - y_t (3_{months}) - y_t (360_{months}). The x axis represents the time and Y axis represents the medium term factor

Fig. 5 Comparison of Extracted Curvature Factor with the Empirical Proxy



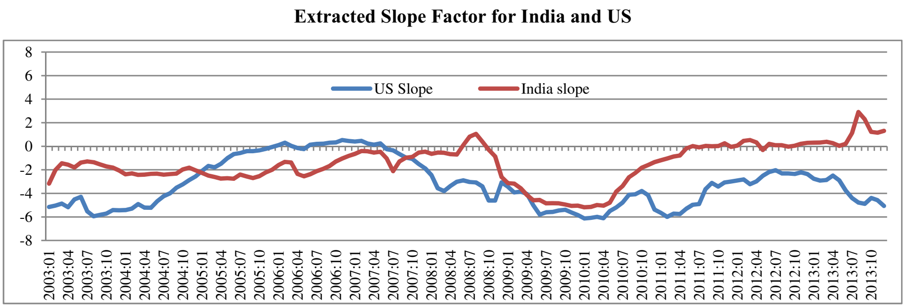
Notes: Figure 6 graph the extracted latent factors for the two countries India and US

Fig. 6 Extracted Level Factor for India and US

effect on the asset returns (Singh et al. 2013). During 2008, when US Fed announced large scale asset purchase program, sovereign yields of emerging economies also fell along with US yields and stock markets soared. Again in 2013 when Fed announced tapering of Quantitative easing program sovereign yields of emerging economies fell (Bowman et al. 2015). These anecdotes motivate us to explore the impact of US yield curve upon India. The India-US yield curve model extends the Diebold et al. (2006) work to an emerging economy environment and examines the interrelationship between the latent factors of US and India. Table 5 presents the US influence on Indian yield curve.

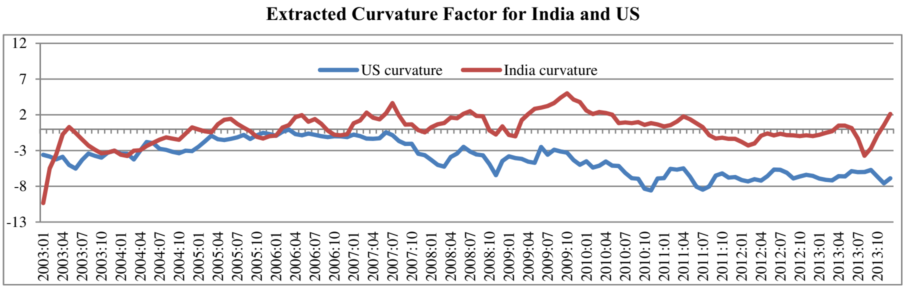
The results of the B matrix as in Eq. (6) are presented in Table 5. The Indian slope was found to be independent and was not influenced by the US slope. Lange (2013) explained that the slope is driven by the contemporary monetary policy of the domestic country. This result was also consistent to the findings of Abbritti et al. (2013), who found that global factors tend to explain the long term movements of the yield curve, as opposed to short term movements which are explained by the domestic factors. Chandra and Unsal (2014) found that US yield rates influenced the long term yields of various Asian countries.

Lag terms of the US level and the US slope had a statistically negative impact upon the Indian level factor. This result contradicts the findings of Kulish and Rees (2011), who reported that the long term interest rates of open economies are highly correlated with the long term interest rates of the United States. Further analysis on the impact of the global financial crisis would provide reasons for this negative relationship.



Notes: Figure 7 graph the extracted latent factors for the two countries India and US

Fig. 7 Extracted Slope Factor for India and US



Notes: Figure 8 graph the extracted latent factors for the two countries India and US

Fig. 8 Extracted Curvature Factor for India and US

US curvature that represents medium term factor leads Indian curvature. An increase in the US curvature triggers an increase in the Indian curvature factor.

The relationship between the Indian and US yield curve is found relatively weak despite the growing capital inflows in to the Indian bond market. The empirical findings suggest that even if the spill over from US affects the Indian bond market, the monetary policy authorities retain significant domestic influence through open market operations and policy actions. Our results corroborate with those of Patra et al. (2016) who noted that Indian government securities are driven more by domestic monetary policy stance than the global correlations.

