# Contagion in International Stock and Currency Markets during Recent Crisis Episodes

Pami Dua and Divya Tuteja[1]
*Department of Economics, Delhi School of Economics, University of Delhi*

ABSTRACT

This paper investigates contagion across stock and currency markets of China, Eurozone, India, Japan and US during global financial crisis and Eurozone crisis. The crisis periods are selected using Markov-switching models for US and Eurozone markets. We, then, utilize the DCC-GARCH model to estimate conditional correlation among the assets and test for contagion/flight to quality effects during the crises. The results show significant contagion as well as flight to quality effects both across and within asset classes. We examine the impact of financial stress index on the correlation across markets and find that portfolio diversification benefits for equity markets may be non-existent.

**Keywords:** Financial contagion; Global Financial Crisis; Eurozone Crisis; Dynamic Conditional Correlation; Markov Switching; Financial Stress
**JEL Classification:** F30, G15, C32

[1] Corresponding Author: Divya Tuteja, Assistant Professor, Department of Economics, Delhi School of Economics. E-mail:divya@econdse.org.

1. INTRODUCTION

The financial crisis of 2008-09 will remain embedded in history as the largest crisis[2] that shook the developed world post the Great Depression of the 1930s. The intensity and spread of the crisis seems to be unparalleled and so are the repercussion effects thereof. This was followed by a sovereign debt crisis in the Eurozone economies in 2010-11. The crises triggered a coordinated fall in financial markets around the world coupled with massive capital outflow from emerging markets. These recent events have led to an increasing interest in financial contagion, its causes and the role played by Emerging Market Economy (EME) financial markets going forward (Batten and Szilagyi, 2011).

'Contagion'[3] refers to the heightened transmission of shocks during crisis periods vis-à-vis the tranquil periods. The most widely recognised channels of transmission for contagion are trade and financial links. This is because more interlinked economies characterized by high trade dependence or large financial flows are likely to be plagued by faster transmission of shocks.

The objective of international portfolio investment is the diversification of risk and it hinges critically upon the lack of currency risk. Moreover, the simultaneous investment across stock and currency markets allows opportunities for diversification across asset classes. In the backdrop of a lack of consensus regarding the relationship between stock and foreign exchange markets with the uncovered equity parity predicting a positive relationship (Hau and Rey, 2006) and the paper by Cavallo and Ghironi (2005) depicting a negative relationship, it is unclear how investors could leverage gains by investing across these asset classes. The issue assumes significance as exchange rate risk may compound losses for international investors in view of a capital outflow synonymous with depreciation of the exchange rate (say, per US Dollar) during episodes of financial crises.

[2] The existing literature characterizes a crash as a drastic fall in the price of a single asset. In contrast, a crisis denotes a period marked by high uncertainty and a simultaneous and coordinated fall in prices of multiple assets. Further, it is noteworthy that co-movements across markets are synonymous with correlations amongst the markets. A rise in co-movement may, however, result from either large common shocks affecting several markets or spillovers that arise due to transmission of shocks originating in one market to other markets or a further intensification of the channels of transmission of market-specific shocks. See, Ozer-Imer and Ozkan (2014), Kole (2005) and chapter 3 of the IMF World Economic Outlook Report on Transitions and Tensions (2013) for details.

[3] According to Pericoli and Sbracia (2003), the five most commonly used definitions in the literature are based on (i) a significant increase in the probability of occurrence of crises in other countries in response to a crisis having occurred in one country (changes in probability of crises), (ii) volatility spillover from asset prices in the crisis country to markets in other countries (volatility spillovers), (iii) excess co-movement among asset prices across countries which cannot be accounted for by fundamentals (multiple equilibria), (iv) a significant increase in co-movements of cross-country asset prices post occurrence of a crisis in one or more countries (correlation breakdowns) and (v) intensification of the international transmission channel in response to a shock in one market (shift-contagion).

The issue of spread of crises is critical from the perspective of financial stability and is especially relevant for portfolio managers, policymakers and central banks. In general, crisis episodes are characterized by falling asset prices and high volatility which gets transmitted both within and across borders. During financial crises, the relationships between international assets undergo a drastic change and tend to breakdown. This necessitates a relook at risk hedging strategies in view of a change in the correlation across assets. If shocks are transmitted internationally, then, it raises a crucial question regarding existence of portfolio diversification benefits. The increased co-movement of markets during crises has significant implications for the portfolio allocation and risk management strategy of international investors. Rising exchange rate volatility and the resultant currency risks associated with international investments are a cause for alarm. The simultaneous downfall of markets exposes institutions which hold internationally diversified portfolios to danger and may have implications for the payment and settlement process. This is notwithstanding the possible effect on the real economy which may result in severe macroeconomic fluctuations and may trigger correspondingly recessions in several economies.

While there exists a huge body of literature on the propagation of financial crises, the empirical literature tends to focus on the transmission of shocks internationally across a single asset class, mostly equities. The objective of this paper is to investigate the phenomenon of financial contagion across asset classes *viz.* stocks and currencies internationally for China, Eurozone (EZ), India, Japan and United States (US) during the global financial crisis and the Eurozone debt crisis. There are few other studies such as Granger *et al.* (2000), Boschi (2005), Kallberg *et al.* (2005), Kanas (2005), Flavin *et al.* (2008), Dungey and Martin (2007), Tai (2007), and Walid *et al.* (2011) which test for contagion and examine inter-linkages across stock and foreign exchange markets during crises.

The pioneering study by King and Wadhwani (1990) seeks to test for contagion between the stock returns of US, U.K. and Japan during the US stock market crash of 1987 by examining whether the correlations across these markets increased during the event and find existence of significant contagion effects across the markets. However, Forbes and Rigobon (2002) show that cross-market correlation coefficients are biased upwards (as higher volatility translates into high correlation coefficients) during periods of crisis due to the heteroscedasticity in the data. As a result, recent work on correlation breakdowns corrects for the sample selection bias which results from arbitrary selection of crisis periods and focuses on conditional correlations instead of unconditional correlation coefficients.

The present study is based on an analysis using conditional correlations and, therefore, it falls within the literature on correlation breakdowns. However, we refrain from an arbitrary selection of crisis periods and use instead a combination of the statistical and the event-based approach (similar to Kenourgios *et al.*, 2011; Ahmad *et al.*, 2013; Dimitriou and Kenourgios, 2013; and Kenourgios *et al.*, 2016). We identify the time periods for the global financial crisis and the Eurozone debt crisis endogenously by utilizing Markov-switching Vector autoregression (MS-VAR) models for the stock and currency markets of the US and EZ respectively. Additionally, we utilize the events during the crises to corroborate our timelines. Subsequently, we estimate the time-varying conditional correlation coefficients across equity and foreign exchange markets of China, EZ, India, Japan and US by employing the DCC-GARCH model (Engle, 2002). Thereafter, we test for the existence of contagion/flight to quality effects/interdependence across the markets. Finally, we utilize the financial stress index constructed by the Federal Reserve Board of St. Louis to appraise the role played by global risk in the transmission process.

It is noteworthy that there is a burgeoning literature on the existence of financial contagion across markets during the recent crises in the U.S. and E.Z. especially in the context of a single asset market internationally (such as Longstaff, 2010; Guo et al., 2011; Samarakoon, 2011; Syllignakis and Kouretas, 2011; Celik, 2012; Ahmad et al., 2013; Dimitriou and Kenourgios, 2013; Gray, 2014; Ozer-Imer and Ozkan, 2014; Kim and Ryu, 2015; Kenourgios et al., 2016). The present paper contributes to the existing literature in the following aspects. First, we add to the empirical research by examining contagion across multiple asset classes viz. international stock and currency markets during recent crises. Second, empirical examination of the impact of financial crises on dynamics between stock and currency returns tend to focus majorly on EMEs. In this paper, we seek to address the issue of transmission of contagion across developed and emerging markets. Third, we present and analyze the time-varying conditional correlation across the markets during various phases of both the global financial crisis (GFC) and the Eurozone debt crisis (EZDC). Another novel feature of the study is that it investigates the impact of the financial stress index on the linkages across international equity and currency markets. Finally, in order to address the criticism of correlation-based studies by Pesaran and Pick (2007), we select crisis periods by utilizing a statistical as well as event based approach and also include market-specific regressors and a global factor in our DCC-GARCH model.

The remainder of the paper is organized as follows: Section 2 succinctly reviews the existing theoretical and empirical literature on contagion and its impact on international financial markets. The empirical strategy and data are presented in the third section. The identification of crisis periods has been expounded in the fourth section. We present the dynamic conditional correlation model and discuss its results in section 5. The impact of the financial stress index on cross-market conditional correlations would form part of section 6. The last section spells out the conclusions.

## 2. CRISES AND IMPACT ON FINANCIAL MARKETS

There are several aspects of contagion that have been highlighted in the existing literature. The theoretical literature attempts to explain the channels which play a role in the transmission of crises and contagion. On the other hand, the empirical literature concerns itself not only with the channels of transmission but also measurement and existence of contagion both within and across asset classes. The present paper utilizes data for a sample of developed and emerging markets to examine the transmission of contagion across stocks and currencies. A lacunae of the existing empirical literature stems from the inadequate attention that has been paid to the transmission of crises across multiple asset classes. We attempt to address this gap in the present study.

The spread of financial contagion may occur through direct economic linkages like trade and financial inter-relations among two economies or due to indirect effects such as a change in the global investor attitude. The theoretical literature broadly focusses on the following major causes of contagion- common global shocks (Masson, 1999; Mishkin, 1997; Calvo *et al.*, 1996), close trade ties (Gerlach and Smets, 1995; Eichengreen *et al.*, 1996; Glick and Rose, 1999; Corsetti *et al.*, 2000; Forbes, 2002), significant financial linkages (Goldfajn and Valdés, 1997; Van Rijckeghem and Weder, 2001), and changes in investor behaviour[4]. Pavlova and Rigobon (2008) propound a dynamic equilibrium model to examine the inter-linkages between stock prices and exchange rates across Center and Periphery economies and attribute the excess co-movement of stock prices to the portfolio constraints faced by the Center's investors which lead to wealth transfers and contagion effects.

[4] Due to liquidity constraints (Valdés, 1997; Kaminsky *et al.*, 2001), incentive issues (Schinasi and Smith, 2001; Broner *et al.*, 2004), asymmetries in information (Calvo and Mendoza, 2000; Agenór and Aizenman, 1998), market coordination problems (Jeanne, 1997; Masson, 1998; Chang and Majnoni, 2001), and risk reassessment by investors. Observed investor herd behaviour is attributed to uncertain beliefs and asymmetric information on the part of market participants which leads to contagion effects.

The measurement of contagion in the empirical literature has been fraught with technical difficulties. Traditional econometric techniques which a majority of the literature employ is inappropriate for the measurement of contagion (or testing for a structural change in the transmission of shocks during crises) since the data are plagued by heteroscedasticity, omitted variable bias and endogeneity (Dungey *et al.*, 2005). Some of the techniques which have been routinely employed in testing for contagion effects are correlation-breakdowns, ARCH/GARCH framework, cointegration, and logit and probit models. Doubts have been raised on the efficacy and reliability of these techniques by several studies (Forbes and Rigobon, 2002; Dungey *et al.*, 2005; Pesaran and Pick, 2007). In particular, Pesaran and Pick (2007) criticize the analyses using correlation-breakdowns for selecting the crisis periods a priori and recommend inclusion of market-specific variables.

There are a plethora of studies that have dealt with contagion across stock markets[5] and speculative attacks on currency markets[6] in the aftermath of a crisis. Studies in the literature that examine multiple crisis episodes include Bekaert *et al.* (2005), Dungey *et al.* (2007), Bodart and Candelon (2009), Yiu *et al.* (2010), Kenourgios *et al.* (2011), Syllignakis and Kouretas (2011), Kenourgios and Padhi (2012), Dimitriou and Kenourgios (2013) and Kenourgios *et al.* (2016) with the findings of contagion mixed and dependent on the sample of countries analysed.

We draw attention towards the research dealing with measurement of contagion internationally across asset classes. Studies dealing with contagion across international stock and currency markets[7] include Granger *et al.* (2000), Boschi (2005), Kallberg *et al.* (2005), Kanas (2005), Flavin *et al.* (2008), Dungey and Martin (2007), Tai (2007), and Walid *et al.* (2011). The existing evidence is mixed as Granger *et al.* (2000), Kallberg *et al.* (2005), Flavin *et al.* (2008), Dungey and Martin (2007), Tai (2007), and Walid *et al.* (2011) report existence of contagion effects, and Boschi (2005) and Kanas (2005) conclude absence of contagion. The empirical research focusing on the impact of financial crises across equity as well as currency returns tends to concentrate on EMEs and only a limited body of literature (Dungey and Martin, 2007) is devoted to an examination of the inter-linkages across developed and EME markets.

[5] Such as Forbes and Rigobon (2002); Bae *et al.* (2003); Bekaert *et al.* (2005); Bodart and Candelon (2009); Baur and Fry (2009); Dungey *et al.* (2010); Kenourgios *et al.* (2011); Yiu *et al.* (2010), Kenourgios *et al.* (2011), Syllignakis and Kouretas (2011); Min and Hwang (2012); Ahmad *et al.* (2013); and Kim and Ryu (2015).

[6] See Eichengreen *et al.* (1996); Van Rijckeghem and Weder (2001); Favero and Giavazzi (2002); Pesaran and Pick (2007); Celik (2012); Dimitriou and Kenourgios (2013); Ozer-Imer and Ozkan (2014) amongst others.

[7] Some of the papers which focused on contagion across stock and bond markets include Hartmann *et al.* (2004), Gravelle *et al.* (2006), Baur and Lucey (2009) and Longstaff (2010). Büttner and Hayo (2010), and Guo *et al.* (2011), Kenourgios and Padhi (2012), Kenourgios *et al.* (2016) investigate the existence of contagion effects across multiple asset classes.

Further, there is a scarcity of papers that investigate the relationship across international equities and currencies during the recent crises in the US and EZ.

## 3. EMPIRICAL STRATEGY AND DATA

This section explicates the empirical strategy adopted and the data utilized to accomplish the stated objectives of this paper.

### *3.1. Empirical Strategy*

Dornbusch *et al.* (2000, p. 177) define the phenomenon of contagion as "*a significant increase in cross-market linkages after a shock to an individual country (or groups of countries) as measured by the degree to which asset prices or financial flows move together across markets relative to this co-movement in tranquil times.*" Therefore, testing for contagion involves the following key points-identification of turbulent/ crisis (and tranquil/non crisis) time periods, measurement of the degree of co-movement among asset markets, and testing for a significant increase in the co-movement during turmoil times. This study is based on an analysis of the conditional correlations and, therefore, as standard in the literature we need to define the source of the crisis. In the case of the global financial crisis and Eurozone debt crisis the origin of the turmoil is clearly the US and EZ economies respectively.

