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Regime switching behavior of Indian VIX and its time dependent correlation with select developed economies

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Abstract:

This paper investigates the international financial market integration as a trigger for regime switching behavior of Indian implied volatility index and its regime-dependent conditional correlations with the selected developed markets. The 2-state dynamic regression model reveals two different regimes using state-dependent variables during the time period 2009 to 2016. The results found that Hong Kong and US markets have a significant effect on the Indian market during highly volatile state, and there is a clear decoupling effect among these markets when the Indian market is stable. The predicted turning point probabilities indicate that the bull market state is persistent.

JEL Classifications: E44

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1. Introduction

Market participants' expectations regarding the future market volatility is one of the important determinant of their investments decisions. This is why the term implied volatility is gaining attention in finance literature. The implied volatility index is often referred as investors' fear gauge and it measures the expected volatility of the underlying market in near future (30 calendar days). The upward trend in the implied volatility is generally characterised by high volatility with negative returns, known as bear stock market condition. A downward trend in the implied volatility indicates low volatility with significant positive returns and it is known as bull market conditions. It is empirically proved that the financial returns exhibit these upward and downward trends. The manifestation of these shifts is attributed to external factors more than the domestic factors. This is due to liberalised policies that the countries are adopting to integrate their domestic market with international one with an intention to attract the global investment. The positive side of this integration is heavy capital flow from developed economies to emerging markets. On the other hand, volatility and uncertainties in the developed economies started putting a lot of pressure on emerging economies which have limited ability to deal with volatility and become vulnerable to this situation. Reduction of such contagion and transmission effect has been the major objective of the recent regulatory reforms.

Now the global economy is in the middle of a significant transition phase. The developed economies are trying to normalise the policies and emerging economies are trying to rebalance; under this situation, financial markets are wobbling. Therefore, understanding the financial market interdependence, co-movements and correlations between these markets will provide valuable inputs to the investors and risk managers. In this context, this paper investigates the interaction effect between the selected implied volatility indices and its time-varying conditional correlations among developed and emerging economies.

2. Review of literature

International integrated market structure channeled unprecedented level of uncertainty and provided a new dimension to theoretical and empirical research in the area of financial literature. This new thrust area in the finance literature, i.e., market integration and its contagious effect unfolded different dimensions to understand the information transmission and the shock spillovers from developed economies to emerging economies. Behavioral theory says investors are risk averse and they shift their risky investment to safer one during the market turmoil. Empirical research by Badshah., Frijns., & Tourani-Rad (2013) supported this theory and found a unidirectional spillover from changes in the implied volatility index to the volatility of gold price and exchange rate. Different results are found by Cohen and Qadan (2010) and Apte(2001). Their empirical findings suggest a unidirectional spillover from gold to VIX during high volatility stage and foreign exchange market to stock market. Narwal, Sheera, & Mittal (2012) and Korkmaz & Cevik (2009) provided evidence of moderate level of correlations among implied volatility indices and found a spillover effect from developed economies to emerging economies. Other research studies such as Aijo (2008), Clements (2007), Nikkinen & Sahlstrom(2004) and Aboura(2003) examined the correlations and spillover effects among developed economies and found positive results.