Table 6 provides the variance and covariance matrix P for the India-US yield curves. The covariance term of P matrix provides evidence of positive correlation between US and Indian curvature factors. The estimated matrix, after including the US latent factors, suggests that the Indian level is least volatile and the Indian curvature is the most volatile component in Indian term structure. The volatility of the slope in India is influenced by the movements in the US level and the volatility of Indian curvature is influenced by the US curvature factor.

To summarize the results, state-space VAR analysis suggested that the Indian slope was independent of US influence, while the curvature had significant positive lead effect and level had negative US impact. The volatility dynamics from transition covariance matrix provides that Indian slope is driven by US level and Indian curvature is driven by US curvature. Volatility of the Indian level is not influenced by the US yield curve.

The synthesis of both the results suggests that though the Indian slope is independent, its volatility is influenced by the volatility of the US level factor. The volatility of

Table 3 VAR transition B Matrix of Indian latent factors

State variable	L_{t-1}	S_{t-1}	C_{t-1}	μ
L_t	0.90*** (0.03)	−0.002 (0.01)	0.03* (0.02)	8.4 (0.28)
S_t	0.10 (0.07)	0.96*** (0.03)	−0.01 (0.04)	−1.63 (0.72)
C_t	0.28*** (0.13)	−0.07 (0.06)	0.77*** (0.07)	−3.11 (0.6)

This table reports the coefficients of B matrix of transition equation (9). Standard error appears in the parenthesis. L_t is the estimated level factor, S_t is the estimated slope factor and C_t is the estimated curvature factor. μ represents the mean of the corresponding latent factors. *, **, *** denote statistical significance at the 10 %, 5 % and 1 % levels respectively

Table 4 Transition disturbance term P matrix

	L_t	S_t	C_t
L_t	0.06*** (0.02)	−0.007 (0.016)	−0.08 (0.06)
S_t		0.21*** (0.03)	−0.077 (0.06)
C_t			0.83*** (0.22)
Test for diagonality of P matrix			
		Test statistic	P-value
Wald test		12.72	0.00***

This table reports the variance and covariance term. Standard error appears in the parenthesis. L_t is the estimated Level factor, S_t is the estimated slope factor and C_t is the estimated curvature factor. *,**,*** denote statistical significance at the 10 %, 5 % and 1 % levels respectively. The wald test rejects the diagonality of the P matrix. The Wald test statistic is chi -square with 3° of freedom

the Indian level factor is independent though it has US influence. The curvature has both lead effect and its volatility is influenced by the US.

It is further proposed to analyse the impact of US monetary policy changes upon the Indian yield curve. The variance decomposition of latent factors identifies the contribution of US monetary policy shocks on the Indian yield curve.

3.5 Variance decomposition

Variance decomposition provides a metric to analyze the interactions of Indian and US latent factors that have evolved over time. The variance decomposition using the VAR (1) Cholesky decomposition model was estimated for the forecast horizons of 1, 12 and 60 months. The variables have been ordered as: India Level, India Slope, India Curvature, US Level, US Slope and US Curvature. Table 7 presents the proportion of variance explained by the latent factors.

Table 7 presents variance decompositions of India and US latent factors at 1 month, 12 months and 60 months horizons. US latent factors explain very little variation of Indian latent factors. This result suggests that the short term variations of Indian latent factors are driven more by the domestic factors than by US factors. There was only a marginal influence of the US monetary policy changes on the Indian yield curve in the long term horizon. The Indian slope was influenced by the US slope and US curvature factor in the long term horizon. However, the influence was very less compared to the own country factors.

Thus variance decomposition provides an understanding of the latent factor movements with the specific forecast horizons. Having understood that domestic factors influence the Indian yield curve, the study now investigates the impact of Indian macro economic factors together with the US latent factors.