Our empirical modelling strategy consists of the following steps. In the first step, we identify the crisis periods endogenously by utilizing a Markov-switching vector autoregression (MS-VAR) formulation for the stock and currency markets of US and EZ respectively. Moreover, we corroborate dates for the crisis regimes obtained statistically from the Markov-switching models by comparing them with major events highlighted in the timeline of crisis events constructed by the Federal Reserve Bank of St. Louis, European Central Bank, The Guardian, The Telegraph and other sources. Thereafter, we specify a DCC-GARCH model which yields time-varying conditional correlation coefficients for the asset market returns[8]. Finally, we test for the existence of contagion/ flight to quality effects/ interdependence in international equity and foreign exchange markets using OLS with robust standard errors. Lastly, we study the impact of a rise in financial stress on the dynamic conditional correlation coefficients among the financial markets by employing AR-GARCH models.

[8] We undertake two unit root tests namely Dickey Fuller-Generalized Least Squares (DF-GLS proposed by Elliot *et al.*, 1996) and Lee and Strazicich (2003). In view of the presence of suspected structural breaks in the financial market returns, we conduct the Lee and Strazicich (2003) test for a unit root which allows for structural breaks in the null hypothesis of the presence of a unit root or non-stationarity. Results of the tests indicate that the null hypothesis of the existence of a unit root is rejected for all the time series. Detailed results for unit root tests are available with the authors on request.

*3.2. Data*

In order to test for contagion across international stock and currency markets during the global financial crisis (GFC) and the Eurozone debt crisis (EZDC), we collect data at weekly frequency from Bloomberg. The sample under study is from August, 2005 to September, 2014[9]. The data for the stock and currency markets in China, EZ, India, Japan and US i.e. the series for Shanghai SE Composite Index, Chinese Yuan/USD ($e^{CN¥}$) exchange rate, S&P Euro 75 Index, Euro/USD ($e^{€}$) exchange rate, CNX Nifty 50 Index, INR/USD ($e^{₹}$) exchange rate, Nikkei Index, Yen/USD ($e^{¥}$) exchange rate[10] and S&P 500 Index have been used. In the present study, we analyse and focus on the impact of recent crisis episodes namely GFC and EZDC on developed economies of Eurozone, Japan, US and two EMEs *viz.* China and India. We select major countries from the two groups i.e. developed (i.e. Eurozone, Japan and US) and emerging economies (namely, China and India) for the analysis. This is done with the objective of evaluating the impact of recent crises across economies in both the categories. According to the IMF World Economic Outlook (2014), the share of world GDP evaluated at Purchasing Power Parity held by these countries is 58%. This is notwithstanding the high stock market capitalization of more than 40% in each of these economies (World Development Indicators, 2015) and the fact that they house major stock exchanges.

It is notable that both the Chinese and Indian exchange rates abide by a managed floating exchange rate regime. The Chinese currency is more regulated with higher intervention and, as a result, we do not expect it to be closely related to international markets. However, in the context of international portfolio diversification especially in 'Fab Five' emerging markets of China and India inclusion of the Chinese currency is critical from the perspective of analysing currency exposure during crises. It is more so since the Chinese market offers a currency marked by low risk coupled with negligible returns and the Indian market tenders one with relatively high risk and higher returns[11].

As has been standard in the literature, the time series for stock market prices and exchange rates are modelled as logarithmic first differences or in returns form[12]. The descriptive statistics

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[9] This time period is selected as the Chinese Renminbi (or Yuan) has been market-determined since July, 2005.
[10] We have defined the exchange rates of China, Eurozone, India and Japan with respect to that of the US
[11] However, as per the IMF Annual Report on Exchange Arrangements and Restrictions, the Chinese and Indian currencies are considerably regulated and, therefore, the findings of this analysis should not be generalized to all emerging and developing countries.
[12] $y_t = 100 \times \log(\frac{Y_t}{Y_{t-1}})$ where $y_t$ denotes the returns form for $Y_t$ which represents exchange rates or stock prices in levels.

and the unconditional correlation matrix for returns in the nine markets are presented in Table 1 (Panel A and B). The average weekly returns are highest for the Indian stock market index Nifty 50 and lowest for the Chinese Yuan per USD exchange rate. Further, the Chinese stock market i.e. Shanghai SE Composite index has the most volatile returns. The least volatile returns series is that for the Chinese Yuan per USD exchange rate returns as it is firmly controlled. Further, the unconditional correlation among the stock markets is generally high (more than 0.5) and positive. The unconditional correlation across the exchange rate returns is negative for 2 out of 3 cases and are relatively much lower in magnitude. However, the correlation coefficients between stock and currency market pairs is mixed (positive as well as negative).

## 4. IDENTIFICATION OF CRISIS PERIODS

The studies by Dungey *et al.* (2005), and Pesaran and Pick (2007) highlight that contagion tests based on correlation-breakdowns may be biased if the crisis periods are selected a priori. To circumvent this issue, we amalgamate the statistical and event based approach to identify the crisis episodes. We construct a Markov-switching VAR model (Hamilton, 1989, 1990) for the stock and exchange market returns in US and Eurozone where the crises transpired and originated. These economy-specific MS-VAR models enable us to identify and select the crisis periods endogenously for GFC and EZDC respectively. This empirical strategy has been adopted by several recent studies such as Kenourgios *et al.* (2011), Ahmad *et al.* (2013), Dimitriou and Kenourgios (2013), and Kenourgios *et al.* (2016). We, then, corroborate the crisis dates from the model with official dates obtained from Federal Reserve Bank of St. Louis, European Central Bank and other sources. This section presents the MS-VAR model and brings out phases of the two crises.

### *4.1. Markov-switching Vector Autoregression Model*

The first and second moments of returns in the US and EZ stock and exchange rate returns are depicted by a two-dimensional multivariate Markov-switching model with heteroscedasticity. This framework allows us to characterize the tranquil and crisis regimes in the US and EZ markets respectively.

The Markov Switching Intercept Autoregressive Heteroscedasticity (MSIAH) model (Guidolin, 2011) has the following general form for a two-regime MSVAR ($p$) process

$$y_t = \mu_{S_t} + \sum_{j=1}^{p} \beta_{j,S_t} y_{t-j} + \varepsilon_t \quad (1)$$

where $y_t = \begin{pmatrix} s^{US\ (or\ EZ)} \\ e^{¥\ (or\ €)} \end{pmatrix}$ is the 2× 1 vector of endogenous variables i.e. returns on the US (or Eurozone stock market $s^{EZ}$) stock market $s^{US}$ and returns on the Yen per Dollar ($e^{¥}$) (or Euro per Dollar i.e. $e^{€}$) exchange rate; $\mu_{S_t}$ is a 2× 1 vector of regime-dependent mean returns; $\beta_{j,S_t}$ is the 2 × 2 matrix of regime-dependent VAR coefficients; $S_t = 1, 2$ is a latent state variable driving all the parameter matrices and is an irreducible, aperiodic and ergodic two-state Markov chain process with the transition matrix

$$P = \begin{bmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{bmatrix} \quad (2)$$

$$P\{S_t = j | S_{t-1} = i, S_{t-2} = k, \ldots, y_{t-1}, y_{t-2}, \ldots\} = P\{S_t = j | S_{t-1} = i\} = p_{ij} \quad (3)$$

Such a process will be called a two-state Markov chain with transition probabilities $\{p_{ij}\}_{i,j=1,2}$. The residuals follow a standard Gaussian distribution conditional on the state i.e. $\varepsilon_t \sim N(0, \Sigma_{S_t})$. The 2 × 2 matrix $\Sigma_{S_t}$ represents the state factor $S_t$ in a regime-dependent variance-covariance matrix such that

$$\Sigma_{S_t} = \begin{bmatrix} \sigma_{1,1,S_t} & \sigma_{1,2,S_t} \\ \sigma_{2,1,S_t} & \sigma_{2,2,S_t} \end{bmatrix} \quad (4)$$

We estimate the intercept switching, intercept-heteroscedasticity switching, coefficient switching, coefficient and heteroscedasticity switching, mean switching, and mean and heteroscedasticity switching specifications (Hamilton, 1990) as given in Krolzig (1997) for both the US and EZ and calculate the AIC, BIC and HQ statistics[13]. Using these criterion, the best specification i.e. Markov switching in intercept and heteroscedasticity (MSIH) specification is selected for both the US and EZ models. Subsequently, we estimate the economy-specific models using the EM Algorithm (Expectations-Maximization algorithm proposed by Dempster *et al.*, 1977) and compute the regime classification measure (RCM[14] propounded by Ang and Bekaert, 2002).

The smoothed probabilities from the above models are utilized to deduce the likelihood that the US (or EZ) economy was in a turmoil/crisis period at any particular point of time. This allows us to specify the time periods for GFC and EZDC based on the data. In other words, smoothed probabilities derived from the MS-VAR model encompassing the US stock market

[13] In order to obtain the appropriate lag length, we first employ the standard VAR lag selection criterion viz. Akaike Information Criterion (AIC), Schwarz Bayesian Criterion (SBC), Hannan-Quinn (HQ) and F-statistics and choose the optimal lag length.
[14] The RCM statistic for a Markov-switching model with two regimes is defined as $RCM = 400 \times \frac{1}{T}\sum_{t=1}^{T} \Pr[S_t = j|\mathcal{F}_T](1 - \Pr[S_t = j|\mathcal{F}_T])$, where the constant term of 400 is used to normalize the statistic between 0 and 100, $\Pr[S_t = j|\mathcal{F}_T]$ is the smoothed probability conditioned on the availability of the full information set $\mathcal{F}_T$. A cut off of about 50 is considered to be standard in the literature.

returns and currency market returns are utilized to select the time periods for GFC, and smoothed probabilities calculated from the MS-VAR model consisting of Eurozone stock market returns and currency market returns are employed to specify the periods for EZDC. The time varying variances of the markets have also been calculated in accordance with Wang and Theobald (2008)[15]. The obtained timelines were then corroborated using various sources such as Bloomberg, Federal Reserve Bank of St. Louis, European Central Bank, The Guardian and so on.

*4.2. Phases of the Crises*

We present estimates of the MS-VAR models in Table 2 (Panels A and B). The Markov-switching models capture two regimes for the US (Panel A) and the EZ (Panel B) markets respectively. The first regime or the crisis state is associated with lower (or negative) returns and higher volatility in comparison to the second regime or the tranquil state which is depicted by higher (or positive) returns and lower volatility. Further, both the regimes are persistent with $p_{ii}$ more than 0.90. The RCM statistic (Ang and Bekaert, 2002) allows us to infer whether the Markov-switching models are performing well. We find that both the models have low RCM statistic and are adequate. The smoothed probabilities and time-varying volatilities of the GFC and EZDC crisis regimes are given in Figure 1 Upper Panels A and B. Further, we define a threshold of 0.80 and above as signifying a high probability of the markets being in the crisis regime. Moreover, GFC has been divided into three phases-pre-crisis phase I, phase II[16] and phase III and EZDC has been divided into two episodes-I and II respectively. After identifying the turbulence/crisis time periods[17], we construct the following set of dummy variables-$DGFC_1$, $DGFC_2$, $DGFC_3$ which represent the three phases of GFC and $DEZDC_1$, $DEZDC_2$ which capture the two episodes of EZDC. The selected crisis episodes are depicted in Figure 1 (Lower Panels A and B).

[15] Wang and Theobald (2008) have proposed constructing the time-varying market volatility for each of the markets at time $t$ i.e. $\tilde{\sigma}_t^2$ based on the full information set by using the smoothed probabilities and the parameter estimates as $E[\tilde{\sigma}_t^2|\mathcal{F}_T] = \tilde{\sigma}_1^2 E[S_t = 1|\mathcal{F}_T] + \tilde{\sigma}_2^2 E[S_t = 2|\mathcal{F}_T]$, where $\tilde{\sigma}_1^2$and $\tilde{\sigma}_2^2$are the estimated conditional variances for regimes one and two respectively, and $\mathcal{F}_T$ is the full information set upto time $T$.
[16] The probability of a crisis regime is close to 1 from 19.09.2008 to 24.10.2008 but declines thereafter. Although it remains high till July, 2009. In order to capture the initial impact of the crisis chaos, we classify the episode separately.
[17] We conduct a sensitivity analysis of the crisis periods that we have identified using the economy-specific Markov-switching models. In order to do that, we estimate the Markov-switching models for US and EZ stock and currency markets on a different sample with the start and end dates as June, 2003 to August, 2013. We find the crisis dates to be the same as those reported in the above sub-section. Detailed results are available with the authors on request.

Pre-crisis Phase I GFC dummy (2008): $DGFC_1 = \begin{cases} 1\ if\ t \in \{04.01.2008 - 08.02.2008\} \\ 0\ otherwise \end{cases}$

Phase II GFC dummy (2008): $DGFC_2 = \begin{cases} 1\ if\ t \in \{19.09.2008 - 24.10.2008\} \\ 0\ otherwise \end{cases}$

Phase III GFC dummy (2008-09): $DGFC_3 = \begin{cases} 1\ if\ t \in \{31.10.2008 - 24.07.2009\} \\ 0\ otherwise \end{cases}$

Phase I EZDC dummy (2010): $DEZDC_1 = \begin{cases} 1\ if\ t \in \{07.05.2010 - 02.07.2010\} \\ 0\ otherwise \end{cases}$

Phase II EZDC dummy (2011): $DEZDC_2 = \begin{cases} 1\ if\ t \in \{15.07.2011 - 16.12.2011\} \\ 0\ otherwise \end{cases}$

Further, this crisis timeline is corroborated from news related to the crises which have been collated and presented in Table 3. The crisis regimes identified from the Markov-switching models correspond to the events highlighted in the table.

## 5. DYNAMIC CONDITIONAL CORRELATION MODEL

Upon obtaining the crisis dates from the Markov-switching models given in Section 4, we estimate the conditional correlations among the asset market returns. These are subsequently used to test for contagion/ flight to quality/ interdependence amongst the markets. In order to accomplish that, we utilize a DCC-GARCH framework along with OLS estimation. This section contains all the aspects regarding the model and presents its results.

