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Inter-dependencies among Asian Bond Markets

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Interdependencies among Asian Bond Markets

Abstract

Purpose: The purpose of the paper is to investigate the global and regional influences on the domestic term structure of nine Asian economies.

Design/Methodology/Approach: The dynamic Nelson Siegel model was used to extract the latent factors of a country's yield curve movements in a state-space framework using the Kalman filter. The global and regional factors of the yield curve were extracted using the Dynamic Factor model. Further, the Bayesian Inference of Gibbs sampling approach was used to identify the influence of global and regional factors on the domestic yield curve.

Findings: The results suggest that financial integration does not reduce the control of monetary authorities on the front end of the yield curve; and long term interest rate is the potential transmission channel through which the contagion of the financial crisis spreads.

Practical Implications: The results of this study would help the monetary authorities to understand the efficacy of the monetary policy transmission mechanism. It also offers the global investors diversification opportunities for investing in the Asian bond markets.

Originality/Value: This is one of the earliest attempts to capture the global and regional yield curve movements and their impact on the yield curves of emerging Asian economies. The study contributes to literature by identifying the linkages in the long term rates, which are the potential channels through which the crisis spreads.

Keywords: Global Yield Curve, Dynamic Nelson Siegel Model, Global Financial Crisis

Paper type: Research paper

1. Introduction

Globalization of financial markets and the resulting capital flows have increased the interdependencies of the domestic term structure of interest rates (Holmes et al., 2011). Earlier research on term structure of interest rates investigated the factors driving the yield curve in the context of a single country (Litterman and Scheinkman, 1991; Diebold and Li, 2006; Alper et al., 2007; Koopman et al., 2010), and found that the three common factors, level (representing long term interest factor), slope (representing short term interest factor) and curvature (representing medium term interest factor) determine the maximum variation in the bond yields. Bond markets respond quickly to macroeconomic news; and term structure movements provide information about the future state of the economy (Wu, 2006). This has led to the investigation of the influence of macroeconomic factors on the term structure of interest rates (Matsumura and Moreira, 2011; Lange, 2013; Kaya, 2013;Aguiar-Conraria et al.,2013; Diebold et al.,2006; Wu,2006). These studies noted the significant influence of macroeconomic factors on the future movements of the term structure of interest rates.

Recent literature has provided evidence that yield curve fluctuations across countries are correlated (Jotikasthira et al., 2015). Davies (2007) found a common bond market trend among the developed economies. Diebold et al., (2008) constructed a global yield curve using the Dynamic Nelson Siegel model (DNS) and found that global factors significantly influence the domestic yield curve. Byrne et al., (2012) also noted the influence of global factors, especially in the long end of the yield curve. Growing evidence of their deeper financial integration with the global debt market has sensitized the Asian economies to the global and regional movements of the bond market (Turner, 2014). This phenomenon necessitates an exploration of the impact of global and regional movements on the domestic yield curves of the Asian countries.

The 1997-1998 Asian financial crisis proved the importance of regional bond markets, and suggested reduced dependence on foreign borrowings as well as channelization of the regional savings. Since then, the Asian bond markets developed steadily with the support of the Asian Bond Market Initiative (ABMI) and the Asian Bond Fund (ABF). In recent years, this development, along with the dynamic economic growth in emerging Asian countries has attracted a large number of domestic and international investors.

Since the global financial crisis, capital inflow in the emerging Asian government debt market has increased steadily (Pradhan et al., 2011).Chandra and Unsal (2014) found that long term interest rates in Asia are driven by global factors, especially during periods of large capital inflows. As a follow up study, this paper investigated the vulnerability of the Asian countries' yield curves to the global and regional movements. The current study contributes to the literature by examining the global and regional influence in the Asian countries' term structure. Apart from having important implications for the monetary authorities in analyzing the efficacy of monetary policy, this study also offers insights to global investors on portfolio diversification strategies.

The aim of the study was to investigate the global and regional influences on the term structure of the following nine Asian countries- Japan, Hong Kong, Singapore, Korea, Malaysia, India, China, the Philippines and Indonesia. The zero coupon yields of various maturity horizons were considered at a monthly frequency for the time period of January 2003 to December 2013. The individual country's term structure was modeled using the Dynamic Nelson Siegel model as in Diebold et al., (2006). The Dynamic Nelson Siegel model decomposes the term structure into three latent factors -the long term factor (level), the short term factor (slope) and the medium term factor (curvature). These latent factors were estimated from the model using the Kalman filter. The global and regional factors were obtained using the Dynamic Factor model in a state-space framework. The global factor was constructed by taking the common factor from developed countries such as the US, UK, Germany and Australia, and the regional factors from the Asian economies. The influence of global and regional factors on the domestic term structure was estimated using the Bayesian Inferences of regression model with auto-correlated disturbances. Further, the sample was divided into two phases, viz., the pre and post crisis periods, to analyze the influence and linkages in the bond markets during the 2008 global financial crisis.

The results of the study indicated that both global and regional factors influenced the long term factors in Japan, Singapore, Hong Kong and Korea. The long term factors of Malaysia and the

Philippines were influenced more by the regional factor than global factors. However, the long term factors in China and Indonesia diverged from the global and regional movements. There was a clear regional influence in the Japanese and Korean curvature factors. On the other hand, global and regional factors had not influenced the short term factors of any of the Asian countries during the sample period. This result indicates that despite financial integration, monetary authorities still retain control of short term interest rates in the Asian economies.

On the whole, the long term interest rate has proved to be the potential channel for international monetary and financial transmissions. It offers diversification opportunities to the global investors for investing in Asian bond markets. The results are robust to changes in the variations of the model.

The contribution of this study is threefold. First, it examines the global and regional influences on the term structure of interest rates of emerging Asian economies. This relationship helps in understanding the co-movement of other financial assets. Earlier studies (Diebold et al., 2008; Abritti et al., 2013) had investigated the effect of global influences on the developed countries' term structure, ignoring regional influences. Bae and Kim (2011) analyzed the global and regional factors on the term structures of Japan, South Korea, Hong Kong and Singapore. The current study extended the work of Bae and Kim (2011) by examining the regional and global influences on emerging Asian economies and used the array of zero coupon yields to model the term structure of interest rates for the sample countries. Hence, compared to the previous works, the results of this study are far more robust, especially in terms of extracting the latent factors.