3.6 India- US yield curve and macroeconomic interactions

The yield curve is closely related with the macro economic factors. Diebold et al. (2006) provided evidence that level factor is related to the expected inflation; slope is connected to business cycle movements and the current stance of monetary policy. The

Table 5 VAR transition B matrix for the India- US yield curve model

	L_{t-1}	S_{t-1}	C_{t-1}	USL_{t-1}	USS_{t-1}	USC_{t-1}	μ
L_t	0.93*** (0.09)	0.01 (0.01)	0.01 (0.04)	−0.08*** (0.04)	−0.03* (0.01)	0.03 (0.02)	8.3*** (0.26)
S_t	0.25 (0.21)	0.90*** (0.03)	−0.09 (.10)	0.09 (0.08)	0.03 (0.03)	−0.03 (0.04)	−1.75*** (0.58)
C_t	0.77 *** (0.28)	−0.06 (0.07)	0.55*** (.13)	−0.07 (0.15)	−0.08 (0.06)	0.16*** (0.07)	−3.25*** (.417)
USL_t	−0.22* (0.13)	0.04 (0.03)	0.08 (0.06)	0.79*** (0.05)	−0.03 (0.02)	0.02 (0.03)	5.26*** (0.303)
USS_t	0.09 (0.06)	−0.08 (0.06)	−0.30** (0.13)	0.16 (.12)	0.96*** (0.05)	0.07 (0.06)	−4.58*** (1.25)
USC_t	0.03 (0.04)	−0.06 (0.05)	0.017 (0.09)	0.21 (0.13)	0.14*** (0.05)	0.80*** (0.06)	−4.33*** (1.05)

This table reports the coefficients of B matrix of transition equation of Yield –US curve model. Standard error appears in the parenthesis. L_t is the estimated Indian Level factor, S_t is the estimated Indian slope factor and C_t is the estimated Indian curvature factor. USL_t is the estimated US level factor, USSt is the estimate US slope factor and USCt is the estimated US curvature factor. μ represents the mean of the corresponding latent factors. *, **, *** denote statistical significance at the 10 %, 5 % and 1 % levels respectively

Table 6 Transition covariance P matrix for the India- US yield curve model

	L_t	S_t	C_t	USL_t	USS_t	USC_t
L_t	0.04*** (0.01)					
S_t	−0.011 (0.01)	0.206*** (0.03)				
C_t	0.003 (0.03)	−0.08*** (0.04)	0.34*** (0.11)			
USL_t	0.005 (0.008)	0.02* (0.01)	0.007 (0.02)	0.07*** (0.01)		
USS_t	0.002 (0.016)	−0.03 (0.02)	−0.06 (0.03)	−0.07*** (0.01)	0.11*** (0.03)	
USC_t	−0.006 (0.02)	−0.02 (0.03)	0.14*** (0.07)	−0.01 (0.01)	−0.06*** (0.03)	0.49*** (0.06)
Test for diagonality of P matrix						
					Test statistic	P-value
Wald test					72.90	0.00
Likelihood ratio					47.09	0.00

This table reports the variance and covariance term. Standard error appears in the parenthesis, L_t is the estimated Level factor, S_t is the estimated slope factor and C_t is the estimated curvature factor. USL_t is the estimated US level factor, USSt is the estimate US slope factor and USCt is the estimated US curvature factor*,**,*** denote statistical significance at the 10 %, 5 % and 1 % levels respectively. The wald test and likelihood ratio rejects the diagonality of the P matrix

US interaction on the Indian latent factors is further analysed by including the Indian macro factors and the exchange rate with respect to US dollar.

Table 7 Variance decomposition of India-US yield curve model

Variable	Horizon	India level	India slope	India curvature	US level	US slope	US curvature
India level	1	100	0.00	0.00	0.00	0.00	0.00
	12	70.64	17.90	6.14	0.44	0.59	4.25
	60	70.6	17.92	6.14	0.44	0.59	4.25
India slope	1	39.72	60.27	0.00	0.00	0.00	0.00
	12	34.21	56.7	1.8	0.93	2.67	3.67
	60	34.21	56.7	1.8	0.93	2.67	3.67
India curvature	1	39.03	3	57.95	0.00	0.00	0.00
	12	18.81	0.67	78.38	1.05	0.39	0.7
	60	18.81	0.67	78.3	1.05	0.39	0.7
US level	1	2.3	0.36	0.1	97.23	0	0
	12	2.82	1.18	1.51	87.18	5.97	1.33
	60	2.82	1.18	1.51	87.18	5.97	1.33
US slope	1	0.00	0.00	0.00	0.00	100	0.00
	12	0.96	0.84	0.62	5.42	91.57	0.6
	60	0.96	0.84	0.62	210	91.57	0.9
US curvature	1	0.58	0.013	0.52	0.07	17.1	81.72
	12	1.85	2.47	2.49	1.72	18.03	73.43
	60	1.85	2.47	2.49	1.72	18.03	73.43