### *5.1. DCC Model*

We utilize the multivariate DCC-GARCH model proposed by Engle (2002) to estimate the dynamic conditional correlations across the selected markets. The model accounts for heteroscedasticity and guarantees parsimony (Chiang *et al.*, 2007) which allows us to estimate the 36 pair-wise dynamic correlation coefficients in a single framework. Additionally, we include an AR(1) term (to correct for possible autocorrelation and) to act as market-specific regressors as well as the Federal Reserve Bank of St. Louis' Financial Stress Index[18] as a global factor (or an exogenous variable) in our model. Upon estimation of the conditional correlation coefficient series, we utilize the same to analyse the regime shifts resulting from the crises. The estimated return equation for the DCC-GARCH model is

[18] The Federal Reserve Board of St. Louis' Financial Stress Index is constructed using the first principal component of 18 weekly series comprising financial variables pertaining to developed markets (mainly US), interest rates and yield spreads for developed and emerging markets (J.P. Morgan Bond Index Plus), and other indicators related to global financial markets. It, therefore, captures global investment climate, global risk attitude, and the strain exerted on international financial markets by global developments appropriately.

$$r_t = \gamma_0 + \gamma_1 r_{t-1} + \gamma_2 x_t + \varepsilon_t \tag{5}$$

where $r_t = (r_{1t}, r_{2t}, \ldots, r_{9t})'$ are the returns in the nine markets; $x_t = (x_{1t}, x_{2t}, \ldots, x_{9t})'$ are exogenous regressors; $\mathcal{F}_{t-1} = \{\varepsilon_{t-1}, \varepsilon_{t-2}, \ldots\}$ is the set of past information on the error $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t}, \ldots, \varepsilon_{9t})'$, $\varepsilon_t | \mathcal{F}_{t-1} \sim t(0, \Sigma_{t|t-1})$ where $t$ denotes the Student's t-distribution and $\Sigma_{t|t-1}$ is the conditional covariance matrix. The multivariate DCC-GARCH model is estimated simultaneously for the nine markets.

The model estimates the conditional covariance matrix in two steps. In the first step, a univariate GARCH model is specified for the conditional variances. Subsequently, given the conditional variances obtained in the first step, the conditional correlation matrix is computed by imposing the assumption that it would be positive definite at all points of time. In Bollerslev (1990)'s Constant Conditional Correlation (CCC) formulation, the conditional correlation matrix is assumed to be constant and the conditional covariances are constructed by taking the product of the conditional correlations and the respective conditional standard deviations.

$$\Sigma_{t|t-1} = D_t R_t D_t = (\rho_{ij}\sqrt{\sigma_{ii,t}\sigma_{jj,t}}) \tag{6}$$

where $D_t = diag(\sigma_{1t|t-1}, \ldots, \sigma_{Nt|t-1})$ is the $N \times N$ diagonal matrix containing time-dependent standard deviations on the diagonal, $\sigma_{ii,t}$ are the conditional variances each of which is estimated as a univariate GARCH model, $R = \rho_{ij}$ is an $N \times N$ constant, symmetric and positive definite matrix of the conditional correlation coefficients $\rho_{ij}$ with $\rho_{ii} = 1, \forall i$.

However, in the case of financial time series, the assumption of constant conditional correlation seems implausible. The Dynamic Conditional Correlation (DCC) model proposed allows the matrix $R$ to be time-dependent. The DCC model (Engle, 2002) is defined as follows

$$\Sigma_{t|t-1} = D_t R_t D_t \tag{7}$$

with $D_t$ defined as above and $R_t$ is now a time-varying matrix defined as

$$R_t = diag\{Q_t\}^{-1} Q_t diag\{Q_t\}^{-1} \tag{8}$$

$R_t$ is the $N \times N$ conditional correlation matrix with the diagonal terms as one and the off-diagonal terms less than one in absolute value, and $Q_t = (q_{ij,t})$ is the $N \times N$ symmetric positive definite matrix of $v_t$ ($v_t$ is the standardized innovation vector with elements $v_{it} = \varepsilon_{it}/\sigma_{it}$) such that

$$Q_t = (1 - \alpha - \beta)S + \alpha(v_{t-1}v'_{t-1}) + \beta Q_{t-1} \tag{9}$$

where $S = E(v_t v'_t)$ is the $N \times N$ unconditional correlation matrix of the standardized residuals $v_t$, the scalar parameters $\alpha$ and $\beta$ are such that $0 \leq \alpha, \beta \leq 1$ $and$ $\alpha + \beta \leq 1$. These restrictions guarantee that the estimated matrix $R_t$ is positive definite. Therefore, the $\rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t}q_{jj,t}}}$ with $i, j = 1,2, \dots, 9$, $i \neq j$ and is the correlation estimator which is positive definite.

The DCC model[19] can be estimated consistently using a two-step procedure to maximize the log-likelihood function. Let $\theta_1$ denote the parameters in $D_t$ and $\theta_2$ be the parameters in $R_t$ then the log-likelihood function $LL_t$ can be written as-

$$LL_t(\theta_1, \theta_2) = \left[-\frac{1}{2}\sum_{t=1}^{T}(Nlog(2\pi) + log|D_t|^2 + v_t'D_t^{-2}v_t)\right] + \left[-\frac{1}{2}\sum_{t=1}^{T}(\log|R_t| + v_t'R_t^{-1}v_t - v_t'v_t)\right] \quad (10)$$

So, the log likelihood function can be written as a sum of the mean and volatility component, and the correlation component (Engle, 2002). In the first part of the above equation, volatility is calculated by adding up the individual GARCH likelihoods and is maximized in the first stage of estimation over the parameters $\theta_1$ in $D_t$. Once the parameters in the first stage are obtained, in the second stage maximization of the correlation part of the likelihood function is undertaken to get the estimated correlation coefficients.

### *5.2. Estimates from DCC-GARCH(1,1) Model*

Table 4 (Panels A and B) presents the results of the multivariate DCC-GARCH model for the stock and currency markets of China, EZ, India, Japan and US. To begin with, we test for the presence of multivariate ARCH effects and the results indicate existence of multivariate ARCH effects. We, then, go on to test for the appropriateness of the CCC-GARCH specification (Tse, 2000) and the null hypothesis of constant conditional correlation is rejected at 1% level. Further, given the fat-tailed distributions for asset returns, we employ the DCC-GARCH model with an underlying t-distribution. The lagged term or the AR(1) term in the mean equation is significant for all the selected stock and foreign exchange markets. The estimated GARCH-DCC(1,1) specification has significant parameters[20] $\alpha$ and $\beta$ at 1% level which indicates that there is a great deal of time-varying co-movement in the asset markets. Furthermore, stock and exchange market returns exhibit high volatility persistence (given by the sum of the constants for ARCH and GARCH) with all the markets depicting persistence greater than 0.95 during the study period. The lowest volatility persistence is displayed by the S&P Euro returns and the highest by the Chinese Yuan exchange rate returns. It is noteworthy

[19] The paper by Tse and Tsui (2002) examines performance of varying-correlation multivariate GARCH models (similar to DCC-GARCH according to Bauwens *et al.*, 2006) in small-samples and find the bias and mean squared error to be small in samples of 500 observations or more.

[20] The estimates of the mean-reverting process are $\alpha = 0.015$ and $\beta = 0.954$. It is noteworthy that $0 < \alpha < \beta < 1$ and $\alpha + \beta < 1$.

that the global factor significantly affects the returns on all the markets with the exception of the Chinese Yuan exchange rate. Moreover, the coefficients for lagged volatility and lagged error terms in the variance equations for all the markets are significant at 5% level (except Indian exchange rate returns which do not depict ARCH effects). Lastly, the standardized residuals do not depict significant autocorrelation which implies that the multivariate GARCH(1,1) specification is appropriate.

*5.3. Analysis of Correlation Coefficients in Different Phases of the Crises*

Several recent studies such as Chiang *et al.* (2007), Syllignakis and Kouretas (2011), Min and Hwang (2012), Ahmad *et al.* (2013), Dimitriou and Kenourgios (2013), and Kenourgios *et al.* (2016) test for contagion on the basis of the conditional correlation coefficients obtained using the DCC-GARCH framework. Upon estimation of the time-varying conditional correlations (TVCCs), testing for contagion across the markets is accomplished using Ordinary Least Squares (OLS) estimation. It is notable that Favero and Giavazzi (2002) have questioned usage of the word ‘contagion’ to describe the transmission of shocks post crisis in an economy or region. They point out that this precludes the prospect of flight to quality effects i.e. the possibility of a lowering of correlations across asset returns in the post crisis scenario.

Using the five dummy variables that we constructed using the MS-VAR models in section 4 for the different sub-samples, we examine the dynamic evolution of the correlation coefficients across the various crisis and non-crisis phases. This univariate regression is estimated for each of the 36 TVCC series obtained from the DCC-GARCH model outlined in subsection 5.1 separately. In order to test for the impact of the two crises on the markets, we utilize an OLS regression with robust standard errors and estimate the following specification for the TVCC estimates

$$\hat{\rho}_{ij,t} = \delta_0 + \delta_1 DGFC_1 + \delta_2 DGFC_2 + \delta_3 DGFC_3 + \delta_4 DEZDC_1 + \delta_5 DEZDC_2 + \vartheta_t \quad (11)$$

where $\hat{\rho}_{ij,t}$ is the pair-wise correlation coefficient between market *i* and market *j*; *i* and *j* denote the stock and currency markets of China, EZ, India, Japan and US respectively, dummy variables $DGFC_1$, $DGFC_2$, $DGFC_3$, $DEZDC_1$and $DEZDC_2$ are as defined in subsection 4.2 and $\delta_0$ is the intercept term which signifies the correlation coefficients during the stable period. A positive and significant coefficient $\delta_i, i = 1, \ldots, 4$ indicates a significant rise in the conditional correlation during the crisis time period vis-à-vis the stable period and is termed ‘contagion’. A negative and significant coefficient would imply a divergence (or fall) in the dynamic conditional correlation among the asset markets during the crises in comparison to the normal time periods and is dubbed 'flight to quality'. An insignificant coefficient during the crises coupled with a significant coefficient in tranquil times is indicative of 'interdependence' among the markets. The estimation framework, therefore, allows us to test for the existence of contagion (flight to quality) or interdependence across stock and currency markets where in a significant rise (fall) in correlation is taken to be signal of the heightened (diminished) co-movement across the markets during the period under study. Utilizing the dummy variables allows us to ascertain the sub-periods which exhibit statistically significant linkages amongst the financial markets.

We present results for the episode-wise impact of GFC and EZDC on the dynamic conditional correlation across asset markets in Table 5 (Panels A, B and C). The first five columns of the table indicate the change in the dynamic correlation coefficient amongst the markets during the sub-phase highlighted in the column heading. The fifth column of the table provides the correlation coefficients during the stable period. The last column gives the summary inference for each of the market-pairs across the crisis episodes in the order of phases I, II and III of GFC followed by phases I and II of EZDC. It is noteworthy that the relationship amongst stock and currency markets is not necessarily positive but, in fact, mixed.

In our analysis, we compare the crisis period results for the market pairs with the results for the stable period in order to infer the direction of the impact. We find that the correlation coefficients across the stock markets are positive and significant at 1% level during the stable period. This means that all the stock markets are significantly correlated during the stable period with the lowest correlation coefficient of 0.192. The stock markets, across the board, depict higher correlation during the global financial crisis periods (except stock market pairs with India in phase I and II and China mostly in phase III) and phase I of the Eurozone debt crisis. Further, if we compare across the three phases of the GFC then we observe that the 2$^{nd}$ and 3$^{rd}$ phases of the crisis triggered significant and large contagion effects amongst the stock markets. The magnitude of the contagion effects is lower in most cases during the EZDC phases than the 2$^{nd}$ and most chaotic phase of GFC marked by adverse news announcements. We now focus on correlations across the developed country stock markets. During GFC, evidence indicates a significant positive contagion across EZ, Japan and US stock markets with the exception of the EZ and US markets during phases I and II of the crisis. Moreover, evidence for the first phase of EZDC also indicates positive and significant contagion across the three stock markets (excluding the US and Japanese stock markets). However, we find evidence of significant flight to quality during phase II of EZDC. Next, we discuss the developed and EME stock markets pairs. We observe flight to quality between Chinese and developed country stock markets during GFC with the exception of the increase in co-movement with the Japanese stock market during phase I and II of GFC. On the contrary, there exists significant contagion across the Chinese and developed economy stock markets at the time of the EZDC except a slight reduction that is witnessed in the correlation between Chinese and EZ stock markets during phase II of EZDC. During the GFC, the Indian stock market depicts significantly lower correlation with the US stock market during the 1$^{st}$ and the 2$^{nd}$ phase but positive and significant contagion with the EZ and Japanese stock markets. It is interesting to note that India was more closely linked with the developed markets during phase I of EZDC but it became delinked with these markets during phase II of EZDC. Lastly, for the EMEs China and India, we find evidence of positive and significant contagion only during phase I of GFC. It is interesting to note here that there is a decline in the number of market pairs depicting contagion after the initial phase in both the crises as it seems that the immediate impact of shocks is the maximum. It is notable that most developed country stock markets pairs are plagued by contagion during the GFC and phase I of EZDC. We find evidence of significant contagion across stock markets which is in tandem with the results obtained by Syllignakis and Kouretas (2011), Min and Hwang (2012), and Ahmad *et al.* (2013).

Among the currency market pairs, the Chinese exchange rate is positively and significantly related to the Japanese and Indian exchange rates during the stable periods whereas the other currency returns have significant and negative correlation coefficients. Further, it is pertinent to note at this juncture that the 2$^{nd}$ and 3$^{rd}$ phases of the GFC and the 1$^{st}$ phase of EZDC have been most severe in terms of the transmission of shocks across the markets. As before, we discuss the developed country currency rates first where we observe that after a negative and significant reduction in the correlation across Euro and Yen returns during the 1$^{st}$ phase of GFC, we witness positive and significant contagion effects during phase III of GFC and phase I of EZDC. Subsequently, we consider the co-movement across developed and EME currency returns. We observe significant flight to quality as the correlations across Euro, Yen and Rupee returns fell significantly during all the crisis phases. However, it is noteworthy that the correlation between Yen and Yuan rates heightened significantly across the crises implying possible contagion effects. The co-movement between Yuan and Euro exchange rates reduced significantly during GFC but increased during phase I of EZDC. Among the EME currencies of China and India, we find that the correlations decreased significantly apart from phase III of GFC. In sum, the developed market currencies seem to be more affected by contagion. According to Dimitriou and Kenourigos (2013), the currencies are known to have different vulnerabilities. The evidence for the currency markets is found to be mixed by Favero and Giavazzi (2002), Dimitriou and Kenourgios (2013), Celik (2012) and Ozer-Imer and Ozkan (2014) as well. Flight to quality effects across the markets especially the currencies is in line with the results of Dimitriou and Kenourgios (2013).