Second, the study helps in understanding the vulnerability of Asian bond markets to the movements in the global and regional bond yields. During the global financial crisis of 2008, the low term premium in the advanced economies and the relatively stable economic fundamentals in emerging economies had attracted the global investors to diversify their portfolios in the emerging markets assets, which led to an increase in their capital flows (Pradhan et al., 2011). Thus, understanding the co-movement of Asian bond markets with global and regional bond markets helps the global investors to plan diversification strategies and also to exercise the choice of asset allocation during times of high market volatility.

Third, this study contributes to the literature by identifying the channels through which the crises spread. The transmission channels are in general divided into two groups - the first channel being trade related fundamental economic factors (Berkmen et al., 2012) and second channel being investor driven stock market linkages (Xu and Hamori, 2012; Samarakoon,2011). While Brekmen et al., (2012) provided evidence of a trade related transmission channel Xu and Hamori (2012) found that stock market linkages were the transmission channel. The present study identified that apart from the stock market, yield curve linkages in the bond market are another channel to spread the financial contagion.

The rest of this paper is organized as follows: Section 2 is about bond market integration; Section 3 presents the model; Section 4 describes the data; Section 5 presents the empirical results and Section 6 summarizes the analysis and concludes the argument.

2. Bond Market Integration: Impact of Global and Regional Factors

Contemporary studies on bond market integration have focused mainly on the co-movement dynamics of bond returns. Piljak (2013) analyzed the co-movement dynamics between ten emerging and four frontier markets with the US bond market. Her study found that domestic monetary policy and macro-economic factors are more influential than the global factors. Bunda et al., (2009) analyzed the co-movement amongst the emerging market bond returns and found that emerging market returns are driven more by external factors during a period of crisis. Yang and Hamori (2014) examined the interdependence of Poland, Czech Republic and Hungarian bond markets with that of Germany and found that integration was more in long term interest rates rather than in the short term interest rates.

There are very few studies related to financial integration in the Asian bond market. While investigating the integration within the Asian bond market during the Asian Financial crisis period, Vo (2009) found that there was a low degree of financial integration between the Australian/US bond yield and the Asian Bond market.

Another strand of literature constructed the global yield curve and explored its impact on the domestic yield curve. In particular, Diebold et al., (2008) constructed a global yield curve using the hierarchical Dynamic Factor model using the government yields of US, UK, Germany and Japan. They decomposed the variations in a country's bond yields into global factors and country specific factors, and found that the global level and slope factors contributed to the significant variation in the yield rates in the domestic market. Bae and Kim (2011) investigated the influence of global and regional factors on the East Asian countries. Their results highlighted that global factors had a significant influence in comparison with the regional factors. Jaramillo and Weber (2013) studied the determinants of domestic bond yields in emerging markets. They used the principal component analysis to obtain the common factors of the domestic bond yields and found the existence of two common factors. Abritti et al., (2013) used the factor augment vector auto regression to get the global factors from the yield curves of seven open economies (Canada, United Kingdom, Japan, Germany, Australia, New Zealand and Switzerland) and found that global factors are the ultimate drivers of the domestic yield curve and term premia.

3. Methodology

The Nelson Siegel (NS) model is widely used by the central bank and practitioners in estimating the Zero coupon yield curve and is the most popular term structure estimation method (Pooter, 2007). According to the Bank of International Settlement report (2005), nine out of thirteen central banks use the Nelson Siegel or the Svensson (1994) an extension of the NS model. The extraction of common factors using the NS model is superior because the three components extracted using the NS model are capable of capturing the various shapes of the yield curve such as S shaped, humped and monotonic. The NS model provides a clear interpretation of three components as the short term, medium term and long term factors of the yield curve. Diebold et al. (2006) proposed a Dynamic Nelson Siegel model which captures the time varying components of the term structure using state-space framework.

3.1. Dynamic Nelson Siegel Model

The Nelson and Siegel (1987) model was used to estimate the cross sectional yields at any point of time. The yield curve is represented as:

$$y(\tau) = \beta_1 + \beta_2\left(\frac{1-e^{-\lambda\tau}}{\lambda\tau}\right) + \beta_3\left(\frac{1-e^{-\lambda\tau}}{\lambda\tau} - e^{-\lambda\tau}\right) \quad (1)$$

Where, y (τ) is the yield and τ denotes maturity of the bond. β_1, β_2, β_3 and λ are parameters. Diebold and Li (2006) represented the Nelson Siegel model in dynamic form as:

$$y(\tau) = L_t + S_t\left(\frac{1-e^{-\lambda\tau}}{\lambda\tau}\right) + C_t\left(\frac{1-e^{-\lambda\tau}}{\lambda\tau} - e^{-\lambda\tau}\right) \tag{2}$$

Where, L_t, S_t and C_t are the latent factors of the yield curve. L_t is the level that represents the long term factor, S_t is the slope that represents the short term factor and C_t is the curvature that represents the medium term factor of the yield curve. These three latent factors were obtained using the Kalman filter in a state-space form for each country. λ is the value that maximizes the curvature factor C_t. The state-space form contains two equations. The measurement equation relates the bond yields to the latent factors and is written as:

$$\begin{pmatrix} y_t(\tau_1) \\ y_t(\tau_2) \\ \cdot \\ \cdot \\ \cdot \\ y_t(\tau_N) \end{pmatrix} = \begin{pmatrix} 1 & \left(\frac{1-e^{-\tau_1\lambda}}{\tau_1\lambda}\right) & \left(\frac{1-e^{-\tau_1\lambda}}{\tau_1\lambda} - e^{-\tau_1\lambda}\right) \\ 1 & \left(\frac{1-e^{-\tau_2\lambda}}{\tau_2\lambda}\right) & \left(\frac{1-e^{-\tau_2\lambda}}{\tau_2\lambda} - e^{-\tau_2\lambda}\right) \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ 1 & \left(\frac{1-e^{-\tau_n\lambda}}{\tau_2\lambda}\right) & \left(\frac{1-e^{-\tau_2\lambda}}{\tau_2\lambda} - e^{-\tau_2\lambda}\right) \end{pmatrix} \begin{pmatrix} L_t \\ S_t \\ C_t \end{pmatrix} + \begin{pmatrix} \varepsilon_t(\tau_1) \\ \varepsilon_t(\tau_2) \\ \cdot \\ \cdot \\ \cdot \\ \varepsilon_t(\tau_N) \end{pmatrix} \tag{3}$$

The transition equation relates the dynamics of the latent factor and is written as:

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

Where, L_t , S_t and C_t are the latent factors in the measurement equation which are extracted using the Kalman filter.