Each value is the proportion of forecast variance at specified forecast horizon. Horizon is measured in terms of months

Table 8 reports the transition B matrix for India- US yield curve-macro model. The Indian level factor continues to exhibit negative relationship with the US level factor (Both leads and lags). The lag term of US slope factor significantly influences the Indian slope. The impact of Indian latent factors on US factors is found insignificant.

Inflation has positive and significant effect on the next period Indian level factor which is consistent with the Fisher hypothesis. The policy rates significantly influences the next period slope of the yield curve. This indicates that the policy rate impulses are transmitted to the short end of the yield curve. Lag terms of Indian latent factors significantly influences the policy rate. The higher IIP rate triggers an increase in the short term rate and there by the slope of the yield curve. The depreciation of Exchange rate triggers increase in the Indian level factor. The increase in the Indian level as well as US level and slope triggers appreciation of the Indian rupee. US influence is found statistically significant indicating the rupee dollar exchange rate is driven by the US level and slope factors.

Table 9 reports the transition covariance P matrix for India- US yield curve-macro model. The Indian slope is positively correlated with US slope. The covariance between the policy rate and Inflation is significant with all the Indian latent factors. The negative covariance between the inflation and the slope factor is consistent with relationship identified in the VAR coefficients in Table 8. The volatility of Indian exchange rate is influenced by the US curvature factor.

3.7 Formal test for India and US yield curve interactions

The interactions between the Indian and US yield curves were assessed using the Wald test. The coefficient matrix B and the covariance matrix P of the India-US yield curve model were used to assess the interactions between India and the US. The coefficient matrix B (6x6) was partitioned into 3x3 as

$$B = \begin{pmatrix} B_1 & B_2 \\ B_3 & B_4 \end{pmatrix}$$

Where B_1 represents the interactions between India latent factors and its lag; B_2 represents the interaction between the contemporaneous values of the India latent factors and the US lags. B_3 represents interactions between the contemporaneous values of the US latent factors and lag of Indian factors. B_4 is the interactions between the contemporaneous and lag of US latent factors.

Similarly the covariance matrix P (6x6) was partitioned as

$$P = \begin{pmatrix} P_1 & P_2 \\ P_3 & P_4 \end{pmatrix}$$

Where P_2 and P3 capture the covariance between the US and Indian latent factors and P_1 captures the covariance of the Indian latent factors and P_4 captures the covariance of the US latent factors.

Table 10 reports the Wald, with various restrictions in the interactions between the US and Indian latent factors. The first hypothesis proposed the existence of a bi-directional relationship between the Indian and US latent factors. The null hypothesis was strongly rejected indicating the US and India yield curve interactions. The second hypothesis articulated the US influence on the Indian yield curve. The rejection of null