Finally, when we analyse the cross-asset market pairs and again find that the correlation coefficients are negative and significant in the stable period for the stock markets and the Yuan and Rupee returns (except significant but low positive correlation amongst the Chinese stock and currency markets) but are positive and significant for the pairs involving the stock markets and the Euro or the Yen returns. Further, the stock markets were displaying negative returns during most of the crisis time periods but it seems that the Euro and Yen returns were also negative or the Euro and the Yen were, in fact, appreciating during most of these periods. For the market pairs with developed country stock and currency markets, we find that the returns on the stock markets and the Yen exchange rate depict significant contagion effects (except the stock markets and Yen returns during phase II of EZDC). Interestingly, the correlation coefficients for EZ and US stock markets and Euro returns fell significantly during the 1$^{st}$ and 2$^{nd}$ phases of GFC but increased, thereafter, till the EZDC. A notable exception is the fall in US and Japanese stock markets and Euro correlations during phase II of EZDC. The market pair for the Japanese stock and the Euro currency returns, however, witnesses only a rise in co-movement during phases II and III of GFC and phase I of EZDC. The most important phases in terms of the transmission of shocks are those of the GFC. Among the cross asset class market pairs of developed stock markets and EME currency returns, the Rupee returns depict significantly lower correlation with the stock markets during phase I of GFC but this heightens subsequently. The Yuan returns show significantly higher co-movement with the developed country markets with the exception of the Japanese stock market post phase II of GFC. It is notable that the magnitude of effects for the Yuan are negligible. For the EME stock markets and developed country currencies, the Yen returns show significant and positive contagion effects across the crises while the Euro returns show switching behaviour alternating between higher and lower correlations. The remaining EME stock market-currency market pairs display a similar behaviour i.e. alternating between contagion, flight to quality and interdependence across the two crises. The evidence on the negative relationship between the stock and currency market pairs has also been proposed by other studies such as Granger *et al.* (2000), Flavin *et al.* (2008), and Büttner and Hayo (2010).

## 6. EXPLAINING THE TIME-VARYING CORRELATION COEFFICIENTS

It is possible to explain the existence of contagion effects by examining the trade and financial linkages amongst the countries (Table 6). In Panel A, the trends in share of imports and exports suggest that the economies have significant trade ties. From Panel B, we observe that the rest of the economies are dependent on Eurozone and US banks. Several existing studies on stock markets (Chiang *et al.*, 2007; Syllignakis and Kouretas, 2011; Ahmad *et al.*, 2013) and currency markets (Dimitriou and Kenourgios, 2013) have advanced evidence suggesting that the international cross-market linkages vary directly with the level of risk in the markets. It is pertinent to note that the nature and extent of trade and financial dependence does not vary substantially in the short-run. As a result, given trade and financial linkages across the economies, risk seems to drive the short-term linkages (and contagion/ flight to quality) across international asset markets.

In this section, we utilize the financial stress index constructed by the Federal Reserve Bank of St. Louis which captures the risk aptitude of international investors, directly impacts the global investment sentiment and, thereby, drives the transmission of shocks across borders and assets[21]. In this section, we study the impact of the financial stress index on the relationship across international stock and currency markets.

In order to assess the role played by financial stress[22] in the markets, we specify the following univariate AR-GARCH model for each of the time-varying correlation coefficients

$$\hat{\rho}_{ij,t} = \nu_0 + \sum_{p=1}^{P} \nu_p \, \hat{\rho}_{ij,t-p} + \omega_1 dfsi_t + e_{ij,t} \qquad (12)$$

$$h_{ij,t} = B_0 + B_1 h_{ij,t-1} + D_1 e_{ij,t-1}^2$$

where $\nu_0$ is the intercept in the mean equation, $\nu_p$ are the autoregressive coefficients, $B_0$is the intercept term in the variance equation, $B_1$and $D_1$ are GARCH and ARCH coefficients in the variance equation, *dfsi* is the first-difference of the financial stress index and $\hat{\rho}_{ij,t}$ is defined before. A positive and significant coefficient $\omega_1$ indicates that the dynamic conditional correlation between market *i* and market *j* goes up as the financial stress index rises. The lag selection of the AR terms has been undertaken on the basis of SBC.

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[21] A recent study by Dua and Tuteja (2016) shows that a rise in the financial stress index negatively and significantly impacts returns on the U.S. and Indian stock markets.

[22] DF-GLS and Lee and Strazicich (2003) unit root tests indicate that financial stress index is non-stationary in levels. Testing of the first-differences corroborates that the variable is stationary.

To examine the impact of risk on the TVCCs, we estimate equation (12) i.e. the AR(*l*)-GARCH(p,q)[23] models were estimated for the 36 pairs of dynamic conditional correlation coefficients. The results of the regressions are presented in Table 7 (Panels A-D).

We now analyse the impact of the financial stress index on the time-varying conditional correlation coefficients across and within asset classes for the sample at hand. In the case of the stock markets (Panel A), the coefficient for *dfsi* is positive and significant except for the TVCC for the pairs involving Chinese and Indian stock markets where the impact is negative and significant. Moving on to the case of the currency markets in Panel D, an increase in the risk associated with lower co-movement as it drives investors away from the Euro-Rupee, Yen-Rupee, Yuan-Rupee and Yen-Yuan pairs. The Euro-Yuan and Euro-Yen pairs, however, depicts higher co-movement as financial stress rises.

Finally, we examine the impact of financial stress on the stock and currency market pairs (Panels B and C). To begin with let us look at the impact on the TVCCs across developed country markets. We find that financial stress has a significant and positive impact on the TVCCs across the board. On the other hand, the developed stock markets and EME currency returns are significantly and negatively affected by a rise in financial stress (except US stock market and the Indian currency where it is insignificant). In the same vein, the EME stock markets and developed currency returns depict a positive impact for rise in financial stress in the global markets. However, there is a negative impact of an increase in financial stress across Indian and Chinese stocks and currencies implying that an increase in the risk in the markets leads to divergence, rather than convergence, of the stock and currency market pairs. Moreover, this highlights a possible avenue for portfolio diversification during high risk periods. Interestingly, the correlations between Chinese stock market and Rupee are positively and significantly affected while those between the Indian stock market and the Yuan are not impacted by changing financial stress.

These results have significant implications for international portfolio investment as the purpose of diversification of assets internationally is hedging of risk. Our results indicate that since there is an increase in correlation of stock market returns in response to a rise in financial stress, portfolio diversification across international stock markets may not be beneficial. Further, a negative and significant correlation among some currency pairs indicates that there is a possibility of portfolio diversification across the currencies. Finally, since stock and currency market correlations decline as financial stress rises, international investors should

[23] The order of the GARCH specification for the TVCCs was tested using the conventional tests.

either take a forward currency cover when investing internationally or simultaneously invest in both the equity and currency markets. Otherwise, an investor who attempts to diversify his portfolio across international equity markets is likely to suffer losses during high risk period on account of falling stock prices as well as depreciating currency rates.

## 7. CONCLUSIONS

The objectives of this paper are to test for contagion in stock and currency markets of China, EZ, India, Japan and US during GFC and EZDC, and to investigate the impact of financial stress on the dynamic linkages across the markets. To begin with, we employ Markov-switching VAR models encompassing currency and equity markets of US and EZ respectively to delineate the periods of GFC and EZDC. The statistically derived timeline is corroborated by the major events that took place during the two crisis episodes. Subsequently, we divide the GFC into three and EZDC into two phases. We, then, utilize the DCC-GARCH model (Engle, 2002) to estimate the time-varying conditional correlation coefficients amongst the asset market returns. The conditional correlation coefficients have a distinct pattern during the crisis phases. Thereafter, we test for the existence of interdependence vs. contagion/flight to quality effects in international stock and currency markets during the crisis periods. Our results indicate that there was significant contagion both within and across asset classes. The impact of the crises is most severe during phases II and III of GFC and phase I of EZDC. Moreover, contagion seems to be more evident within developed country stock and currency markets rather than across. Further, we also obtain evidence of flight to quality in some of the cases. In particular, behaviour of the Euro and Yen exchange rates is markedly different from that of the Yuan and Rupee exchange rates. In view of substantial trade (as discussed in Gerlach and Smets, 1995; Eichengreen *et al.*, 1996; Glick and Rose, 1999; Corsetti *et al.*, 2000; Forbes, 2002) and financial linkages (explained in Goldfajn and Valdés, 1997; Van Rijckeghem and Weder, 2001) between China, India, and Japan with the US and EZ economies, these results are not surprising.

Finally, in order to examine the impact of rising global risk in the markets, we utilize the financial stress index constructed by the Federal Reserve Bank of St. Louis. The results suggest that financial stress is an important factor that governs inter-linkages across the markets. Our findings suggest that international stock markets are prone to global risks and usually fall simultaneously implying that the benefits of portfolio diversification may, in fact, be non-existent. Further, there may be some avenues for portfolio diversification across asset classes during such crisis episodes. The analysis highlights that holding a portfolio across stock and currency markets may be beneficial from the perspective of diversification as it is likely to be subject to lower risks in view of the negative correlation between most equity and foreign exchange returns.

The results have crucial implications for portfolio managers and hedgers, governments and central banks. In view of the heightened co-movement of stock markets whenever there is a spike in financial stress, international portfolio diversification benefits may not exist. However, currency market pairs react differently to a rise in financial stress which means that diversification of risk by investment in currencies may be a fruitful strategy. Finally, evidence suggest that correlations across some of  stock and currency markets fall in response to higher risk indicating that international investors could compound losses from investment in stock markets during bad times unless they invest in a forward cover for currencies simultaneously. Karolyi (2004) emphasizes the role of taking up the appropriate national level policies as a response to common shocks especially regulation of the domestic financial sector, supervision by the central bank and improvement of risk management practices[24]. We find that it may be a good idea to simultaneously invest in emerging markets as well in order to diversify the portfolio. However, the Indian Rupees per Dollar exchange rate is extremely volatile and subject to depreciation in the face of outflows which may reduce the returns to foreign investors. China, on the other hand, has a stable Chinese Yuan per Dollar exchange rate which aids foreign institutional investment (FII) in the economy.

The prospect of contagion, capital flight and resulting exchange rate depreciation is a cause of concern for the policy makers. According to Gupta *et al.* (2007) economies which receive higher private capital inflows in the pre-crisis periods and impose fewer restrictions on the capital account have an increase in the likelihood of a contraction in growth during a currency crisis. Therefore, in view of the possible impact of a simultaneous downfall in world stock markets and the transmission of shocks to investment in an economy via Tobin's q (which may lead to domino effects in the real economy), international policy coordination may be required to insulate the real sectors of the economy from external shocks. Existing evidence advanced by Goldfajn and Gupta (1999) highlights the limitations of monetary policy in being able to contain a currency crisis since economies facing both banking and currency crises may not respond to policy changes by the central bank. Studies such as Eichengreen *et al.* (2008)

[24] In the context of the market for credit risk, the paper by Breitenfeller and Wagner (2010) advises that regulation is a partial solution which needs to be supplemented by better risk management.

suggest that IMF supported programmes decrease the likelihood of sudden stops in capital inflows.

Future research may focus on testing for contagion across more than two asset classes internationally during recent crises and understanding the role played by institutional investors such as hedge funds and mutual funds in propagation of contagion.

## REFERENCES


Ahmad, W., S., Sehgal and N.R. Bhanumurthy (2013), Eurozone Crisis and BRIICKS Stock Markets: Contagion or Market Interdependence?, *Economic Modelling*, Vol. 33, 209-225.

Agénor, P.-R., and J. Aizenman (1998), Contagion and Volatility with Imperfect Credit Markets, *IMF Staff Papers*, 207-235.

Ang, A., and G. Bekaert (2002), International asset allocation with regime shifts, Review of Financial Studies, Vol. 15, 1137–1187.

Bae, K.H., G.A. Karolyi, and R.M. Stulz (2003), A New Approach to Measuring Financial Contagion, *Review of Financial Studies*, Vol. 16, 717-763.Baig, T., and I. Goldfajn (1999), Financial Market Contagion in the Asian Crisis, *IMF Staff Papers*, Vol. 46, 167-195.

Batten, J.A., and P.G. Szilagyi (2011), The Impact of the Global Financial Crisis on Emerging Financial Markets: An Introduction, in J.A. Batten and P.G. Szilagyi (eds.) *The Impact of the Global Financial Crisis on Emerging Financial Markets*, Contemporary Studies in Economic and Financial Analysis, Vol. 93, Emerald Group Publishing Limited, 3-17.

Baur, D.G., and R.A. Fry (2009), Multivariate Contagion and Interdependence, *Journal of Asian Economics*, Vol. 20, 353-366.

Baur, D., and B.M. Lucey (2009), Flights-and Contagion-An Empirical Analysis of Stock-bond correlations, *Journal of Financial Stability*, Vol. 5, 339-352.

Bauwens, L., S., Laurent, and J.V.K. Rombouts (2006), Multivariate GARCH Models: A Survey, *Journal of Applied Econometrics*, Vol. 21, 79-109.

Bekaert, G., C.R. Harvey, and A. Ng (2005), Market Integration and Contagion, *The Journal of Business*, Vol. 78, 39-69.

Bodart, V., and B. Candelon (2009), Evidence of Interdependence and Contagion using a Frequency Domain Framework, *Emerging Markets Review*, Vol. 10, 140-150.

Bollerslev, T. (1990), Modelling the Coherence in Short-run Nominal Exchange Rates: A Multivariate Generalized ARCH model, *Review of Economics and Statistics*, Vol. 72, 498-505.

Boschi, M. (2005), International Financial Contagion: Evidence from the Argentine Crisis of 2001–2002, *Applied Financial Economics*, Vol. 15, 153-163.

Breitenfellner, B., and N. Wagner (2010), Government intervention in response to the subprime financial crisis: The good into the pot, the bad into the crop, *International Review of Financial Analysis*, Vol. 19, 289-297.

Broner, F., R.G. Gelos, and C. Reinhart (2004), When in Peril, Retrench: Testing the Portfolio Theory of Contagion, IMF Working Paper No. 04/131.

Büttner, D., and B. Hayo (2010), News and Correlations of CEEC-3 Financial Markets, *Economic Modelling*, Vol. 27, 915-922.