3.2. Extraction of Global and Regional Factors using a Dynamic Factor Model

The global yield rates are not observable in reality; hence the dynamic factor model was used to capture the co-movement of bond yields into a single global factor. The Dynamic factor model is the time series extension of factor models. The co- variation of set of time series variables at various leads and lags are captured with few unobservable common factors.

In the first step, the country level latent factors of the Dynamic Nelson Siegel model was extracted using the Kalman filter. In the second step, the commonality of each latent factor was captured using the Dynamic Factor Model. The co-movement of the developed countries' latent factors was captured and was termed as the global factor. Similarly, for the regional factor, the co-movement of Asian countries was extracted.

Let $L_{US,t}$, $L_{UK,t}$, $L_{Germany,t}$ and $L_{Australia,t}$ be the level factors of developed countries used to extract the global level factor. The dynamic factor model is written as:

$\Delta L_{it} = \varsigma_i \Delta g_t + e_{it}$ i= 1,2,3,4. (5)

$\Delta g_t = \delta_1 g_{t-1} + \delta_2 g_{t-2} + z_{it}$, $z_{it} \sim$ i.i.d. N (0, 1) (6)

$e_{it} = \omega_{i1} e_{i,t-1} + \omega_{i2} e_{i,t-2} + \varepsilon_{it}$, $\varepsilon_{it} \sim$ i.i.d. $N(0,\sigma^2_i)$ (7)

Where ΔL_{it} is the first difference of the level factor of the developed countries, and g_t is the unobserved common component representing the global factor. In order to estimate the unobserved common component the above model was written in a state-space equation and the Kalman filter was used to obtain the unobserved common component g_t. Similarly the regional factors were extracted from the level factors of Asian countries. The same procedure was followed to extract the global and regional factors for slope and curvature.

The impact of the global and regional factors on the country's factors was analyzed using the regression model.

$$L_{it} = \alpha_i^l + \beta_i^l L_{gt} + \beta_i^l L_{rt} + \beta_i^l L_{i,t-1} + \varepsilon_{it}^l \quad (8a)$$

$$S_{it} = \alpha_i^s + \beta_i^s S_{gt} + \beta_i^s S_{rt} + \beta_i^s S_{i,t-1} + \varepsilon_{it}^s \quad (8b)$$

$$C_{it} = \alpha_i^c + \beta_i^c C_{gt} + \beta_i^c C_{rt} + \beta_i^c C_{i,t-1} + \varepsilon_{it}^c \quad (8c)$$

Where, α_i^l , α_i^s , α_i^c are constant terms,

$\beta_i^l L_{gt}$, $\beta_i^s S_{gt}$, $\beta_i^c C_{gt}$ are the global factor loadings

$\beta_i^l L_{rt}$, $\beta_i^s S_{rt}$, $\beta_i^c C_{rt}$ are the regional factor loadings, and

$\beta_i^l l_{i,t-1}$, $\beta_i^s s_{i,t-1}$, $\beta_i^c c_{i,t-1}$ represent the lag of the domestic latent factor.

The error terms are auto-correlated, hence the equations 8a, 8b and 8c were modeled using AR (1) errors. Therefore, the Bayesian Inference using Gibbs sampling was applied to model the regression of Eqns. 8a, 8b and 8c with AR (1) errors. The priors were assigned for all the unknown parameters. α_i was set to zero , $\beta_i^l l_{gt}$, $\beta_i^l l_{rt}$ were set to 1,σ^2 = 1 and φ=0.5. The inference of α_i, $\beta_i^l l_{gt}$,$\beta_i^l l_{rt}$,$\beta_i^l l_{i,t-1}$ φ, σ were based on 4000 draws from the posterior distribution after 1000 draws were discarded. A similar procedure was followed for Eqns (8b) and (8c).

4. Data Description

The monthly yields of maturities 3,6 12,24,36,48,60,72, 84,96,108, and 120 months for US, UK, Germany, Japan, Australia, Singapore, Malaysia, Hong Kong, Korea, India, Indonesia, China and the Philippines were considered for the period January 2003 to December 2013 at monthly frequency. The zero coupon yields were obtained from the Bloomberg database, except for India. Indian yields were taken from the National Stock Exchange (NSE) of India archives.

Table1: Descriptive Statistics of monthly yields of Asian countries

Maturity	Mean	Std. Dev	Minimum	Maximum	ρ (1)	ρ (12)
Japan						
3 months	0.19	0.21	0.002	0.69	0.98	0.55
12 months	0.23	0.23	0.01	0.83	0.98	0.58
60 months	0.67	0.37	0.12	1.53	0.96	0.59
120 months	1.32	0.36	0.57	1.97	0.94	0.47
Hong Kong						
3 months	1.12	1.39	0.03	4.09	0.97	0.57
12 months	1.34	1.45	0.03	4.43	0.98	0.64
60 months	2.46	1.33	0.24	4.80	0.97	0.72
120 months	3.13	1.27	0.61	5.01	0.97	0.64
Singapore						
3 months	1.04	0.93	0.12	3.28	0.98	0.69
12 months	1.10	0.93	0.15	3.21	0.99	0.71
60 months	1.82	0.88	0.46	3.45	0.97	0.71
120 months	2.72	0.67	1.40	4.21	0.95	0.43
Malaysia						
3 months	2.84	0.45	1.78	3.51	0.95	0.15
12 months	2.89	0.48	1.77	3.82	0.96	0.13
60 months	3.68	0.38	2.91	4.63	0.90	-0.09
120 months	4.14	0.52	3.17	5.41	0.91	0.07
Korea						
3 months	3.86	1.55	1.90	17.58	0.43	0.13
12 months	3.96	0.95	2.54	7.11	0.92	0.40
60 months	4.52	0.84	2.68	6.16	0.94	0.46
120 months	4.82	0.84	2.90	6.15	0.94	0.48
India						
3 months	6.2	1.72	3.07	11.08	0.95	0.30
12 months	6.37	1.49	3.57	9.49	0.94	0.31
60 months	6.84	1.10	3.83	8.85	0.88	0.41
120 months	7.27	0.93	4.89	8.91	0.88	0.36
China						
3 months	2.42	0.83	0.96	4.96	0.87	-0.01
12 months	2.50	0.79	0.99	4.25	0.94	-0.06
60 months	3.33	0.67	1.89	4.79	0.92	-0.22