Table 8 VAR transition B matrix for the India- US yield curve-macro model

	L_{t-1}	S_{t-1}	C_{t-1}	USL_{t-1}	USS_{t-1}	USC_{t-1}	$policyrate_{t-1}$	$Inflation_{t-1}$	IIP_{t-1}	$Exchange_{t-1}$	μ
L_t	0.70*** (0.04)	0.03 (0.02)	0.12*** (0.02)	_0.015 (0.05)	0.006 (0.02)	0.015 (0.01)	0.006 (0.013)	0.043* (0.02)	0.003 (0.004)	0.014** (0.006)	8.30*** (0.26)
S_t	0.27*** (0.06)	0.89*** (0.03)	_0.10*** (0.03)	0.11 (0.07)	0.05** (0.02)	0.002 (0.005)	0.27*** (0.11)	0.06 (0.05)	0.016*** (0.006)	_0.004 (0.007)	−2.07*** (0.64)
C_t	0.122 (0.29)	_0.11** (0.05)	0.75*** (0.07)	_0.008 (0.12)	_0.002 (0.05)	0.035 (0.03)	_0.059 (0.03)	_0.008 (0.05)	_0.02 (0.01)	_0.036 (0.019)	−3.28*** (0.55)
USL_t	−0.31 (0.20)	0.42 (0.28)	0.41 (0.47)	0.84*** (0.06)	0.00 (0.05)	_0.015 (0.01)	0.008 (0.01)	_0.008 (0.02)	0.014*** (0.004)	0.025*** (0.00)	5.57*** (0.29)
USS_t	0.04 (0.07)	−0.08 (0.10)	−0.14 (0.17)	0.11 (0.15)	0.96*** (0.07)	0.017 (0.03)	_0.01 (0.02)	0.04 (0.03)	_0.02*** (0.008)	_0.073*** (0.027)	−4.58*** (1.25)
USC_t	0.018 (0.040	0.04 (0.05)	0.04 (0.09)	0.52*** (0.15)	0.22*** (0.04)	0.82*** (0.03)	0.09*** (0.03)	__0.02 (0.07)	_0.03** (0.01)	0.05*** (0.02)	−3.78*** (0.93)
Policyrate	0.342*** (0.11)	0.68*** (0.05)	0.20*** (0.05)	0.017 (0.14)	0.045 (0.04)	_0.03 (0.05)	0.33*** (0.03)	0.06 (0.10)	_0.00 (0.01)	0.014 (0.013)	6.09*** (0.61)
Inflation	_0.021 (0.11)	_0.06 (0.05)	0.17*** (0.05)	0.15 (0.13)	0.07 (0.04)	_0.08 (0.05)	0.02 (0.04)	0.973*** (0.01)	_0.04*** (0.01)	_0.01 (0.01)	0.58*** (0.13)
IIP	0.82 (0.54)	−0.28 (0.26)	0.421* (0.24)	3.7 (0.49)	0.16 (0.15)	_0.08 (0.16)	0.11 (0.17)	_0.35 (0.34	0.41*** (0.06)	_0.02 (0.05)	4.67* (2.4)
Exchange	_0.13 (0.13)	0.37*** (0.06)	0.06 (0.06)	_0.41*** (0.12)	_0.13*** (0.04)	0.05 (0.04)	_0.11*** (0.04)	0.36 (0.09)	_0.024 (0.01)	0.93*** (0.01)	50.80*** (3.45)

This table reports the coefficients of B matrix of transition equation of India-US yield curve-macro model. Standard error appears in the parenthesis. L_t is the estimated Indian Level factor, S_t is the estimated Indian slope factor and C_t is the estimated Indian curvature factor. USL_t is the estimated US level factor, US St is the estimated US slope factor and USCt is the estimated US curvature factor, policy rate is the Indian monetary policy rate, inflation is the Inflation rate of India, IIP is Index of industrial production of India and Exchange is the exchange rate of USD in terms of INR (Indian Nation Rupee). μ represents the mean of the corresponding latent factors. *, **, *** denote statistical significance at the 10 %, 5 % and 1 % levels respectively