2.1. Literature review on regime switching behavior of stock return volatility

A study by Di Persio (2014) used regime-switching model to estimate volatility parameter for Standard & Poor's 500 and the Deutsche Börse index series and this study found that these financial time series fit four stages-switching model during the selected time period. Another study by Hardy (2001) tried comparing the lognormal model, autoregressive model, autoregressive conditional heteroskedastic model and Markov switching models to derive the distribution function of stock volatility and found that a two-stage Markov model appears to be the best fit out of all alternative models. Marabel Romo(2011) identified two possible conditional volatility states, i.e., high volatility and low volatility and also found that conditional volatility is not constant over the time. Bahloul (2014) investigated the time varying behavior of MANA region's stock market volatility using three-stage Markov regime-switching behavior. Chen (2009) used bivariate Markov regime switch GARCH model for understanding the volatilities and correlations of bond and stock returns. The following studies focused on regime switching of the implied volatility index. Baba (2011) examined the macroeconomic variables as leading indicators for the switching behavior of US implied volatility index (VIX), and he found that there are three distinct states (turmoil, tranquil and recession) of the US implied volatility index. Maghrebi (2007) estimated that the regime switching volatility expectations is governed by its long memory process and leverage effect. These empirical studies used many econometric tests like correlation analysis, heterogeneity tests and vector autoregressive test to understand the repercussions of financial integration on implied volatility index behavior. The literature mainly focused on shocks originated and emanated from developed economies to emerging economies and have generally ignored this integration as a trigger for the shift in the behavior of the implied volatility index. So, understanding the volatility shifts and its triggering factors is not only important for pricing the financial assets and hedging, but also has a strong bearing on monetary policy making and financial regulations. So far, no research has been attempted to investigate this international financial market integration as a trigger for the regime-switching behavior of the implied volatility index. This study investigates the regime-switching behavior of implied volatility index and regime dependent determinants, which is crucial to enhance the market predictability. The regime-switching behavior is important for cross-country portfolio assets allocation and application of hedge strategies to manage the international financial risk.

3. Data and methodology

3.1. Data

Under the broad heading of international financial market integration this current study divided the list of international markets into two categories. First one is emerging economies like India implied volatility index (IVIX)). In the second category are developed economies Chicago Board Options Exchange S &P 200 implied volatility index (VIX), Japan implied volatility index (VXJ) and Hong Kong implied volatility index (VHSI), European zone developed stock markets' Germany implied volatility index (VDAX) and Euronext implied volatility index of 12 European economies (VSTOXX). These six implied volatility indices are studied to understand the dependence of Indian implied volatility index on developed markets and its state dependent correlations with these markets. The list of selected implied volatility indices and its underlying series are presented in Table1.

TABLE 1. LIST OF SELECTED VARIABLES AND ITS UNDERLYING SERIES

REGION	IMPLIED VOLATILITY INDEX	UNDERLYING SERIES
India	Indian Implied volatility index (IVIX)	Nifty 50
USA	Implied volatility index (VIX)	S&P 100
Japan	Japan implied volatility index (VXJ)	Nikkei 225
Germany	German implied volatility index (VDAX)	Germany DAX 30 by Deutsche Borse
Euronext	Euronext VSTOXX	Dow Jones Euro STOXX 50 options by STOXX 50 Ltd
Hong Kong	Hong Kong VHSI	Hang Seng Index

Source: Output file generated from the data by using STATA14

The chosen sample has been taken keeping in view that the growing importance of these economies in equity investment and availability of the data. This study aims to understand the regime switching nature of IVIX and its time-dependent relationship with developed nations in each state. After the global financial crisis and Eurozone uncertainty global investors are looking at India as an alternative investment hub.

The sample data spans from 02nd March 2009 to 30th December 2016. This study employs low-frequency data, i.e., daily data. High-frequency data may obscure the identification of regimes information about the implied volatility index.

4. Markov switching dynamic regression model

Hamilton (1989) proposed Markov switching model which is also known as regime switching model. This model involves multiple equations which characterise the time series behaviour in different regimes of the selected variable. This model captures more complex dynamics of the variables by allowing them to switch between these regimes. In this model switching behavior is controlled by an unobservable state variable which follows first-order Markov chain process and it is suitable for explaining correlated data that exhibits dissimilar dynamic patterns during various time periods.

$$\text{State 1: } y_t = \mu_1 + \varepsilon_t \quad (1)$$

$$\text{State 2: } y_t = \mu_2 + \varepsilon_t$$

(2)

Where, μ_1 , μ_2 are the intercepts of state 1 and state 2 equations respectively and ε_t is the white noise term with variance σ^2. If the s_t is the timing of switches then the equations can be expressed as follows:

$$y_t = s_t \mu_1 + (1 - s_t)\mu_2 + \varepsilon_t \quad (3)$$

Where, s_t is 1 if the process state is one other wise 2. It is difficult to infer the process state by knowing the intercept. Markov switching model allows the parameters to change over the states. Markov-switching dynamic regression model with state dependent intercept is expressed as follows:

$$y_t = \mu_{st} + \varepsilon_t \quad (4)$$

If s_t =1, then μ_{st} = μ_1 , if s_t =2, then μ_{st} = μ_2, where μ_{st} is an intercept parameter. In Markov switching regression the transition probabilities are of greatest interest and it can be expressed as $p_{s,s+1}$. In two states process, P_{11} denotes the probability of remaining in state 1 in the next period, given that the state is 1 at current period. If the value is close to 1 then it is expected to stay in state 1 for a long time or process is said to be persistent.