120 months	3.83	0.63	2.68	5.45	0.92	-0.20
Indonesia						
3 months	7.94	2.60	3.89	15.20	0.95	0.23
12 months	8.14	2.63	3.89	15.33	0.96	0.28
60 months	9.73	2.85	4.75	16.85	0.96	0.46
120 months	10.40	2.78	5.37	17.99	0.95	0.48
Philippines						
3 months	4.40	2.33	0.12	8.15	0.96	0.64
12 months	5.36	2.71	0.60	9.97	0.97	0.70
60 months	7.46	2.94	2.43	13.05	0.97	0.66
120 months	8.62	3.10	2.95	14.49	0.97	0.62
UK						
3months	2.67	2.11	0.26	5.93	0.99	0.73
1year	2.70	2.07	0.16	5.78	0.99	0.74
5year	3.37	1.53	0.65	5.72	0.99	0.73
10 year	3.95	1.02	1.65	5.42	0.98	0.64
US						
3months	1.52	1.78	0.01	5.15	0.99	0.68
1year	2.36	1.69	0.57	5.66	0.98	0.71
5year	2.78	1.34	0.65	5.10	0.98	0.74
10 year	3.68	1.00	1.56	5.19	0.97	0.65
Australia						
3months	4.70	1.30	2.38	7.16	0.97	0.37
1year	4.72	1.30	2.40	7.16	0.97	0.39
5year	4.98	1.11	2.50	6.77	0.97	0.47
10 year	5.22	0.89	2.96	6.68	0.98	0.44
Germany						
3months	1.69	1.39	0.01	4.28	0.98	0.63
1year	1.84	1.42	0.01	4.56	0.98	0.64
5year	2.59	1.20	0.34	4.55	0.98	0.66
10 year	3.29	0.95	1.31	4.59	0.97	0.63

Notes: This table provides the descriptive statistics of monthly bond yields at representative maturities for the period January 2003 to December 2013. ρ represents the autocorrelation at displacement t. The yield rates are expressed in percentage terms.

Table 1 presents the descriptive statistics of monthly bond yields of representative maturities of the Asian markets and the developed markets (US, UK, Germany and Australia).The yield curves were upward sloping for all the Asian markets. The short term maturity yields exhibited higher volatility. The average yield rates were high in Indonesia - ranging from 7.94% to 12.01%, and low in Japan - ranging from 0.19% to 2.30%. There was high persistence among the yield rates in the Asian markets.

4.1. Extraction of Latent factors

The yield curve for each country was modeled by the Dynamic Nelson Siegel model (DNS) as in Diebold et al., (2006).The DNS model quantifies the yield curve into three latent factors viz., level, slope and curvature, which are extracted using the Kalman filter in a state-space form[1].

[1] 12 maturities were considered for each country. The λ value was initialized at 0.06 representing medium term as 30 months for all the countries (Refer Appendix 1).

Table 2: Descriptive statistics of extracted level and slope factors for Asian countries

	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	-3.48475	0.00***
Slope	-3.27	1.51	-6.03	-0.01	5.34	0.07*	0.96	-2.13887	0.23
Curvature	-3.69	2.05	-7.66	0.07	5.80	0.06*	0.96	-1.35491	0.60
Malaysia									
Level	4.77	0.66	3.50	6.84	9.50	0.01***	0.90	-3.83255	0.00***
Slope	-1.94	1.06	-4.47	-0.15	10.92	0.00***	0.95	-2.59003	0.09**
Curvature	-1.78	0.90	-4.33	0.48	0.47	0.79	0.83	-2.33224	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	4.4 0	-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**
UK									
Level	4.87	0.63	3.49	6.41	1.12	0.57	0.93	-2.24	0.19
Slope	-2.20	2.37	-6.12	1.23	12.97	0.00***	0.99	1.02	0.74
Curvature	-2.08	2.65	-6.78	1.95	11.70	0.00***	0.97	1.27	0.64
US									
Level	5.31	0.71	3.67	6.74	2.94	0.23	0.93	2.82	0.05**
Slope	-3.76	2.23	-7.00	0.29	11.47	0.00***	0.97	1.41	0.57
Curvature	-2.95	1.96	-7.99	0.06	10.76	0.00***	0.92	-2.28	0.18
Australia									
Level	5.54	0.64	3.69	6.59	39.25	0.00**	0.92	-2.72	0.07*
Slope	-0.80	1.13	-3.58	1.21	6.19	0.05**	0.94	-1.42	0.57
Curvature	-1.07	1.76	-4.98	2.80	4.06	0.13	0.95	-2.26	0.19
Germany									
Level	4.50	0.76	2.89	5.97	4.64	0.10*	0.95	-1.90	0.33
Slope	-2.75	1.45	-5.05	-0.05	8.47	0.01***	0.98	-1.57	0.50
Curvature	-2.72	1.71	-5.81	0.38	6.17	0.05**	0.94	-2.23	0.19

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. The values are represented in percentage,

Table 2 represents the descriptive statistics of the extracted level, slope and curvature factors for each country. The average level factor was highest in Indonesia, reflecting the higher long term interest rates among Asian economies. The average 10 year interest rate in the country was noted to be 10.51% (Table 1).Japan exhibited the lowest level factor, indicating the lowest long term interest rates of around 1.30% (Table 1). The average slope was highest in Korea and lowest in Indonesia, while volatility was higher in Hong Kong, Indonesia and the Philippines.