Table 9 Transition covariance P matrix for the India- US-macro yield curve model

	L_t	S_t	C_t	USL_t	USS_t	USC_t	$Policyrate_t$	$Inflation_t$	IIP_t	$Exchange_t$
L_t	0.048*** (0.00)									
S_t	0.135*** (0.01)	0.141*** (0.02)								
C_t	−0.020 (0.01)	0.187*** (0.02)	0.106*** (0.03)							
USL_t	0.062 (0.01)	−0.23 (0.05)	0.137 (0.01)	0.038*** (0.00)						
USS_t	−0.138 (0.10)	0.538*** (0.07)	−0.263 (0.16)	0.16*** (0.05)	0.351*** (0.11)					
USC_t	0.053 (0.04)	−0.116 (0.12)	0.02 (0.06)	−0.022 (0.06)	−0.049 (0.14)	0.504*** (0.06)				
$Policyrate_t$	0.105*** (0.02)	0.257** (0.11)	0.186*** (0.06)	−0.221 (0.15)	0.155 (0.10)	−0.1095 (0.13)	0.556*** (0.20)			
$Inflation_t$	0.171*** (0.02)	-.667*** (0.08)	0.379*** (0.07)	−0.28 (0.15)	0.18 (0.10)	−0.066 (0.17)	−0.704*** (0.16)	0.558*** (0.07)		
IIP_t	0.078 (0.17)	−0.15 (0.58)	−0.017 (0.25)	−0.015 (0.25)	0.245 (0.55)	−0.35 (0.18)	−0.276 (0.52)	−0.540 (0.71)	8.31*** (1.18)	
$Exchange_t$	−0.038 (0.05)	0.256 (0.19)	−0.108 (0.09)	0.057 (0.09)	−0.218 (0.19)	0.188** (0.06)	0.341* (0.18)	0.319 (0.24)	−0.471 (0.34)	0.75*** (0.16)
Test for Diagonality of P matrix										
						T statistic		P value		
Wald test						154.95		0.00		
Likelihood Ratio						134.37		0.00		

This table reports the variance and covariance term. Standard error appears in the parenthesis, L_t is the estimated Level factor, S_t is the estimated slope factor and C_t is the estimated curvature factor. USL_t is the estimated US level factor, USSt is the estimate US slope factor, USCt is the estimated US curvature factor, policy rate is the Indian policy rate, inflation is the Inflation rate of India, IIP is Index of industrial production of India and Exchange is the exchange rate of USD in terms of INR (Indian Nation Rupee).*,**,*** denote statistical significance at the 10 %, 5 % and 1 % levels respectively. The wald test and likelihood ratio rejects the diagonality of the P matrix

Table 10 Test of India- US yield curve interactions

Null hypothesis	Number of restrictions	Wald statistic
No Bidirectional interaction between India and US yields ($B_2 = 0$, $B_3 = 0$ and $P_2 = 0$)	27	214.9 (0.00)
No US to India Interaction ($B_2 = 0$ and $P_2 = 0$)	18	46.35 (0.00)
No India to US Interaction ($B_3 = 0$ and $P_2 = 0$)	18	109.56 (0.00)

The Wald test is reported with chi-square statistic. *,**,*** denote statistical significance at the 10 %, 5 % and 1 % levels respectively

hypothesis further suggested that the US yield curve influences the Indian yield curve. The third hypothesis articulates India influence on the US yield curve. The null hypothesis is rejected suggesting the linkages between Indian and US yield curve.

3.8 Impact of the global financial crisis

Further, the impact of the global financial crisis on the inter-relationship of US and Indian bond markets was investigated. The total sample of 11 years was sub-divided into two periods, representing the pre and post crisis period. The sample was sub-divided based on the Zivot- Andrews structural change test. The distinguishing effect between the two periods would provide a vivid picture of the impact of the global crisis on the Indian yield curve (Table 11).

Table 12 provides the VAR estimates of the US latent factors and the Indian latent factors across all the periods. During the pre-crisis period, the US latent factors had a significantly positive impact upon the Indian level and curvature factors. While the Indian level was significantly influenced by the US level and slope, the Indian curvature was influenced by the US curvature. However, the slope was found to be a country specific factor and did not exhibit external influence.

The post-crisis period has seen a tremendous change in the US influence upon the Indian yield curve. It is interesting to note that during the crisis affected period, the

Table 11 Descriptive statistics of the Indian Latent factors for the subsamples

	Mean	Std. Dev	Minimum	Maximum	Mean	Std. Dev	Minimum	Maximum
	Sample Period : Jan 2003: December 2007				Sample Period : January 2008: December 2013			
India								
Level	7.39	0.6	6.22	8.98	7.93	0.41	7.19	8.68
Slope	−1.56	0.92	−3.17	1.05	−1.43	2.27	−5.18	2.91
Curvature	−0.39	2.18	−10.34	3.63	0.45	1.84	−3.72	5
US								
Level	5.35	0.52	4.46	6.5	4.77	0.90	3.04	6.12
Slope	−2.3	2.18	−5.95	0.52	−4.18	1.28	−6.13	−2.03
Curvature	−2.4	1.45	−5.53	−0.07	−5.96	1.40	−8.59	−2.49