Calvo, G. and E. Mendoza (2000), Rational Contagion and the Globalization of Securities Markets, *Journal of International Economics*, Vol. 51, 79-113.

Calvo, G., L. Leiderman and C.M. Reinhart (1996), Inflows of Capital to Developing Countries in the 1990s, *Journal of Economic perspectives*, Vol. 10, 123-139.

Cavallo, M., and F. Ghironi (2002), Net Foreign Assets and the Exchange Rate: Redux Revived, *Journal of Monetary Economics*, Vol. 49, 1057-1097.

Celik, S. (2012), The More Contagion Effect on Emerging Markets: The Evidence of DCC-GARCH Model, *Economic Modelling*, Vol. 29, 1946-1959.

Chang, R., and G. Majnoni (2001), International Contagion: Implications for Policy, in S. Claessens and K. Forbes (Eds.), *International Financial Contagion*, Boston, MA: Kluwer Academic Publishers.

Chiang, T.C., B.N. Jeon, and H. Li (2007), Dynamic Correlation Analysis of Financial Contagion: Evidence from Asian Markets, *Journal of International Money and Finance*, Vol. 26, 1206-1228.

Corsetti, G., P. Pesenti, and C. Tille (2000), Competitive Devaluations: Toward a Welfare-Based Approach, *Journal of International Economics*, Vol. 51, 217-41.

Dempster, A.P., N.M. Laird, and D.B. Rubin (1977), Maximum likelihood from incomplete data via the EM algorithm, *Journal of the royal statistical society, Series B (methodological)*, 1-38.

Dimitriou, D. and D. Kenourgios (2013), Financial Crises and Dynamic Linkages among International Currencies, *Journal of International Financial Markets, Institutions and Money*, Vol. 26, 319-332.

Dornbusch, R., Y.C. Park and S. Claessens (2000), Contagion: Understanding How it Spreads, *The World Bank Research Observer*, Vol. 15, 177-197.

Dua, P., and D. Tuteja (2016), Linkages between Indian and US Financial Markets: Impact of Global Financial Crisis and Eurozone Debt Crisis, *Macroeconomics and Finance in Emerging Market Economies*, DOI: 10.1080/17520843.2016.1166144.

Dungey, M., G. Milunovich, and S. Thorp (2010), Unobservable Shocks as Carriers of Contagion, *Journal of Banking & Finance*, Vol. 34, 1008-1021.Dungey, M. and V.L. Martin (2007), Unravelling Financial Market Linkages during Crises, *Journal of Applied Econometrics*, Vol. 22, 89-119.

Dungey, M., R. Fry, B. González-Hermosillo, and V.L. Martin (2007), Contagion in Global Equity Markets in 1998: The Effects of the Russian and LTCM Crises, *The North American Journal of Economics and Finance*, Vol. 18, 155-174.

Dungey, M. and V.L. Martin (2007), Unravelling Financial Market Linkages during Crises, *Journal of Applied Econometrics*, Vol. 22, 89-119.

Dungey, M., R. Fry, B. González-Hermosillo and V.L. Martin (2005), Empirical Modelling of Contagion: A Review of Methodologies, *Quantitative Finance*, Vol. 5, 9-24.

Eichengreen, B., A. Rose and C. Wyplosz (1996), Contagious Currency Crises, *Scandinavian Economic Review*, Vol. 98, 463–84.

Eichengreen, B., P. Gupta, and A. Mody (2008), Sudden Stops and IMF-Supported Programs, in Sebastian Edwards and Márcio G. P. Garcia (eds.), *Financial Markets Volatility and Performance in Emerging Markets*, University of Chicago Press, 219-266.

Elliott, G., T.J. Rothenberg and J.H. Stock (1996), Efficient Tests for an Autoregressive Unit Root, *Econometrica*, 64, 813-36.

Engle, R.F. (2002), Dynamic Conditional Correlation: A Simple Class of Multivariate Generalized Autoregressive Conditional Heteroscedasticity Models, *Journal of Business and Statistics*, 20, 339-350.

Favero, C.A., and F. Giavazzi (2002), Is the International Propagation of Financial Shocks Non-Linear? Evidence from the ERM, *Journal of International Economics*, Vol. 51, 231-246.

Flavin, T.J., E. Panopoulou, and D. Unalmis (2008), On the Stability of Domestic Financial Market Linkages in the Presence of Time-varying Volatility. *Emerging Markets Review*, Vol. 9, 280-301.

Forbes, K. (2002), Are Trade Linkages Important Determinants of Country Vulnerability to Crises?, in S. Edwards and J.A. Frankel (Eds.), *Preventing Currency Crises in Emerging Markets*, Chicago: The University of Chicago Press, 77–124.

Forbes, K. and R. Rigobon (2002), No Contagion, Only Interdependence: Measuring Stock Market Co-movements, *Journal of Finance*, Vol. 57, 2223-2261.

Gerlach, S. and F. Smets (1995), Contagious Speculative Attacks, *European Journal of Political Economy*, Vol. 11, 5-63.

Glick, R., and A.K. Rose (1999), Contagion and Trade: Why are Currency Crises Regional?, *Journal of International Money and Finance*, Vol. 18, 603-617.

Goldfajn, I., and R. Valdés (1997), Capital Flows and Twin Crises: The Role of Liquidity, IMF Working Paper No. 97/87.

Goldfajn, I., and P. Gupta (1999), Does Monetary Policy Stabilize the Exchange Rate following a Currency Crisis?, International Monetary Fund.

Granger, C., B. Huang and C. Yang (2000), Bivariate Causality between Stock Prices and Exchange Rates in Asian Countries, *The Quarterly Review of Economics and Finance*, Vol. 40, 337-354.

Gravelle, T., M., Kichian and J. Morley (2006), Detecting Shift-contagion in Currency and Bond Markets, *Journal of International Economics*, Vol. 68, 409-423.

Gray, D. (2014), Central European Foreign Exchange Markets: A Cross-spectral Analysis of the 2007 Financial Crisis, *The European Journal of Finance*, Vol. 20, 550-567.

Guidolin, M. (2011), Markov switching models in empirical finance, Missing Data Methods: Time-series Methods and Applications, *Advances in Econometrics*, Vol. 27B, 1-86.

Guo, F., C.R. Chen, and Y. S. Huang (2011), Markets Contagion during Financial Crisis: A Regime-switching Approach, *International Review of Economics & Finance*, Vol. 20, 95-109.

Gupta, P., D. Mishra, and R. Sahay (2007), Behaviour of Output during Currency Crises, *Journal of International Economics*, Vol. 72, 428-450.

Hamilton, J.D. (1989), A new approach to the economic analysis of nonstationary time series and the business cycle, *Econometrica*, Vol. 57, 357-384.

Hamilton, J.D. (1990), Analysis of time series subject to changes in regime, *Journal of Econometrics*, Vol. 45, 39-70.

Hartmann, P., S. Straetmans, and C.G. De Vries (2004), Asset Market Linkages in Crisis Periods, *The Review of Economics and Statistics*, Vol. 86, 313-326.

Hau, H. and H. Rey (2006), Exchange Rates, Equity Prices, and Capital Flows, *The Review of Financial Studies*, Vol. 19, 273-317.

Jeanne, O. (1997), Are Currency Crisis Self Fulfilling?, *Journal of International Economics*, Vol. 43, 263-286.

Kallberg, J.G., C.H. Liu, and P. Pasquariello (2005), An Examination of the Asian Crisis: Regime Shifts in Currency and Equity Markets, *The Journal of Business*, Vol. 78, 169-211.

Kaminsky, G.L., R. Lyons and S. Schmukler (2001), Mutual Fund Investment in Emerging Markets: An Overview, in S. Claessens and K. Forbes (Eds.), *International Financial Contagion.* Boston: Kluwer Academic Publishers, 158-85.

Kanas, A. (2005), Regime Linkages between the Mexican Currency Market and Emerging Equity Markets, *Economic Modelling*, Vol. 22, 109-125.

Karolyi, G.A. (2004), Does International Financial Contagion Really Exist?, *Journal of Applied Corporate Finance*, Vol. 16, 136-146.

Kenourgios, D., N. Naifar, and D. Dimitriou (2016), Islamic Financial Markets and Global Crises: Contagion or Decoupling?, *Economic Modelling*, Vol. 57, 36-46.

Kenourgios, D., and P. Padhi (2012), Emerging Markets and Financial Crises: Regional, Global or Isolated Shocks?, *Journal of Multinational Financial Management*, Vol. 22, 24-38.

Kenourgios, D., A. Samitas, and N. Paltalidis (2011), Financial Crises and Stock Market Contagion in a Multivariate Time-varying Asymmetric Framework, *Journal of International Financial Markets, Institutions and Money*, Vol. 21, 92-106.

Kim, J.S., and D. Ryu (2015), Effect of the subprime mortgage crisis on a leading emerging market, *Investment Analysts Journal*, Vol. 44, 20-42.

King, M. and S. Wadhwani (1990), Transmission of volatility between stock markets, Review of Financial Studies, Vol. 3, 5-33.

Kole, E. (2006), On Crises, Crashes and Comovements, ERIM Ph.D. Series Research in Management, 83.

Krolzig, H.-M. (1997), *Markov-switching Vector Autoregressions: Modelling, Statistical Inference, and Application to Business Cycle Analysis*, Lecture Notes in Economics and Mathematical Systems 454, Berlin: Springer-Verlag.

Lee, J. and M.C. Strazicich (2003), Minimum Lagrange Multiplier Unit Root Test with Structural Breaks, *The Review of Economics and Statistics*, 85, 1082-1089.

Longstaff, F.A. (2010), The Subprime Credit Crisis and Contagion in Financial Markets, *Journal of Financial Economics*, Vol. 97, 436-450.

Masson, P. (1998), Contagion: Monsoonal Effects, Spillovers, and Jumps Between Multiple Equilibria, *IMF Working Paper* No. 98/142.

Masson, P. (1999), Contagion: Monsoonal Effects, Spillovers, and Jumps Between Multiple Equilibria, in P.R. Agénor, M. Miller, D. Vines and A. Weber (Eds.), *The Asian Financial Crisis: Causes, Contagion and Consequences*, Cambridge UK: Cambridge University Press.

Min, H.-G., and Y.-S. Hwang (2012), Dynamic Correlation Analysis of US Financial Crisis and Contagion: Evidence from Four OECD Countries, *Applied Financial Economics*, Vol. 22, 2063-2074.

Mishkin, F. (1997), Understanding Financial Crises: A Developing Country Perspective, in M. Bruno and B. Pleskovic (Eds.), *Annual World Bank Conference on Development Economics*, Washington: World Bank, 29–62.

Ozer-Imer, I., and I. Ozkan (2014), An Empirical Analysis of Currency Volatilities during the Recent Global Financial Crisis, *Economic Modelling*, Vol. 43, 394-406.

Pavlova, A., and R. Rigobon (2008), The Role of Portfolio Constraints in the International Propagation of Shocks, *Review of Economic Studies*, Vol. 75, 1215-1256.

Pericoli, M., and M. Sbracia (2003), A Primer on Financial Contagion, *Journal of Economic Surveys*, Vol. 17, 571-608.

Pesaran, M.H. and A. Pick (2007), Econometric issues in the analysis of contagion, *Journal of Economic Dynamics and Control*, Vol. 31, 1245-1277.

Samarakoon, L.P. (2011), Stock Market Interdependence, Contagion, and the US Financial Crisis: The Case of Emerging and Frontier Markets, *Journal of International Financial Markets, Institutions and Money*, Vol. 21, 724-742.

Schinasi, G.J., and T. Smith (2001), Portfolio Diversification, Leverage, and Financial Contagion, in S. Claessens and K. Forbes (Eds.), *International Financial Contagion*, Boston, MA: Kluwer Academic Publishers, 187–223.

Syllignakis, M.N., and G.P. Kouretas (2011), Dynamic Correlation Analysis of Financial Contagion: Evidence from the Central and Eastern European Markets, *International Review of Economics & Finance*, Vol. 20, 717-732.

Tai, C.-S. (2007), Market Integration and Contagion: Evidence from Asian Emerging Stock and Foreign Exchange Markets, *Emerging Markets Review*, Vol. 8, 264-283preclude

Tse, Y.K. (2000), A Test for Constant Correlations in a Multivariate GARCH Model, *Journal of Econometrics*, Vol. 98, 107-127.

Tse, Y.K. and A.K.C. Tsui (2002), A Multivariate Generalized Autoregressive Conditional Heteroscedasticity Model with Time-Varying Correlations, *Journal of Business and Economic Statistics*, 20, 351-362.

Valdés, R. (1997), Emerging Markets Contagion: Evidence and Theory, Central Bank of Chile, Working Paper No.7.

Van Rijckeghem, C. and B. Weder (2001), Sources of Contagion: Is it Finance or Trade?, *Journal of International Economics*, Vol. 54, 293-308.

Walid, C., A. Chaker, O. Masood, and J. Fry (2011), Stock Market Volatility and Exchange Rates in Emerging Countries: A Markov-state Switching Approach, *Emerging Markets Review*, Vol. 12, 272-292.

Wang, P., and M. Theobald (2008), Regime-switching Volatility of Six East Asian Emerging Markets, *Research in International Business and Finance*, Vol. 22, 267-283.

Yiu, M.S., W.-Y.A. Ho, and D.F. Choi (2010), Dynamic Correlation Analysis of Financial Contagion in Asian Markets in Global Financial Turmoil, *Applied Financial Economics*, Vol. 20, 345-354.