4.2. Pair-wise unconditional correlation among the extracted factors across the countries

Table 3: Correlation matrix of level factor across countries

	US	UK	Germany	Australia	Japan	Singapore	Hong Kong	Korea	Malaysia	India	China	Philippines	Indonesia
US	1												
UK	.739***	1											
Germany	.713***	.679***	1										
Australia	.803***	.688***	.697***	1									
Japan	.485***	.402***	.383***	.473***	1								
Singapore	.615***	.401***	.513***	.621***	.566***	1							
Hong Kong	.617***	.474***	.482***	.591***	.339***	.621***	1						
Korea	.451***	.347***	.302***	.546***	.310***	.495***	.423***	1					
Malaysia	.309***	.122	.311***	.271***	.121	.479***	.292***	.269***	1				
India	.193**	.125	.190**	.223**	.086	.218**	.159	.221**	.356**	1			
China	.097	.103	.173	.102	-.095	.134	.214**	.185**	.215**	.110	1		
Philippines	.155	.184**	.114	.206**	.213**	.188**	.147	.166	.211**	.224**	-.057	1	
Indonesia	.172	.035	.082	.072	.035	.101	.054	.128	.098	.097	-.110	.203**	1

Notes: This table presents the pair wise unconditional correlation among the long term factor. The figures in the table represent the coefficients. *** and ** shows the significance at 1% and 5% respectively.

Table 3 presents the pair-wise unconditional correlation between the level factors across the countries. Singapore, Japan, Hong Kong and Korea were significantly correlated with the long term factor of developed markets. It was also noted that most of the Asian markets co-move with the US and Australian markets.

Table 4: Correlation matrix of the slope factor across countries

	US	UK	Germany	Australia	Japan	Singapore	Hong Kong	Korea	Malaysia	India	China	Philippines	Indonesia
US	1												
UK	.180**	1											
Germany	.411***	.226**	1										
Australia	.185**	.492***	.282***	1									
Japan	.257***	.018	.317***	.093	1								
Singapore	.074	-.003	.127	.094	.204**	1							
Hong Kong	.198**	.101	-.021	.074	.108	.241***	1						
Korea	.169	-.046	.162	.008	.324***	.059	.098	1					
Malaysia	.392***	.056	.157	.072	.144	.339***	.196**	.141	1				
India	.060	.112	.137	.001	.131	.102	.026	.092	.062	1			
China	-.025	.003	.022	-.031	-.029	.101	.063	.067	.032	.097	1		
Philiphines	-.044	.098	.110	.200***	-.019	.163	.057	.135	.184***	-.055	.168	1	
Indonesia	.126	.199***	.122	.077	.035	.189***	.073	.035	.033	-.062	-.093	-.075	1

Notes: This table presents the pair wise unconditional correlation among the slope factor. The figures in the table represent the coefficients. *** and ** shows the significance at 1% and 5% respectively

Table 4 presents the pair-wise unconditional correlation between the slope factors. Significant correlations were observed among developed markets (viz., US, UK, Germany, Australia and Japan). Similarly, higher regional influence was also noted among Asian countries such as Singapore, Malaysia, Korea, Hong Kong and Japan. India and China were the only two countries found to be independent and not sharing significant relationship with other countries, indicating the independence of their monetary policies.

Table 5 reports the pair-wise unconditional correlation between the curvature factors across the countries. It was found that developed markets exhibit significant correlations. Singapore, Japan, and Hong Kong had higher influence with US, UK, Germany and Australia. Japan’s curvature had a significant correlation with the Asian countries, except Indonesia and the Philippines. The pair-wise unconditional correlation across all the factors provided the basis for analyzing the global and regional influence amongst the factors across the Asian markets.

Table 5: Correlation matrix of curvature factor across countries

	US	UK	Germany	Australia	Japan	Singapore	Hong Kong	Korea	Malaysia	India	China	Indonesia	Philippines
US	1	.800**											
UK	.800**	1											
Germany	.794**	.840**	1										
Australia	.673**	.685**	.774**	1									
Japan	.245**	.310**	.427**	.184*	1								
Singapore	.549**	.750**	.700**	.447**	.596**	1							
Hong Kong	.551**	.530**	.591**	.409**	.459**	.676**	1						
Korea	.095	.135	.236**	.273**	.251**	.062	.053	1					
Malaysia	.144	.361**	.358**	.179*	.527**	.441**	.041	.038	1				
India	.189*	-.096	.220*	.357**	.223*	-.095	.266**	.236**	-.158	1			
China	-.268**	-.329**	-.114	-.151	.487**	-.092	-.127	.013	.405**	.250**	1		
Indonesia	-.414**	-.440**	-.346**	-.305**	-.117	-.311**	-.256**	-.151	-.036	.003	.218*	1	
Philippines	-.166	.179*	.020	-.069	.005	.236**	-.092	-.150	.235**	-.409**	.080	.061	1

Notes: This table presents the pair wise unconditional correlation among the curvature factor. The figures in the table represent the coefficients. *** and ** shows the significance at 1% and 5% respectively

4.3. Estimation of Global and Regional factors

The dynamic factor model in state-space framework was applied as in Stock and Watson (1991), separately for the level, slope and curvature factors of developed countries (US, UK, Germany and Australia) to extract the global level slope and curvature factor. Regional factors were extracted from the latent factors of all the Asian countries.

Table 6: Descriptive statistics of the extracted global and regional factors

	Mean	**Std. Dev**	**Minimum**	**Maximum**	**Jarque-Bera t- statistics**	**P values**	**ADF t- statistics**	**P values**
Global								
Level	0.003	1.20	-5.01	2.90	27.96	0.00***	-9.94	0.00***
Slope	-0.05	1.22	-2.93	3.88	0.53	0.76	-4.31	0.00***
Curvature	-0.11	1.47	-4.04	3.36	0.317	0.85	-4.52	0.00***
Regional								
Level	0.036	1.64	-4.91	5.91	16.25	0.00***	-6.97	0.00***
Slope	-0.029	1.27	-3.25	3.12	0.11	0.94	-19.62	0.00***
Curvature	-0.016	1.31	-3.69	2.63	2.39	0.30	-8.05	0.00***

Notes: This table presents the descriptive statistics of extracted global and regional factor using dynamic factor models. 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.

Table 6 presents the descriptive statistics of the extracted global and regional factors using the Dynamic Factor model. The global and regional factors were found to be stationary at level and were used to identify their contribution on the latent factors of each country as in Eqns (8a), (8b) and (8c). The regression equations were modeled with AR (1) disturbances using the Bayesian Inferences of Gibbs sampling approach. Further, the results were checked for regression with the AR (1) method using maximum likelihood estimates and the Corchane Orcutt method. All these three methods yielded the same results.

5. Empirical Results

5.1. Global and Regional Influence on Asian Markets' Yield Curve

5.1a: Association across level factor

The level representing long term factor of yield curve indicates the future economic conditions and is driven by investor preferences and risk attitudes (Yang, 2005). The long term interest rates represent the fundamental financial stability in an economy (Turner, 2014). Long term interest rates fluctuate because of changes in term premium and the capital flows into the economy. Thus, it is expected that the influence of the global and regional factors would exist in the long term factors of the economies.