This table reports the descriptive statistics of the extracted latent factors at two different sample periods

Table 12 VAR Estimates of Indian Latent Factors for the Pre-Crisis and Post-Crisis Period

	L_{t-1}	S_{t-1}	C_{t-1}	USL_{t-1}	USS_{t-1}	USC_{t-1}
	Subsample : 2003–2007					
L_t	−0.215 (0.22)	−0.108 (0.135)	−0.003 (0.015)	1.283*** (0.473)	0.450* (0.279)	−0.040 (0.109)
S_t	−0.063 (0.379)	−0.130 (0.231)	−0.014 (0.027)	−1.280 (0.809)	−0.368 (0.477)	−0.077 (0.186)
C_t	−0.077 (0.433)	0.042 (0.263)	0.996*** (0.03)	0.701 (0.922)	0.984* (0.544)	0.028 (0.213)
	Subsample : 2008–2013					
L_t	1.004*** (0.006)	−0.009 (0.064)	0.025 (0.023)	−0.099 (0.277)	−0.196 (0.197)	0.001 (0.06)
S_t	0.009 (0.011)	0.195* (0.11)	0.023 (0.04)	1.656*** (0.475)	1.129*** (0.337)	0.25*** (0.101)
C_t	−0.016 (0.01)	−0.059 (0.171)	0.877*** (0.06)	0.922 (0.733)	0.78 (0.521)	0.302** (0.156)

The table reports the VAR estimates of US influence on Indian yield curve. Standard error appears in the parenthesis,. L_t is the estimated Indian Level factor, S_t is the estimated Indian slope factor and C_t is the estimated Indian curvature factor.. USL_t is the estimated US level factor, USSt is the estimate US slope factor and USCt is the estimated US curvature factor.*, **, *** denote statistical significance at the 10 %, 5 % and 1 % levels respectively

Indian slope, which remained very independent otherwise in the rest of the analysis, had exhibited statistically significant lead effect of all the US latent factors. A pre-crisis analysis revealed that the US had a statistically significant positive influence on the Indian level, as observed by Kulish and Rees (2011). On the contrary, it was noted that the level demonstrated a negative relationship with the US level in the post-crisis period. The results broadly infer that the crisis resulted in Indian short term rates being influenced by the US markets.

4 Summary and policy implications

This study examined the impact of the US yield curve on the Indian economy. The three latent factors that according to Nelson Siegel would decompose the yield rates are level, slope and curvature. These latent factors were extracted for the US and India, using the Dynamic Nelson Siegel model applying the Kalman filter.

There was notable persistence and domestic market influence among all the latent factors in both the countries, supporting the observations made by Kanjilal (2013). While the own factor dynamics was found in all the three factors, cross factor dynamics differed across the two countries. In India, level leads the curvature, while in the US, slope leads curvature. These results indicate that medium term rates are influenced by the long term rates in India, whereas, they are influenced by short term rates in the US.

The study also investigated the influence of the US latent factors on the Indian latent factors. The results revealed that the US level and slope had a negative relationship with the Indian level during the full sample period analysis. However, the pre-crisis period analysis explained that this relationship was very positive and statistically significant. It is only in the post-crisis period that the relationship turned negative. The results infer that until the global financial crisis, both short and long term rates of the US markets had a statistically significant positive impact upon the long and medium term factors of the Indian yield curve.

The Indian slope is domestic in nature and was not influenced by the US markets till the onset of the crisis. The linkages during the global financial crisis resulted in the US yield curve leading Indian short term factors.

This study offers valuable insights in understanding the influence of external factors upon the domestic yield curve of an emerging economy. The monetary policy makers use the short term rates to induce the long end of the yield curve and there by the aggregate demand. The findings help them to understand the degree of monetary policy independence especially to exert the influence on the long end of yield curve.

Monetary authorities also use the information contained in the yield curve to understand the expectation of market participants about future inflation and economic activity. These expectations induce the policy action by the monetary authorities to shift the short term rates accordingly.

The study helps the market participants to exploit the arbitrage opportunities present in the bond markets. Higher US influence on the domestic yield rates will reduce arbitrage opportunities for cross border investors.

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