TABLES

Table 1: Descriptive Statistics and Unconditional Correlations

Panel A-Descriptive Statistics

| | $s^{IND}$ | $s^{US}$ | $e^{₹}$ | $s^{EZ}$ | $e^{€}$ | $s^{JAP}$ | $e^{¥}$ | $s^{CHI}$ | $e^{CN¥}$ |
|---|---|---|---|---|---|---|---|---|---|
| **Mean** | 0.113 | 0.043 | 0.031 | 0.011 | 0.005 | 0.029 | -0.003 | 0.070 | -0.025 |
| **Std. Dev** | 1.319 | 0.881 | 0.425 | 1.074 | 0.488 | 1.180 | 0.4801 | 1.373 | 0.075 |
| **Skewness** | -0.358 | -1.491 | -0.042 | -0.852 | 0.051 | -0.940 | -0.194 | -0.368 | 0.215 |
| **Kurtosis** | 6.741 | 11.861 | 6.048 | 6.005 | 5.868 | 8.349 | 4.387 | 4.553 | 7.869 |
| **Maximum** | 7.109 | 3.064 | 1.770 | 3.321 | 2.792 | 4.607 | 1.994 | 5.720 | 0.434 |
| **Minimum** | -6.432 | -6.635 | -1.925 | -5.418 | -1.909 | -7.722 | -2.086 | -5.579 | -0.287 |

Table 1: Panel B-Unconditional Correlations

| | $s^{IND}$ | $s^{US}$ | $e^{₹}$ | $s^{EZ}$ | $e^{€}$ | $s^{JAP}$ | $e^{¥}$ | $s^{CHI}$ | $e^{CN¥}$ |
|---|---|---|---|---|---|---|---|---|---|
| $s^{IND}$ | 1 | | | | | | | | |
| $s^{US}$ | 0.59 | 1 | | | | | | | |
| $e^{₹}$ | -0.58 | -0.49 | 1 | | | | | | |
| $s^{EZ}$ | 0.64 | 0.86 | -0.50 | 1 | | | | | |
| $e^{€}$ | 0.34 | 0.42 | -0.42 | 0.38 | 1 | | | | |
| $s^{JAP}$ | 0.58 | 0.70 | -0.39 | 0.70 | 0.28 | 1 | | | |
| $e^{¥}$ | 0.22 | 0.30 | -0.08 | 0.30 | -0.14 | 0.55 | 1 | | |
| $s^{CHI}$ | 0.33 | 0.20 | -0.26 | 0.25 | 0.18 | 0.24 | 0.09 | 1 | |
| $e^{CN¥}$ | -0.09 | -0.04 | 0.14 | -0.07 | -0.29 | -0.09 | 0.08 | 0.02 | 1 |

Note: $s^{IND}$, $s^{US}$, $e^{₹}$, $s^{EZ}$, $e^{€}$, $s^{JAP}$, $e^{¥}$, $s^{CHI}$ and $e^{CN¥}$ denote the returns on Indian stock market, U.S. stock market, Rs. Vs. USD exchange rate, Eurozone stock market, Euro vs. USD exchange rate, Japanese stock market, Yen vs. USD exchange rate, Chinese stock market and Chinese Yuan vs. USD exchange rate.

Table 2: Parameter estimates for multivariate two-state MSIH model

Panel A-US Stock and Currency Markets: $\boldsymbol{s^{US}}$, $\boldsymbol{e^{¥}}$

| | $\boldsymbol{s^{US}}$ | $\boldsymbol{e^{¥}}$ |
|---|---|---|
| $\boldsymbol{\mu_1}$ | -0.2020 | 0.0948*** |
| $\boldsymbol{\mu_2}$ | -0.1204 | 0.0303 |
| $\boldsymbol{\beta_{s^{US}}}$ | 0.1594*** | -0.0482 |
| $\boldsymbol{\beta_{e^{¥}}}$ | -0.0352 | 0.2712*** |
| $\boldsymbol{\sigma_1}$ | 2.5208*** | 0. 0.3034*** |
| $\boldsymbol{\sigma_2}$ | 0.4003*** | 0.1672*** |
| $\boldsymbol{P_{11}}$ | 0.9433*** | |
| $\boldsymbol{P_{22}}$ | 0.9868*** | |
| **RCM** | 10.99 | |

Panel B-Eurozone Stock and Currency Markets: $\boldsymbol{s^{EZ}}$, $\boldsymbol{e^{€}}$

| | $\boldsymbol{s^{EZ}}$ | $\boldsymbol{e^{€}}$ |
|---|---|---|
| $\boldsymbol{\mu_1}$ | -0.2855 | 0.0809** |
| $\boldsymbol{\mu_2}$ | -0.1110 | 0.0296 |
| $\boldsymbol{\beta_{s^{EZ}}}$ | 0.1945*** | -0.1274 |
| $\boldsymbol{\beta_{e^{€}}}$ | -0.0285 | 0.2907*** |
| $\boldsymbol{\sigma_1}$ | 3.4849*** | 0.5359*** |
| $\boldsymbol{\sigma_2}$ | 0.5325*** | 0.1346*** |
| $\boldsymbol{P_{11}}$ | 0.9391*** | |
| $\boldsymbol{P_{22}}$ | 0.9859*** | |
| **RCM** | 12.69 | |

Note: $\boldsymbol{s^{US}}$, $\boldsymbol{s^{EZ}}, \boldsymbol{e^{€}}$ *and* $\boldsymbol{e^{¥}}$, denote the returns on U.S. stock market, Eurozone stock market, Euro vs. USD exchange rate, and Yen vs. USD exchange rate. *, ** and *** indicate significance at 10%, 5% and 1% respectively. All the variance terms are significant at the 1% level.

Table 3: Crisis Timeline (Selected Events and Dates)

Panel A- Global Financial Crisis (2008-09)

| Date | Events |
|---|---|
| **December 29, 2007** | US Census Bureau announces that new home sales for November are down by 34% on a year-on-year basis, the lowest since 1991 |
| **January 9, 2008** | World Bank forecasts indicate growth slowdown in 2008 |
| **January 11, 2008** | Countrywide Financial is to be purchased by Bank of America for $4 billion |
| **January 18, 2008** | Ambac Financial Group's rating is downgraded by Fitch Ratings and Standard and Poor's to negative on the Credit Watch |
| **January 24, 2008** | US home sales witness largest single-year drop in a quarter of a century |
| **February 7, 2008** | Ben Bernanke, Governor of the US Federal Reserve voices concerns about monoline insurers |
| **February 9, 2008** | Bush Administration announces $168 billion stimulus package for the economy |
| **September 15, 2008** | Lehman Brothers files for bankruptcy, Bank of America takes over Merill Lynch and global stock indices plummet |
| **September 17-21, 2008** | Stock prices of UK mortgage lender HBOS nosedive causing Lloyds TSB to rescue it |
| **September 25-29, 2008** | US banks Washington Mutual and Wachovia collapse |
| **October 3, 2008** | Congress passes $700 billion Troubled Asset Relief Program (TARP) to rescue the US financial sector |
| **October 6-8, 2008** | Germany, Iceland and UK Governments announce rescue packages for their sinking banking sectors |
| **October 13, 2008** | British Government plans to nationalize Royal Bank of Scotland, Llyods TSB and HBOS with £37 billion of emergency recapitalization |
| **October 14, 2008** | US Government plans to purchase capital in troubled financial institutions under TARP worth $250 billion |
| **October 24, 2008** | UK economy is shrinking for the first time in 16 years with growth down by 0.5% in Q3 of 2008 |
| **October 30, 2008** | US Federal Reserve slashes federal funds rate by 50 basis points to 1% |
| **November 14, 2008** | Eurozone is into a recession with the economy shrinking by 0.2% in Q3 of 2008 |
| **November 23, 2008** | US Government rescues Citigroup with $20 billion |
| **November 25-26, 2008** | US Federal Reserve injects $800 billion more into the US economy and European Commission unveils recovery plan worth €200 billion |
| **December 1, 2008** | National Bureau of Economic Research officially declares the US economy to be in a recession |
| **December 29, 2008** | US Treasury bails out General Motors with $6 billion |
| **January 16, 2009** | Bank of America receives $20 billion fresh aid from the US Government |
| **February 17, 2009** | US Government announces recovery package worth $787 billion |
| **March 2, 2009** | AIG receives additional $30 billion from the US Government after posting losses |
| **March 18, 2009** | US Federal Reserve to buy $1.2 trillion worth of debt to boost recovery |
| **April 2, 2009** | G20 countries announce stimulus package of $1.1 trillion |
| **May 4, 2009** | European Commission forecasts suggest that E.U. countries are likely to shrink by 4% in 2009 |
| **June 24, 2009** | OECD announces that the global recession is nearly bottomed out |
| **July 20, 2009** | A 0.7% rise in the US leading economic indicators' index for June impels US stock markets up |
| **July 24, 2009** | Dow Jones Industrial Index closes at a high of 9093.24 surpassing its past high in January that year |

Panel B- Eurozone Debt Crisis (2010-11)

| Date | Events |
|---|---|
| **May 2, 2010** | Eurozone finance ministers grant loans worth €110 billion to bail out Greece for the first time |
| **May 10, 2010** | IMF and EU set up financial stability fund worth €750 billion |
| **May 12-13, 2010** | Governments of Spain and Portugal announce fiscal austerity measures |
| **June 30, 2010** | Having served its purpose of bringing stability, the covered bond programme is discontinued by the European Central Bank |
| **July 5-12, 2011** | Moody downgrades Ireland and Portugal’s ratings to junk |
| **July 21, 2011** | Eurozone leaders meet in Brussels in the wake of the ongoing Debt Crisis and Greece is bailed out again with €159 billion |
| **August 7, 2011** | European Central Bank announces that it will buy Italian and Spanish bonds |
| **September 15, 2011** | ECB to grant unlimited dollar loans for three months as EU institutions struggle to access US dollar |
| **October 6, 2011** | Bank of England injects £75 billion into the UK economy |
| **October 21, 2011** | Eurozone approves €8 billion worth of bailout loans for Greece |
| **December 9, 2011** | Eurozone leaders convene in Brussels again with the intention of building a stronger Economic Union |
| **December 21, 2011** | In a long term financing operation involving three year loans at low rates of interest, the European Central Bank allocates €489 billion to more than 500 European banks |

Sources: Compiled using Crisis Timeline by Federal Reserve Bank of St. Louis; European Central Bank, The Guardian; The Telegraph; Bloomberg Business Week; BBC News and National Center for Policy Analysis.

Table 4: Estimation Results from the DCC-GARCH Model (Robust standard errors)

| **Panel A: Preliminary Tests** | |
|---|---|
| **Test** | **Statistic** |
| **Multivariate ARCH Effects** | 6207.08*** |
| **CCC-GARCH specification** | 89.91*** |
| **Number of observations** | 478 |

| | **Panel B: Estimates** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $s^{IND}$ | $s^{US}$ | $e^{₹}$ | $s^{EZ}$ | $e^{€}$ | $s^{JAP}$ | $e^{¥}$ | $s^{CHI}$ | $e^{CN¥}$ |
| | | | | **Mean Equations** | | | | | |
| **Constant** | 0.153*** | 0.105*** | 0.009 | 0.082** | 0.013 | 0.060 | 0.009 | 0.065 | -0.020*** |
| **Lagged Term** | 0.164*** | 0.077*** | 0.284*** | 0.133*** | 0.230*** | 0.206*** | 0.205*** | 0.240*** | 0.228*** |
| **Global Factor** | -3.628*** | -3.596*** | 0.907*** | -3.718*** | -0.781*** | -4.006*** | -0.798*** | -1.861*** | 0.016 |
| | | | | **Variance Equations** | | | | | |
| **Constant** | 0.065* | 0.029*** | 0.011 | 0.065*** | 0.004 | 0.047* | 0.007* | 0.033 | 0.000 |
| $\varepsilon^2_{t-1}$ | 0.077*** | 0.102*** | 0.155 | 0.104*** | 0.069*** | 0.063*** | 0.094*** | 0.107*** | 0.254*** |
| $\sigma^2_{t-1}$ | 0.885*** | 0.861*** | 0.798*** | 0.845*** | 0.920*** | 0.906*** | 0.877*** | 0.886*** | 0.801*** |
| **Standardized Residuals Q(6)** | 7.05 (0.32) | 7.53 (0.27) | 3.95 (0.68) | 4.33 (0.63) | 6.80 (0.34) | 3.71 (0.72) | 3.06 (0.80) | 7.34 (0.29) | 5.65 (0.46) |
| | | | | **Multivariate DCC Equation** | | | | | |
| $\alpha$ | 0.015*** | | | | | | | | |
| $\beta$ | 0.954*** | | | | | | | | |
| **t-distribution** | 9.496*** | | | | | | | | |

Note: $s^{IND}$, $s^{US}$, $e^{₹}$, $s^{EZ}$, $e^{€}$, $s^{JAP}$, $e^{¥}$, $s^{CHI}$ and $e^{CN¥}$ denote the returns on Indian stock market, U.S. stock market, Rs. Vs. USD exchange rate, Eurozone stock market, Euro vs. USD exchange rate, Japanese stock market, Yen vs. USD exchange rate, Chinese stock market and Chinese Yuan vs. USD exchange rate. *, ** and *** indicate significance at 10%, 5% and 1% respectively. Values in parentheses are p-values. $\alpha$ and $\beta$ denote the DCC coefficients. Equations for $e^{₹}$ and $e^{CN¥}$ include dummies for exchange rate regimes.