Markov-Switching Dynamic Regression with exogenous variables is expressed as follows:

$$y_t = \mu_{st} + X_t \alpha + Z_t \beta_{st} + \varepsilon_s \quad (5)$$

Where, μ_{st} is a time dependent intercept, y_t is a dependent variable, X_t is a vector of exogenous variables with state invariant parameter α, Z_t is a vector of exogenous variable with state dependent variable β_{st}. Here X_t and Z_t can include lag of dependent variable y_t. The error term ε_s is independent and identically distributed with mean zero and error variance σ^2.

Transition probability from one state to other can be expressed in K x K matrix

$$P=\begin{bmatrix} p_{11} & \cdots & p_{1k} \\ \vdots & \ddots & \vdots \\ p_{1k} & \cdots & p_{kk} \end{bmatrix}$$

The probability of the state s_t is equal to j, where j= {1,…, k-1}, is dependent on the most recent realised value of s_{t-1} and can be express as $P_r\ (s_t = j \mid s_{t-1} = i) = p_{ij}$

P is non-negative and some of each column equal to 1.

$$p_{ij} = \frac{\exp(-q_{ij})}{1+\exp(-q_{i1})+\cdots+\exp(-q_{ij})}$$

$$p_{ik} = \frac{1}{1+\exp(-q_{i1})+\cdots+\exp(-q_{ij})}$$

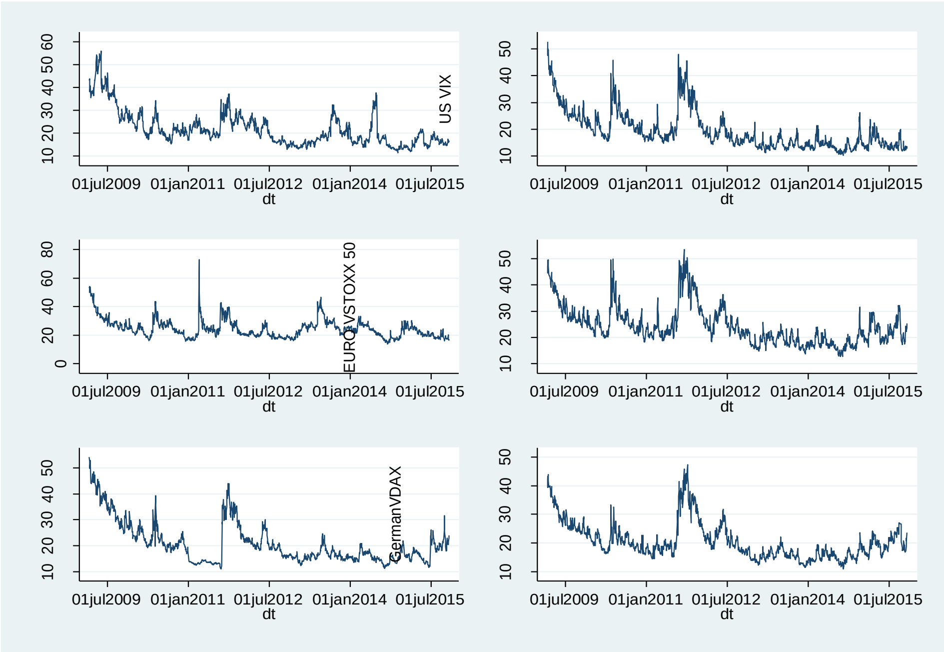
Where $j \in$ (1,…, k-1) and transmitted parameter q can be computed as