Table 7 presents the model estimates of global and regional factors upon the level, which is the fag end of the yield curve. These results demonstrate that while the global and regional influences were positive in all Asian countries, the degree of influence differs across these countries. Japan, Singapore, Hong Kong and Korea level are influenced by both global and regional factors, indicating the internationalization of the bond markets in those regions. This finding strengthens the premise that movements in the long term rates are driven by global investors' cash flows in these countries.

Table 7: Estimates of Global and Regional Level Factors

$\text{Level}_{countires,t} = \alpha + \beta_{1t}\text{global}^{level} + \beta_{2t}\text{regional}^{level} + \beta_{3t}\ \text{level}_{countries,t-1} + e_t$				
		Global factor	Regional factor	Lag of Dependent variable
$L_{japan,t}$	-0.00 (0.008)	0.022*** (0.005)	0.027*** (0.084)	-0.218*** (0.07)
$L_{Singapore,t}$	0.167 (0.10)	0.049*** (0.01)	0.149*** (0.01)	0.96*** (0.02)
$L_{Hong\ Kong,t}$	-0.004 (0.009)	0.031*** (0.00)	0.025*** (0.00)	0.236*** (0.06)
$L_{Korea,t}$	-0.002 (0.004)	0.012*** (0.003)	0.010*** (0.00)	0.054 (0.08)
$L_{Malaysia,t}$	0.81 (0.25)	0.003 (0.001)	0.04** (0.01)	0.83*** (0.05)
$L_{india,t}$	0.00 (0.00)	0.003* (0.001)	0.001 (0.001)	0.426*** (0.07)
$L_{china,,t}$	0.453 (0.158)	0.006 (0.014)	0.001 (0.01)	0.890*** (0.03)
$L_{philiphines,,t}$	- 0.009 (0.008)	0.005 (0.003)	0.006** (0.003)	0.359*** (0.08)
$L_{indonesia,,t}$	- 0.002 (0.004)	0.002 (0.005)	0.004 (0.005)	-0.863*** (0.04)

Notes: The table reports the posterior mean estimates of global and regional influence on country's level factor.*, ** and *** shows significance at 10%, 5% and 1 % respectively.

The Indian long term factor is influenced by the global movements. Malaysia and the Philippines are influenced more by the regional factor than the global factor. The Malaysian economy attracts a high level of investments from foreign investors in their local currency bonds (32.6% at the end of March 2013). Despite being the hot spot with foreign investors for investment, the economy is not influenced by the global factors. This is because Malaysian bonds are considered safe, as they maintain a moderate level of inflation and capital account surplus. The selloff of local currency bonds in Malaysia by the foreign investors was noted to be much lower during the recent global turmoil (Source: Policy Brief, 2013, Asian Development Bank).

On the other hand China and Indonesia exhibited independent behavior. Neither global nor regional factors have a significant influence upon China and Indonesia. The Chinese market is not influenced because their bond market still operates under tight controls. This result was consistent with Glick and Hutchison's (2013) findings that the linkages between Asian economies and long term interest rates of China are weak. Chueng et al., (2008) also found that US interest rates don't drive the Chinese interest rates, which are found to be independent of the rest of the world economies.

5.2. **Sub-sample Analysis**

These results were further examined to assess their validity, both during tranquil as well as crisis affected periods. The eleven years sample period was subdivided into two periods, viz., the pre-crisis and post-crisis periods. The results reported in Table 8 would provide a better understanding of the effect of the global crisis on the Asian countries' term structure.

In general, the sub-sample analysis reconfirmed the global and regional influences upon Asian markets, during both the pre and post crisis periods. However, the persistence of country level factors in the post-crisis period in all the Asian markets indicates the intervention of monetary policy authorities to stabilize the crisis effect on the economy. Only three countries behaved differently during the crisis affected period.

India did not exhibit either global or regional influence during the pre-crisis period. In the post crisis period, global factors were found influencing the country's yield curve. During the 2008 global financial crisis, India witnessed heavy sell off by foreign institutional investors in the equity markets. The reversal of capital inflows and reduced access of Indian entities to international funds led to reduction in the policy rates, which in turn impacted the long term interest rates.

Malaysia was found to be influenced by the regional factor in the pre-crisis period but was unaffected in the crisis affected period. This indicates that the Malaysian bonds were insulated during the crisis period because of the stability of the economy, which reduced the capital outflows from the economy.

Table 8: Sub Sample Analysis of Global and Regional Estimates of Level factor

		Global factor	Regional factor	Lag of Dependent variable
Pre-crisis Period :January 2003 – December 2007				
Japan	-0.002 (0.008)	0.020* (0.01)	0.04*** (0.007)	0.005 (0.12)
Singapore	-0.006 (0.006)	0.012* (0.006)	0.03*** (0.004)	0.05 (0.09)
Hong Kong	-0.008 (0.005)	0.039*** (0.006)	0.007* (0.004)	0.285*** (0.10)
Korea	-0.002 (0.010)	0.019*** (0.008)	0.019*** (0.006)	-0.21* (0.12)
Malaysia	0.80 (0.39)	-0.025 (0.05)	0.05*** (0.03)	0.837*** (0.07)
India	0.001 (0.006)	-0.000 (0.003)	0.002 (0.002)	0.565*** (0.09)
China	0.243 (0.18)	0.02 (0.03)	-0.02 (0.03)	0.939*** (0.04)
Philippines	- 0.009 (0.008)	-0.004 (0.007)	0.000 (0.005)	0.23* (0.13)
Indonesia	0.000 (0.02)	-0.010 (0.007)	-0.004 (0.006)	-0.96*** (0.04)
POST CRISIS PERIOD- January 2008- December 2013				
Japan	-0.007 (0.01)	0.023*** (0.005)	0.019*** (0.006)	-0.25** (0.09)
Singapore	0.004 (0.00)	0.015** (0.005)	0.029*** (0.004)	0.05 (0.07)
Hong Kong	0.002 (0.016)	0.019** (0.009)	0.042*** (0.009)	0.184** (0.09)
Korea	-0.002 (0.004)	0.014*** (0.003)	0.006** (0.003)	0.193** (0.09)
Malaysia	0.98 (0.37)	0.014 (0.017)	0.026 (0.018)	0.793*** (0.07)
India	-0.000 (0.003)	0.004** (0.002)	0.0002 (0.001)	0.21* (0.10)
China	1.62 (0.42)	0.002 (0.014)	0.009 (0.01)	0.609*** (0.10)
Philippines	- 0.005 (0.008)	0.007 (0.004)	0.009* (0.004)	0.35** (0.10)
Indonesia	- 0.002 (0.019)	0.008 (0.007)	0.005 (0.008)	-0.726*** (0.08)

Notes: The table reports the estimates posterior mean of global and regional influence on country's level factor. Pre crisis period includes January 2003 to December 2007. Post crisis period include January 2008 to December 2013. The figure in the parenthesis represents the posterior standard deviation. *, ** and *** shows significance at 10%, 5% and 1 % respectively.