Table 5: Tests of Impact on Dynamic Conditional Correlations among asset markets during the phases of Global Financial Crisis and Eurozone Debt Crisis (OLS with robust standard errors)

| Panel A: Stock Markets | | | | | | | |
|---|---|---|---|---|---|---|---|
| | $DGFC_1$ | $DGFC_2$ | $DGFC_3$ | $DEZDC_1$ | $DEZDC_2$ | Stable Period | Inference |
| $s^{US}$ and $s^{EZ}$ | 0.008 | 0.001 | 0.043*** | 0.012*** | -0.103*** | 0.847*** | I, I, C, C, F |
| $s^{US}$ and $s^{IND}$ | -0.035*** | -0.025*** | 0.058*** | 0.040*** | -0.016*** | 0 .557*** | F, F, C, C, F |
| $s^{US}$ and $s^{JAP}$ | 0 .061*** | 0 .061** | 0 .076*** | -0.000 | -0.014** | 0 .674*** | C, C, C, I, F |
| $s^{US}$ and $s^{CHI}$ | -0 .001 | -0.046*** | -0.081*** | 0.012*** | 0.024*** | 0 .192*** | I, F, F, C, C |
| $s^{EZ}$ and $s^{IND}$ | 0 .018* | 0 .059*** | 0.104*** | 0.045*** | -0.075*** | 0 .610*** | C, C, C, C, F |
| $s^{EZ}$ and $s^{JAP}$ | 0 .048*** | 0 .065*** | 0 .111*** | 0.010*** | -0.021*** | 0 .663*** | C, C, C, C, F |
| $s^{EZ}$ and $s^{CHI}$ | 0.019 | 0.023 | -0.029*** | 0.016** | -0.007* | 0.238*** | I, I, F, C, F |
| $s^{IND}$ and $s^{JAP}$ | 0.016*** | 0 .029*** | 0 .123*** | 0.022*** | -0.050*** | 0 .537*** | C, C, C, C, F |
| $s^{IND}$ and $s^{CHI}$ | 0 .062*** | 0 .004 | -0.003 | 0.003 | 0.003 | 0 .315*** | C, I, I, I, I |
| $s^{CHI}$ and $s^{JAP}$ | 0.030*** | 0.045** | 0.005 | -0.001 | 0.018*** | 0 .223*** | C, C, I, I, C |
| **Panel B: Currency Markets** | | | | | | | |
| | $DGFC_1$ | $DGFC_2$ | $DGFC_3$ | $DEZDC_1$ | $DEZDC_2$ | Stable Period | Inference |
| $e^{€}$ and $e^{¥}$ | -0.023*** | 0 .011 | 0 .155*** | 0.037*** | -0.008 | -0.161*** | F, I, C, C, I |
| $e^{€}$ and $e^{₹}$ | -0.022*** | -0.037*** | -0.119*** | -0.010*** | 0.014 | -0.401*** | F, F, F, F, I |
| $e^{€}$ and $e^{CN¥}$ | -0.043*** | -0.067*** | -0.028*** | 0.037*** | 0.011 | -0.288*** | F, F, F, C, I |
| $e^{¥}$ and $e^{₹}$ | -0.024*** | -0.074** | -0.085*** | -0.074*** | -0.025*** | -0.068*** | F, F, F, F, F |
| $e^{¥}$ and $e^{CN¥}$ | 0 .024* | 0 .040*** | 0 .018*** | -0.007 | 0.027*** | 0 .087*** | C, C, C, I, C |
| $e^{₹}$ and $e^{CN¥}$ | -0.041*** | -0.008 | 0 .018*** | -0.009*** | 0.006 | 0 .142*** | F, I, C, F, I |

| Panel C: Stock and Currency Markets | | | | | | | |
|---|---|---|---|---|---|---|---|
| | $DGFC_1$ | $DGFC_2$ | $DGFC_3$ | $DEZDC_1$ | $DEZDC_2$ | Stable Period | Inference |
| $s^{US}$ **and** $e^{¥}$ | 0.092*** | 0.036*** | 0.075*** | 0.029*** | -0.027*** | 0.283*** | C, C, C, C, F |
| $s^{US}$ **and** $e^{₹}$ | -0.022*** | -0 .012 | -0.081*** | -0.044*** | 0.025** | -0.468*** | F, I, F, F, C |
| $s^{US}$ **and** $e^{€}$ | -0.048*** | -0.014 | 0 .090*** | 0.016*** | -0.025*** | 0.406*** | F, I, C, C, F |
| $s^{US}$ **and** $e^{CN¥}$ | 0 .073*** | 0 .050*** | 0 .021*** | 0.013* | 0.028*** | -0.040*** | C, C, C, C, C |
| $s^{EZ}$ **and** $e^{¥}$ | 0 .053*** | 0 .047** | 0.110*** | 0.029*** | -0.034*** | 0 .277*** | C, C, C, C, F |
| $s^{EZ}$ **and** $e^{₹}$ | -0.021*** | -0 .040*** | -0.114*** | -0.036*** | 0.033*** | -0.476*** | F, F, F, F, C |
| $s^{EZ}$ **and** $e^{€}$ | -0.014*** | -0.041* | 0 .078*** | 0.010* | 0.031*** | 0 .367*** | F, F, C, C, C |
| $s^{EZ}$ **and** $e^{CN¥}$ | 0.055*** | 0.062*** | 0 .021*** | 0.016*** | 0.011* | -0.069*** | C, C, C, C, C |
| $s^{IND}$ **and** $e^{¥}$ | -0 .008 | 0 .071*** | 0 .139*** | 0.042*** | 0.041*** | 0 .194*** | I, C, C, C, C |
| $s^{IND}$ **and** $e^{₹}$ | 0 .023** | 0 .028*** | -0.109*** | -0.038*** | 0.009** | -0.553*** | C, C, F, F, C |
| $s^{IND}$ **and** $e^{€}$ | 0 .045*** | -0.103*** | 0 .111*** | 0.012*** | -0.025*** | 0 .310*** | C, F, C, C, F |
| $s^{IND}$ **and** $e^{CN¥}$ | -0.047*** | 0.089*** | 0 .027*** | 0.017*** | 0.064*** | -0.101*** | F, C, C, C, C |
| $s^{JAP}$ **and** $e^{¥}$ | 0.038*** | 0.003 | 0.050** | 0.028*** | -0.047*** | 0.538*** | C, I, C, C, F |
| $s^{JAP}$ **and** $e^{₹}$ | -0 .024*** | -0.057*** | -0.138*** | -0.051*** | -0.001 | -0.353*** | F, F, F, F, I |
| $s^{JAP}$ **and** $e^{€}$ | 0.008 | 0 .044* | 0 .175*** | 0.021*** | -0.033*** | 0 .255*** | I, C, C, C, F |
| $s^{JAP}$ **and** $e^{CN¥}$ | 0 .066*** | 0 .018* | 0.002 | 0.004 | -0.018*** | -0.090*** | C, C, I, I, F |
| $s^{CHI}$ **and** $e^{¥}$ | 0.048*** | 0 .032* | 0.015*** | 0.008* | 0.032*** | 0.076*** | C, C, C, C, C |
| $s^{CHI}$ **and** $e^{₹}$ | 0.008** | -0.028 | 0.019*** | -0.004 | -0.008*** | -0.241*** | C, I, C, I, F |
| $s^{CHI}$ **and** $e^{€}$ | -0.023*** | 0.073*** | 0.005 | 0.080*** | -0.019*** | 0 .160*** | F, C, I, C, F |
| $s^{CHI}$ **and** $e^{CN¥}$ | 0.011 | 0.008 | -0.005 | -0.002 | 0.015* | 0.022*** | I, I, I, I, C |

Note: $s^{IND}$, $s^{US}$, $e^{₹}$, $s^{EZ}$, $e^{€}$, $s^{JAP}$, $e^{¥}$, $s^{CHI}$ and $e^{CN¥}$ denote the returns on Indian stock market, U.S. stock market, Rs. Vs. USD exchange rate, Eurozone stock market, Euro vs. USD exchange rate, Japanese stock market, Yen vs. USD exchange rate, Chinese stock market and Chinese Yuan vs. USD exchange rate. The alphabets C, F and I denote contagion, flight to quality and interdependence respectively. $DGFC_1$, $DGFC_2$, $DGFC_3$, $DEZDC_1$, and $DEZDC_2$ denote the dummy variables for phases I, II and II of GFC and phases I and II of EZDC respectively. *, ** and *** indicate significance at 10%, 5% and 1% respectively.

Table 6: Trade and Financial Linkages between China, India, Japan, Eurozone and US Economies

Panel A: Trade Linkages-Share of Trade

| | 2005 | | 2015 | |
|---|---|---|---|---|
| **Countries/Region** | Share of Imports (%age) | Share of Exports (%age) | Share of Imports (%age) | Share of Exports (%age) |
| | | **China** | | |
| **Eurozone** | 9.5 | 14.8 | 10.1 | 11.4 |
| **US** | 7.4 | 21.4 | 8.2 | 17.0 |
| | | **Eurozone** | | |
| **US** | 5.4 | 7.4 | 5.2 | 6.7 |
| | | **India** | | |
| **Eurozone** | 17.9 | 16.4 | 8.8 | 11.9 |
| **US** | 8.0 | 16.5 | 4.9 | 13.4 |
| | | **Japan** | | |
| **Eurozone** | 9.0 | 11.0 | 7.8 | 7.8 |
| **US** | 12.7 | 22.9 | 9.0 | 19.0 |
| | | **US** | | |
| **Eurozone** | 13.8 | 15.4 | 13.9 | 12.8 |

Source: Direction of Trade Statistics, IMF, 2015

Panel B: Financial Linkages-Consolidated Foreign Claims of Reporting Banks (Ultimate Risk Basis)

| | 2005 Q4 | | 2014 Q4 | |
|---|---|---|---|---|
| **Claims vis-à-vis** | Share of Eurozone Banks (%age) | Share of US Banks (%age) | Share of Eurozone Banks (%age) | Share of US Banks (%age) |
| **China** | 25.3 | 13.0 | 17.4 | 12.7 |
| **Eurozone** | 62.2 | 5.7 | 54.4 | 11.4 |
| **India** | 32.2 | 25.3 | 17.5 | 30.2 |
| **Japan** | 49.7 | 8.6 | 31.2 | 40.7 |
| **US** | 35.7 | - | 26.6 | - |

Source: Quarterly Review, Bank of International Settlement, 2015

Table 7: Impact of Financial Stress on dynamic conditional correlations

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Panel A: Stock Markets** | | | | | | | | | | |
| | $\rho^{s^{US}s^{EZ}}$ | $\rho^{s^{US}s^{IND}}$ | $\rho^{s^{US}s^{JAP}}$ | $\rho^{s^{US}s^{CHI}}$ | $\rho^{s^{EZ}s^{IND}}$ | $\rho^{s^{EZ}s^{JAP}}$ | $\rho^{s^{EZ}s^{CHI}}$ | $\rho^{s^{IND}s^{JAP}}$ | $\rho^{s^{IND}s^{CHI}}$ | $\rho^{s^{CHI}s^{JAP}}$ |
| **Mean Equation** | | | | | | | | | | |
| ***Constant*** | 0.859*** | 0.557*** | 0.667*** | 0.192*** | 0.640*** | 0.692*** | 0.252*** | 0.572*** | 0.334*** | 0.228*** |
| $\rho_{t-1}$ | 0.959*** | 0.944*** | 0.948*** | 0.963*** | 0.967*** | 0.969*** | 0.954*** | 0.967*** | 0.965*** | 0.841*** |
| $\rho_{t-2}$ | 0.004*** | - | - | - | - | . | - | - | - | - |
| $dfsi$ | 0.001*** | 0.024*** | 0.008*** | 0.002*** | 0.001** | 0.001*** | 0.001*** | 0.0004*** | -0.001* | 0.019*** |
| **Variance Equation** | | | | | | | | | | |
| ***Constant*** | 6.12E-07 | 1.04E-06 | 7.61E-06 | 6.13E-06*** | 7.44E-06** | 1.35E-06 | 8.86E-06* | 1.05E-05 | 2.40E-06 | 1.72E-05*** |
| $e^2_{ij,t-1}$ | 0.101** | 0.093*** | 0.134*** | 0.258** | 0.129* | 0.041 | 0.233** | 0.060* | 0.060** | 0.190*** |
| $h_{ij,t-1}$ | 0.869*** | 0.899*** | 0.737*** | 0.757*** | 0.748*** | 0.934*** | 0.748*** | 0.866*** | 0.923*** | 0.711*** |
| ***ARCH (6)*** | 0.264 (0.953) | 0.207 (0.975) | 0.419 (0.866) | 0.276 (0.948) | 0.049 (0.999) | 1.136 (0.341) | 0.086 (0.998) | 0.054 (0.999) | 0.028 (0.999) | 0.248 (0.959) |
| **Panel B: Currency and Stock Markets** | | | | | | | | | | |
| | $\rho^{s^{US}e^{¥}}$ | $\rho^{s^{US}e^{₹}}$ | $\rho^{s^{US}e^{€}}$ | $\rho^{s^{US}e^{CN¥}}$ | $\rho^{s^{EZ}e^{¥}}$ | $\rho^{s^{EZ}e^{₹}}$ | $\rho^{s^{EZ}e^{€}}$ | $\rho^{s^{EZ}e^{CN¥}}$ | $\rho^{s^{IND}e^{¥}}$ | $\rho^{s^{IND}e^{₹}}$ |
| **Mean Equation** | | | | | | | | | | |
| ***Constant*** | 0.287*** | -0.459*** | 0.399*** | -0.038*** | 0.289*** | -0.461*** | 0.382*** | -0.056*** | 0.130** | -0.550*** |
| $\rho_{t-1}$ | 0.971*** | 0.979*** | 0.967*** | 0.949*** | 0.965*** | 0.978*** | 0.957*** | 0.965*** | 0.917*** | 0.930*** |
| $\rho_{t-2}$ | - | - | - | -0.004** | - | - | 0.006 | - | 0.068 | - |
| $dfsi$ | 0.010*** | -0.000 | 0.014*** | -0.001*** | 0.021*** | -0.007*** | 0.003*** | -0.001 | 0.035*** | -0.020*** |
| **Variance Equation** | | | | | | | | | | |
| ***Constant*** | 6.73E-06*** | 1.59E-06 | 4.52E-06 | 6.71E-06*** | 8.57E-06*** | 1.70E-06*** | 1.02E-05 | 4.14E-06*** | 8.40E-06 | 1.22E-05 |
| $e^2_{ij,t-1}$ | 0.206*** | 0.117*** | 0.246*** | 0.122*** | 0.176*** | 0.122*** | 0.176*** | 0.052*** | 0.129*** | 0.279*** |
| $h_{ij,t-1}$ | 0.762*** | 0.869*** | 0.731*** | 0.829*** | 0.797*** | 0.876*** | 0.783*** | 0.914*** | 0.832*** | 0.601*** |
| ***ARCH (6)*** | 0.898 (0.496) | 0.830 (0.547) | 1.56 (0.144) | 0.055 (0.999) | 0.248 (0.960) | 0.559 (0.762) | 0.942 (0.465) | 0.253 (0.958) | 0.192 (0.979) | 0.145 (0.990) |

Note: $s^{IND}$, $s^{US}$, $e^{₹}$, $s^{EZ}$, $e^{€}$, $s^{JAP}$, $e^{¥}$, $s^{CHI}$ and $e^{CN¥}$ denote the returns on Indian stock market, U.S. stock market, Rs. Vs. USD exchange rate, Eurozone stock market, Euro vs. USD exchange rate, Japanese stock market, Yen vs. USD exchange rate, Chinese stock market and Chinese Yuan vs. USD exchange rate.*, ** and *** indicate significance at 10%, 5% and 1% respectively.