$$q_{ij} = -\left(\frac{p_{ij}}{p_{ik}}\right) \tag{6}$$

5. Empirical results and analysis

The empirical analysis employed six implied volatility indices to understand the Indian stock market dependency on advanced economies. The implied volatility indices considered for this study are IVIX, VIX, VSTOXX, VHSMI, VXJ and VDAX. The time series plots of these indices are presented in Figure 1. Most of these implied volatility indices indicate major upheavals between January 2011 and June 2012 and confirming the co-movement across the financial markets. This graphical representation further confirms the non-linearity with very high jumps and halts during the sample period. Both these inferences confirm the application of Markov dynamic regression model on the implied volatility indices. In the application of Markov regression model common difficulty is identifying the correct number of states. This paper considers to two and three states because of the existing literature on emerging economies and volatility studies supports three regime states (Baba & Sakurai, 2011; Di Persio & Vettori, 2014). The estimates of Markov Dynamic Regression with three states model has convergence problem. So, this study reports the existence of only two regimes under mean and variance switching model and results are supporting to Marabel Romo (2001) and Chen (2007) bivariate Markov regime model. The estimates of Markov dynamic regression with two regime results are presented in Table 2. The Markov regime switching results are estimated by using expectations-maximisation algorithm. The results in Table 2 reported the information about the regimes transition probabilities and its persistence.

FIGURE 1. TIME SERIES PLOTS FOR SELECTED IMPLIED VOLATILITY INDICES.



Source: Own elaboration.

The state 1 is associated with higher mean 1.619 compared to state 2's mean value, which is 0.120. The standard deviation of state 1 is 2.01 and state 2 reported the lowest standard deviation of 0.71 which indicates that state 2 is less risky regime compared to first state. These distinctions are crucial to understand that state 1 as highly volatile compared to state 2. The Volatility is high during stock market fall and volatility is low when stock market rises. So, the state 1 represent a bear market situation and the state 2 can be considered as bull market situation. The two states dynamic regression model exhibit dissimilar dynamics across unobserved regimes using state dependent variables. The estimated coefficients on lagged dependent variable in both the regime are statistically significant and positive and this indicates that the today's low (high) volatility could be one of the reasons for the probability to continue the same low (high) volatile state tomorrow. The results also suggests that the S&P 100 implied volatility index and Hong Kong implied volatility index are significant and positively affecting the Indian Implied volatility index during the high volatile state. The Euronext implied volatility index is significant and negatively affecting the Indian implied volatility index in the bear regime.

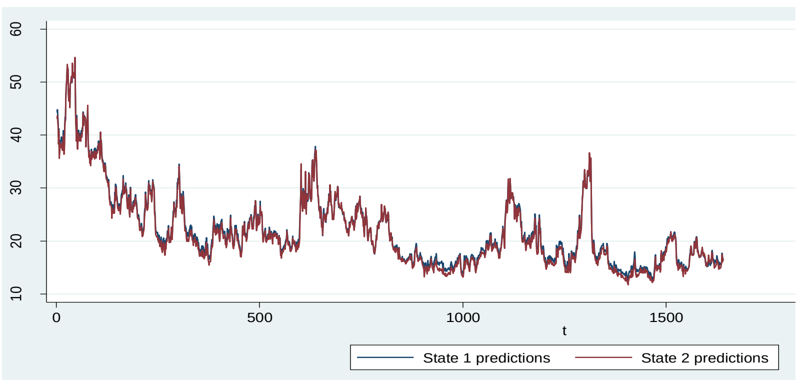
To summarise these results, Indian implied volatility index previous value is the only variable significantly correlated with the bull market conditions. But in a high volatility state all the markets are coupled with each other and moving together. This indicates, during the market turmoil state portfolio asset allocation among these markets will not have much use, but investors can consider the Euronext zone for the diversification. Turning to the regime switching probabilities, the P11 is the estimated probability that the Indian implied volatility index to stay in state 1 for the next period and the process is in state 1 in the current period. The estimated value of 0.92 indicates that state 1 is highly persistent. P21 indicates that the probability of shifting to state 1 from state 2 and the estimate is 0.03. P12 is the estimated probability that the Indian implied volatility index shift to state 2 from the current state, ie., state 1. The estimated probability value is 0.07. P22 is the estimated probability of Indian implied volatility index to continue in state 2 in the next period and the estimated value is 0.97, which infers that the state 2 is also highly persistent.