The Philippines was another country which was unaffected by any regional or global influence during the pre-crisis period. However, there was a regional influence during the crisis affected period. The rise in the risk premium of the Philippines bonds after the 2008 global financial crisis was balanced by a lower rate of the expected currency depreciation.

5.3. Association across Short Term Interest Rates

Slope of term structure represents the short term interest rates. It is the policy channel where the monetary authorities change the short term rates to manage domestic growth and inflation. Thus, the co-movement in the short term rates represents the co-movement in the economic fundamentals (Jotikasthira et al., 2015). If the global business cycle is synchronized with the Asian economies' business cycle, it is expected that short term rates would be correlated with the global movements (Kumar and Okimoto, 2011).

Table 9: Estimates of Global and Regional influence in the Slope factor

Countries	Intercept	Global factor	Regional factor	Lag of Dependent variable
Japan	0.003 (0.00)	-0.008 (0.011)	0.013 (0.01)	0.22** (0.08)
Singapore	-0.289 (0.14)	0.04 (0.05)	-0.016 (0.03)	0.917*** (0.03)
Hong Kong	0.012 (0.019)	-0.005 (0.02)	-0.012 (0.025)	0.298*** (0.08)
Korea	-0.177 (0.07)	-0.098 (0.08)	0.05 (0.08)	0.87*** (0.04)
Malaysia	-0.26 (0.09)	-0.069 (0.04)	0.04 (0.03)	0.88*** (0.04)
India	-0.205 (0.167)	-0.067 (0.243)	0.244 (0.26)	0.31*** (0.08)
China	-0.046 (0.05)	-0.011 (0.07)	0.011 (0.08)	0.30*** (0.09)
Philippines	-0.79 (0.24)	-0.13 (0.08)	0.08 (0.06)	0.846*** (0.04)
Indonesia	-0.915 (0.167)	-0.060 (0.11)	0.059 (0.15)	0.531*** (0.07)

Notes: The table reports the posterior mean estimates of global and regional influence on country's slope factor. *, ** and *** shows significance at 10%, 5% and 1 % respectively.

Table 9 provides the results of the global and regional influences on the slope of the yield curve of the Asian economies. Global and regional factors were not found to be influencing the slope factor of the Asian economies. However, the country factor captured in the lag of the country slope factor was found to be significant, indicating the influence of domestic monetary policy. These results are consistent with the study of Miyajima et al., (2014) who found that the US monetary policy's spillover in Asia is only in the long term rates, and financial integration does not reduce the control of monetary authorities on short term rates. The slope is country specific and more sensitive to the business cycles within the economy; it reflects the current stance of the monetary policy in a country.

The results indicate that despite the spillover effects and financial contagion across the financial markets, the domestic monetary authorities were exercising a strong control in the short end of the yield curve. Further, no difference in the relationship was found in the pre-crisis, post-crisis and full sample period.

5.5 Association of Curvature Factor across the Asian Economies

Curvature represents the medium term factor. Diebold et al., (2006) found that the curvature lacks the link between the macro-economic factors. Thus, it is expected that linkages to curvature factor will be less.

Table 10: Estimates of Global and Regional influence in the Curvature factor

Countries	Intercept	Global factor	Regional factor	Lag of Dependent variable
Japan	-2.39 (0.318)	-0.09* (0.04)	0.576*** (0.06)	0.182*** (0.06)
Singapore	-0.238 (0.122)	-0.069 (0.05)	0.00 (0.05)	0.945*** (0.02)
Hong Kong	-0.20 (0.11)	-0.02 (0.07)	-0.02 (0.07)	0.897*** (0.03)
Korea	-.429 (0.11)	-0.044 (0.06)	0.167** (0.07)	0.55*** (0.07)
Malaysia	0.004 (0.02)	0.010 (0.03)	0.04 (0.03)	0.148* (0.06)
India	0.01 (0.12)	0.126 (0.08)	-0.08 (0.07)	0.71*** (0.06)
China	-0.33 (0.13)	-0.015 (0.05)	0.014 (0.04)	0.838*** (0.04)
Philippines	-0.022 (0.16)	-0.33 (0.19)	0.175 (0.16)	0.816*** (0.04)
Indonesia	-0.915 (0.167)	-0.060 (0.11)	0.059 (0.15)	0.531*** (0.07)

Notes: The table reports the posterior mean estimates of global and regional influence on country's curvature factor *, ** and *** shows significance at 10%, 5% and 1 % respectively.

Table 10 presents the influence of global and regional factors on the curvature of the Asian economies. It is found that lag of the country factor are highly significant in the Asian economies. Japan and Korea has significant regional influence in the curvature factor. Global influence is not present in the curvature of the Asian economies. The pre-crisis, post-crisis period analysis doesn't found any difference in the influences in comparison with the full sample period.

6. Conclusion

This paper investigated the global and regional influences on the domestic yield curve of Asian countries. The countries' term structure of interest rate was modeled by estimating the Dynamic Nelson Siegel model as in Diebold et al., 2006. The latent factors of the model viz., level, slope and curvature, were extracted using the Kalman filter. The global and regional factors were extracted using the dynamic factor model. The global factor captured the commonality of US, UK, Germany and Australian latent factors, and the regional factor captured the commonality of the nine Asian countries, namely Japan, Singapore, Malaysia, Hong Kong, Korea, China, India, Indonesia and the Philippines.