**Panel C: Currency and Stock Markets**

| | $\rho^{s^{IND}e^{€}}$ | $\rho^{s^{IND}e^{CN¥}}$ | $\rho^{s^{JAP}e^{¥}}$ | $\rho^{s^{JAP}e^{₹}}$ | $\rho^{s^{JAP}e^{€}}$ | $\rho^{s^{JAP}e^{CN¥}}$ | $\rho^{s^{CHI}e^{¥}}$ | $\rho^{s^{CHI}e^{₹}}$ | $\rho^{s^{CHI}e^{€}}$ | $\rho^{s^{CHI}e^{CN¥}}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| **Mean Equation** | | | | | | | | | | |
| ***Constant*** | 0.303*** | -0.094*** | 0.566*** | -0.347*** | 0.248*** | -0.085*** | 0.075*** | -0.239*** | 0.171*** | 0.011 |
| $\rho_{t-1}$ | 0.974*** | 0.963*** | 0.982*** | 0.962*** | 0.977*** | 0.898*** | 0.957*** | 0.940*** | 0.943*** | 0.966*** |
| $dfsi$ | 0.014*** | 0.000 | 0.013*** | -0.012*** | 0.025*** | -0.007*** | 0.005* | 0.008*** | 0.004* | -0.005* |
| **Variance Equation** | | | | | | | | | | |
| ***Constant*** | 8.55E-06*** | 4.48E-07 | 4.48E-06*** | 3.47E-06 | 8.77E-05*** | 3.87E-06 | 4.68E-06*** | 9.51E-06*** | - | 2.90E-06 |
| $e^2_{ij,t-1}$ | 0.169*** | 0.128*** | 0.165*** | 0.032*** | 0.616*** | 0.162*** | 0.059*** | 0.181*** | 0.072*** | 0.028*** |
| $h_{ij,t-1}$ | 0.791*** | 0.868*** | 0.827*** | 0.939*** | 0.079*** | 0.809*** | 0.921*** | 0.777*** | 0.928*** | 0.954*** |
| ***ARCH (6)*** | 0.382 (0.891) | 0.579 (0.747) | 0.177 (0.983) | 0.297 (0.938) | 0.143 (0.990) | 0.149 (0.989) | 0.277 (0.948) | 0.347 (0.912) | 0.868 (0.518) | 0.287 (0.943) |

**Panel D: Currency Markets**

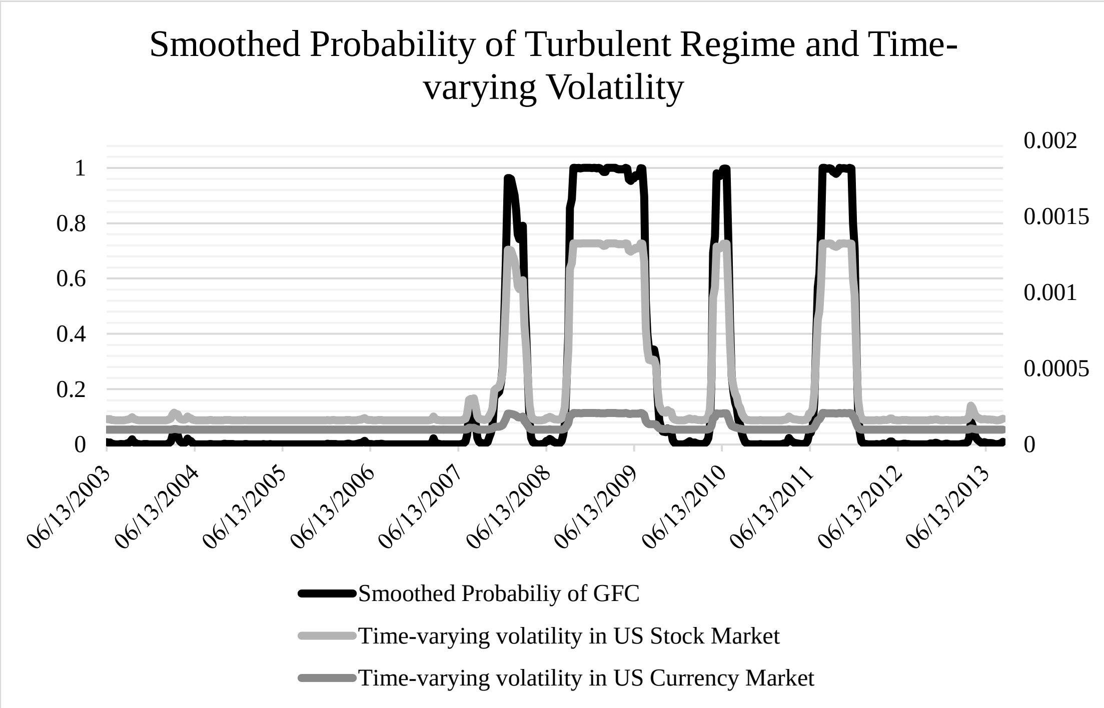
| | $\rho^{e^{€}e^{¥}}$ | $\rho^{e^{€}e^{₹}}$ | $\rho^{e^{€}e^{CN¥}}$ | $\rho^{e^{¥}e^{₹}}$ | $\rho^{e^{¥}e^{CN¥}}$ | $\rho^{e^{₹}e^{CN¥}}$ |
|---|---|---|---|---|---|---|
| **Mean Equation** | | | | | | |
| ***Constant*** | -0.182*** | -0.422*** | -0283*** | -0.067*** | 0.080*** | 0.141*** |
| $\rho_{t-1}$ | 0.983*** | 0.969*** | 0.967*** | 1.107*** | 0.959*** | 0.931*** |
| $\rho_{t-2}$ | - | - | - | -0.139* | - | - |
| $dfsi$ | 0.014*** | -0.003*** | 0.001* | -0.015*** | -0.0003* | -0.004** |
| **Variance Equation** | | | | | | |
| ***Constant*** | 7.92E-06 | 8.55E-06 | 3.00E-06 | 1.06E-05 | 4.22E-06 | 7.94E-07 |
| $e^2_{ij,t-1}$ | 0.167*** | 0.066 | 0.126*** | 0.174*** | 0.133*** | 0.101*** |
| $h_{ij,t-1}$ | 0.808*** | 0.860*** | 0.852*** | 0.774*** | 0.841*** | 0.889*** |
| ***ARCH (6)*** | 0.288 (0.943) | 0.379 (0.892) | 0.619 (0.714) | 0.244 (0.962) | 0.435 (0.856) | 0.283 (0.945) |

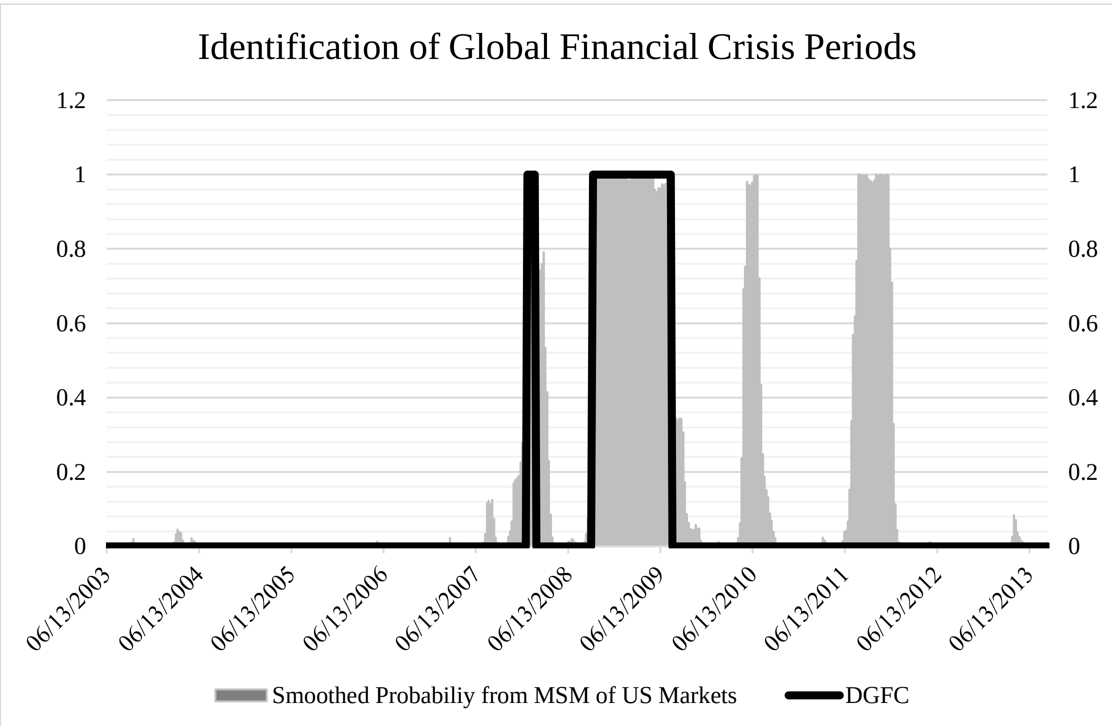
Note: Note: $s^{IND}$, $s^{US}$, $e^{₹}$, $s^{EZ}$, $e^{€}$, $s^{JAP}$, $e^{¥}$, $s^{CHI}$ and $e^{CN¥}$ denote the returns on Indian stock market, U.S. stock market, Rs. Vs. USD exchange rate, Eurozone stock market, Euro vs. USD exchange rate, Japanese stock market, Yen vs. USD exchange rate, Chinese stock market and Chinese Yuan vs. USD exchange rate.*, ** and *** indicate significance at 10%, 5% and 1% respectively.

FIGURES

Figure 1: Smoothed Probability of the Turbulent Regime, Time-varying volatility and Identification of Crisis Periods from multivariate MSIH models

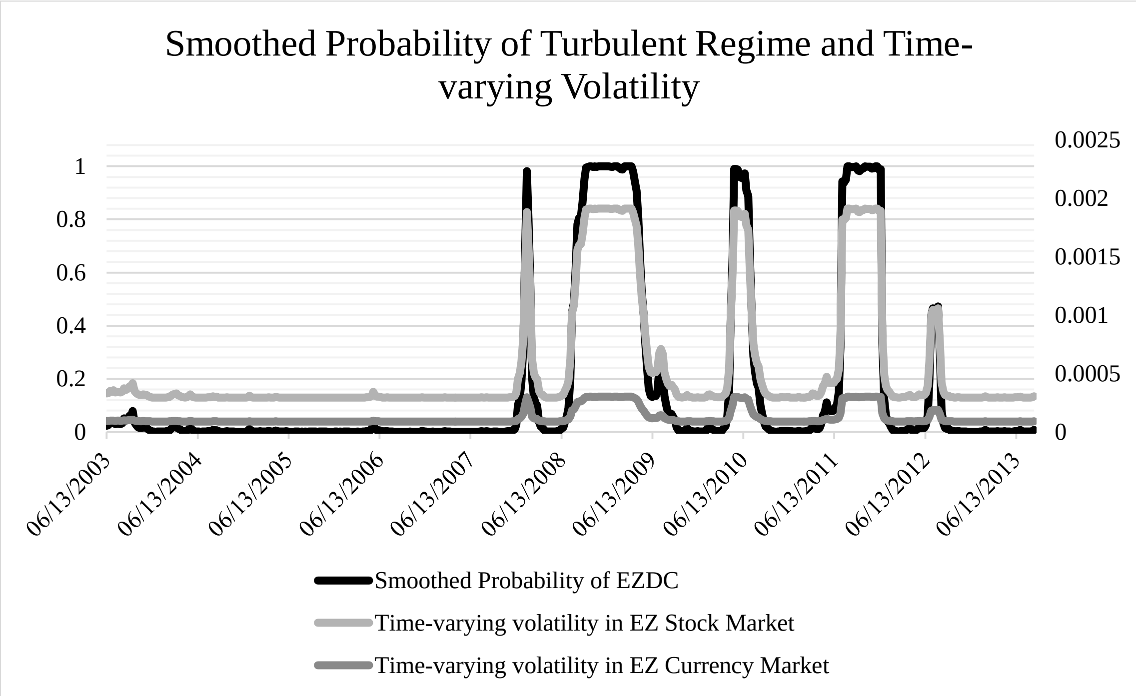
Figure 1A: U.S. Stock and Currency Markets

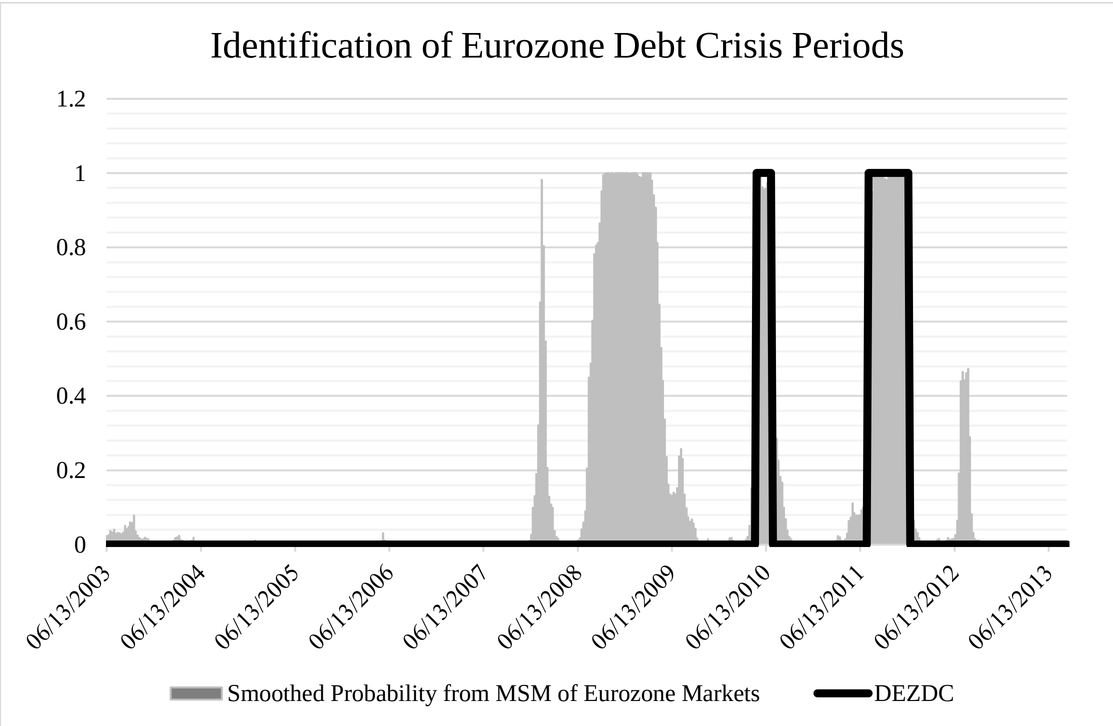



Note: The overall dummy variable DGFC is the aggregate of all the GFC episode dummies i.e. $DGFC = DGFC_1 + DGFC_2 + DGFC_3$.

Figure 1B: E.Z. Stock and Currency Markets




Note: The overall dummy variable DEZDC is the aggregate of all the EZDC episode dummies i.e. $DEZDC = DEZDC_1 + DEZDC_2$.