TABLE 2. MARKOV DYNAMIC REGRESSION ESTIMATED RESULTS USING EXPECTATION-MAXIMISATION ALGORITHM

	State 1			State 2		
VARIABLE	COEFFICIENT	STANDARD ERROR	P VALUE	COEFFICIENT	STANDARD ERROR	P VALUE
L.ivix	.9073565	.0175213	0.000	.9526475	.0095792	0.000
Vix	.1173718	.0366669	0.001	.0073003	.0100073	0.466
Vxj	.0069338	.0186796	0.710	.0061401	.005048	0.224
Vstoxx	-.0863734	.0357817	0.016	-.0009712	.0121413	0.936
Vdax	-.0263022	.0339526	0.439	.0153268	.0139806	0.273
Vhsi	.0466498	.0214121	0.029	.0101214	.0090355	0.263
Mean	1.619565	.5010025	0.001	.1203844	. 1608928	0.454
sigma1/ sigma2	2.018311	.0950377		.7183796	.0249496	
p11	.9255674	.0221081				
P12	.0744326	.0221081				
P21	.030115	.0080708				
P22	.969885	.0080708				
State 1 (expected duration)	13.43497	3.990484				
State 2 (expected duration)	33.20606	8.899188				

Note: *Shows the level of significance 5% and better.
Source: Output file generated from the data by using STATA14.

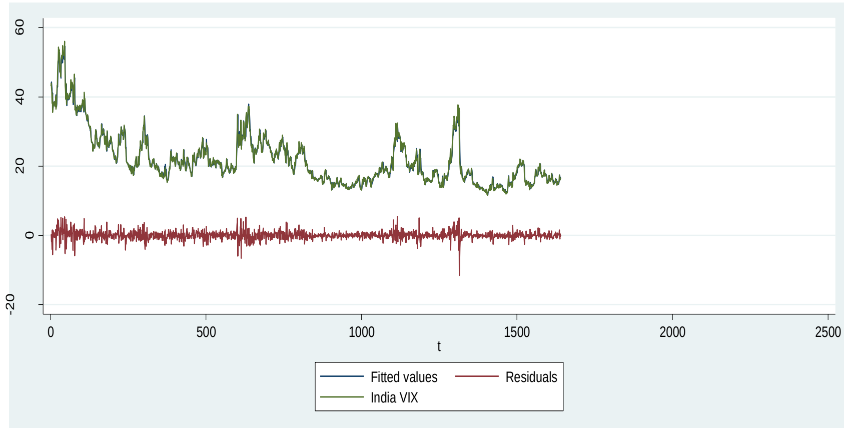
FIGURE 2. COMPARISON BETWEEN THE STATE 1 AND STATE 2 ONE-STEP A HEAD PREDICTED VALUES



Source: Own elaboration.

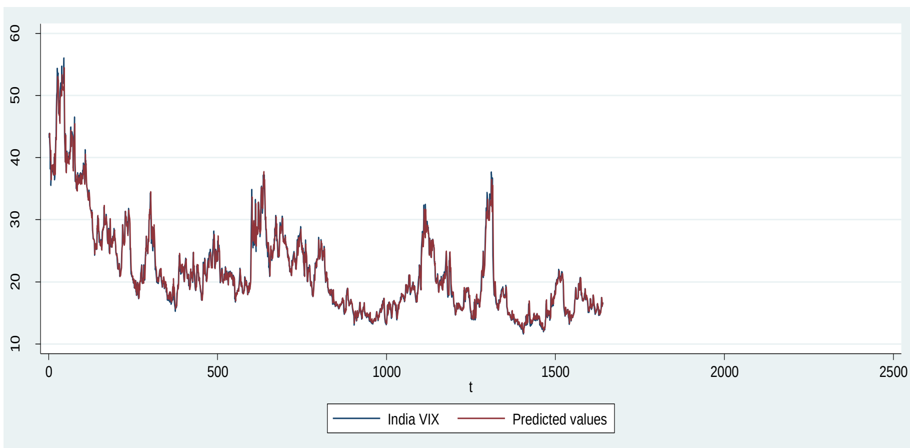
The expected average stay in each of the states also estimated. The bull or less volatile state will continue for 33 days, which is more than one month and then market shifts to bear or highly volatile state, and will continue in that state for 13 days. Both the states are highly persistent. This indicates that the emerging market investors buy and hold till they perceive that the market is going to move adverse conditions.