It was found that open markets such as Japan, South Korea, Singapore and Hong Kong exhibited both global and regional influences, indicating higher global integration. Malaysian and Philippines' long term rates were influenced by the regional factors. India and China continued to be independent from the global and regional movements. This result provides evidence to the premise that long term rates of open economies are more correlated than the short term interest rates. The slope factor of all the Asian countries diverged as they are more driven by country specific variables. This coincides with the premise that the slope factor is driven the domestic economic fundamentals and the current stance of monetary policy. Financial integration doesn't reduce the control of monetary authorities on short term interest rates. The findings also reiterate that long term interest rates are the potential transmission channel through which the crisis spreads. The results vouch for crisis transformation through market contagion.

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Appendix 1

The λ varies for each country. The initial lambda is the value that maximizes the curvature factorC_t. The maximization procedure was done to make the derivative function equal to zero.

$$\frac{\partial}{\partial x}\left(\frac{1-e^{-x}}{x}-e^{-x}\right)=x^2+x-e^x+1$$

Solving this equation gives x= 1.79328

x= $\lambda\tau$

Curvature refers to medium term factor which is considered as 30 months in this study. Given the value of X=1.79328 and τ that refers to the time factor 30 months, the initial λ is derived as 0.06.

However, the model calibrates different λ values for each country.

Appendix 2: Robustness

The robustness of the dynamic factor model in the extraction of global and regional factors was examined using the principal component analysis. The global and regional factors were extracted using the principal component analysis. The factors extracted using the Dynamic Factor model and principal components analysis has been graphed for level, slope and curvature factors.

Fig 1: Comparison of Dynamic factor model and PCA in Level factor

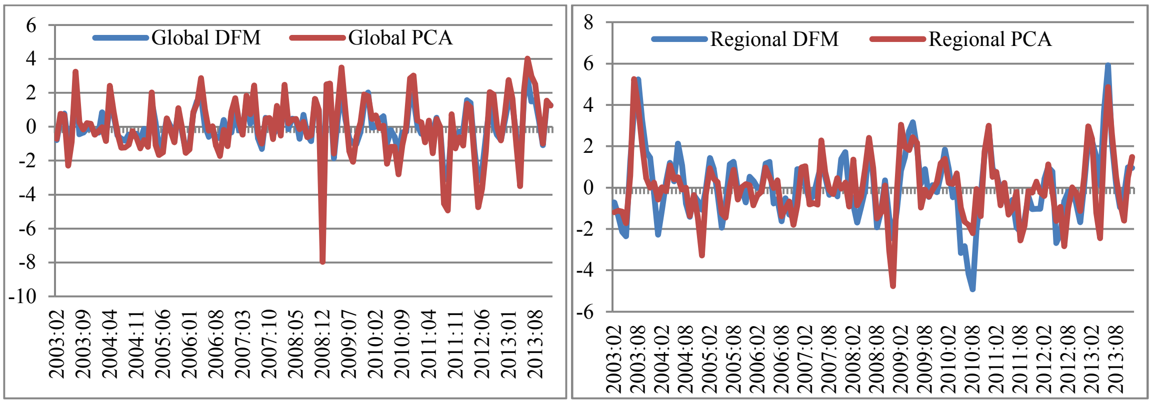


Fig 2: Comparison of Dynamic factor model and PCA in slope factor

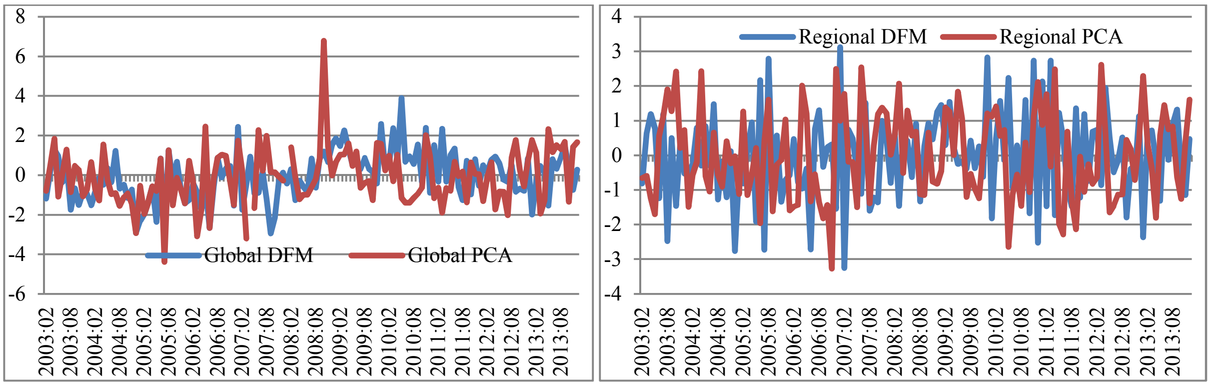
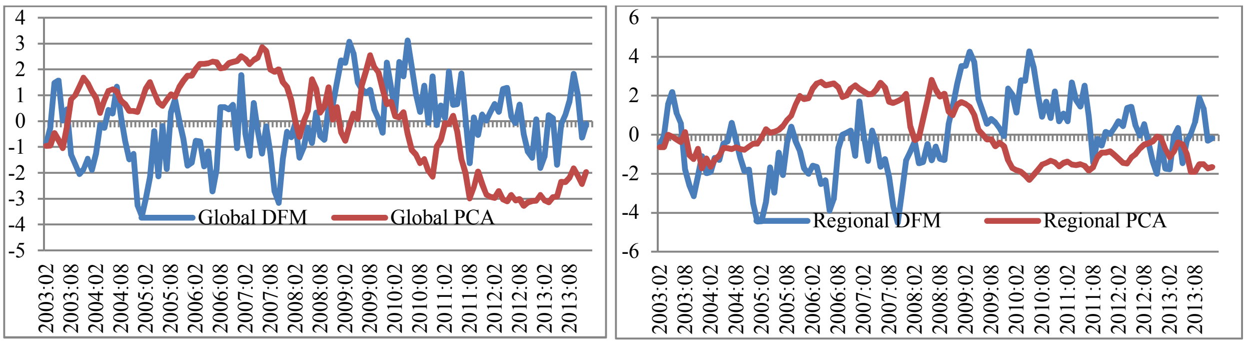


Fig3.Comparison of Dynamic factor model and PCA in curvature factor



The factors which are extracted using two different models exactly co-moved in level and slope factors.