FIGURE 3. MODEL FITNESS BY COMPARING FITTED VALUES OF IVIX, RESIDUALS AND ACTUAL VALUES OF INDIAN IMPLIED VOLATILITY INDEX



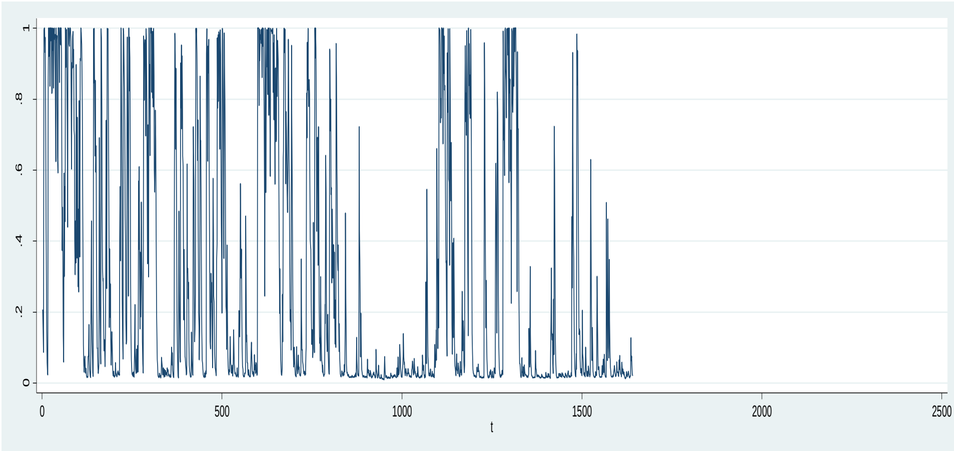
Source: Own elaboration.

FIGURE 4. INDIAN VIX AND ITS ONE-STEP A HEAD PREDICTED VALUES



Source: Own elaboration.

FIGURE 5. PREDICTED STATE TURNING PROBABILITIES



Source: Own elaboration.

The Figure 2 presents the predicted values of these two states. These predictions are one-step a head probabilities and weighted average of state specific predictions. The state 1 predicted value are slightly higher than the state 2 predicted value, which confirms state 2 as a low volatile state.

Figure 3 represents the model fitness by comparing fitted values of Indian implied volatility index, residuals and actual values. Figure 4 presents the actual values of India VIX and its one-step ahead predicted values, both the graphs represent the good model fit.

The smoothed probabilities are estimated to understand the turning probabilities of the Indian implied volatility index (Figure 5).

6. Summary and conclusions

The paper aims at modeling Indian Implied volatility index regime switching behavior and determine the state dependent time varying correlations with developed economies. The results found evidence of regime switching behavior of Indian implied volatility index and is characterised with two states for the selected sample period, i.e. 2nd March 2009 to 30th December 2016. There exists a high degree of synchronicity between Indian VIX and VIX of developed markets during the bear market situation. So, there is less or very limited opportunities to hedge the risk by diversifying the investments to these markets. The investors and risk managers can consider the Euronext zone for cross-county asset allocations to insure their portfolio during the bear market condition of emerging economies. The results also support that the interaction effect is less during bull market conditions and this state is highly persistent. So, international investors can consider the Indian stock market to insure their portfolio risk during this bullish state. Due to the interaction between markets during the turmoil period, shocks are transmitting from developed economies to emerging economies and these economies has limited capability to deal with this shocks and becoming vulnerable to this situation. So, there is a need to build a strong international financial architecture that will help the Indian markets to ensure self-reliance and insulate it from adverse international contagion effect. A further research on policy intervention and international policy coordination will help the investors, risk managers and volatility traders to take the opportunity behind the volatility dynamics.

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