Mean and Volatility Spillovers between REIT and Stocks Returns: A STVAR-BTGARCH-M Model

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Abstract

In this study we have examined volatility spillovers as well as volatility-in-mean effect between REIT returns and stock returns for both the USA and the UK by applying a bivariate GARCH-M model where the conditional mean is specified by a smooth transition VAR model. Dynamic conditional correlation approach has been applied with the GJR-GARCH specification so that the intrinsic nature of asymmetric volatility in case of positive and negative shocks can be duly captured. The major findings that we have empirically found is that the mean spillover effect from stock returns to REIT returns is significant for both the countries while the same from REIT returns to stock returns is significant only in the UK. It is also evident from the results that own risk-return relationship of REIT market is positive and significant only in the bear market situation in both the countries while for the stock market own risk-return relationship is insignificant for both the bull and bear markets in the USA but it is negative in the bear market condition and positive in the bull market situation for the UK. We have also found that asymmetric nature of conditional variance and dynamic behavior in the conditional correlation holds as well. Finally, several tests of hypotheses regarding equality of various kinds of spillover effects in the bull and bear market situations show that these spillover effects are not the same in the two market conditions in most of the aspects considered in this study.

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1. Introduction

Substantial development of the REIT market preceded by increased interest and perception of the investors has encouraged researchers to examine the performance of this asset. Much of this increased interest has taken place due to some important factors, which include the enhanced liquidity, strong performance of this asset relative to other assets like stocks and bonds. Moreover, inclusion of REIT in the mainstream benchmark indices of S&P 500 coupled with an imperfect correlation between REIT and other assets influencing investors' willingness to consider it in their multi-asset portfolio. However, less attention has been paid in the risk associated with REIT market measured by time varying volatility. Volatility plays an important role in hedging, derivative pricing, portfolio selection and financial risk control (see, for instance, Zhou and Kang (2011), for details). Kyle (1985) indicated that volatility of financial market revealed much information than price itself. Following him, a numbers of studies have examined the return-volatility relationship for different financial markets (see, for instances, Chen et al. (1990); Liu et al. (1990); Peterson and Hsieh (1997); Ling and Naranjo (1999); Cotter and Stevension (2006); Michayluk (2006); Fei et al. (2010); Yang et al. (2012)). These studies have documented that risk premium in one market is determined not only by that particular market but also by other financial markets as the capital markets become increasingly integrated. In the context of equity returns it is only evident in the literature that the spillover effect of different market is not fixed over time, rather it is changing depending on situations faced by the financial markets. But such studies have focused on the time-varying nature of market integration by high and low volatility periods. To the best of our knowledge, no such studies have seen the volatility spillover and cross market risk transmission of REIT and stock returns in two different market conditions. Hence, spillover effects are subject to time and state variations. Hence, it is important to examine the time varying nature of return and volatility spillovers between REIT and stock market for diversifying portfolio among them.

In this article, our intent is to analyze several aspects of spillover effect among these two markets. The objectives can be put in plain words in terms of the following questions – (a) Does REIT (stock) return is affecting stock (REIT) return? If so, how it differ with market conditions like 'bull' and 'bear' market. (b) Does the volatility of stock market returns transmit to REIT market and *vice-versa*? (c) Does the risk of one market affecting return of another market? (d) Does negative and positive shock of same magnitude have different impact on volatility? These questions have been addressed by a bivariate threshold GARCH-in-mean (BTGARCH-M) framework. The volatility transmission has been captured by the dynamic conditional correlation (DCC) TGARCH specification. Insofar as the conditional mean model is considered, we have used the VAR model with consideration to regime-switching behavior. The regime switching behavior in stock returns and other macroeconomic variables are very well documented in the literature (see, for instances, Lundbergh and Terasvirta (1998); Hamilton (1989); Turner et al. (1989); Hamilton and Susmel (1994); Chkili and Nguyen (2014); Kundu and Sarkar (2016); Pan et al. (2017) etc., for details) while in case of REIT the evidence is very few. In our study, we have considered two regimes in the conditional mean model representing 'bull' and 'bear' markets. A gradual transition from 'bear' to 'bull' market has been confined by considering a continuous smooth transition function. The conditional mean model thus have a smooth transition specification in VAR (STVAR). The choice of smooth transition function has been made from consideration of capturing different impacts of different market conditions such as bull and bear markets and the switch over is slow rather than abrupt from one market condition to another. Lastly, the risk-return relationship is taken care by incorporating the TGARCH-in-mean (TGARCH-M) component in STVAR structure. By incorporating "in-mean" component in the conditional mean we can examine own and cross market risk – return relationship in both the market conditions for REIT and stock markets. The advantage of using this framework is that, it is addressing all our objectives in a single model. Our empirical results suggest that there is a significant and asymmetric spillover effect from mean, variance, as well as GARCH-in-mean component between REIT returns and stock returns in the two market conditions.

The remainder of this paper is laid out as follows. Section 2 presents the review of literature. The model and methodology used in this study is discussed in the Section 3. Section 4 outlines several tests of hypotheses of interests. The empirical results are presented and discussed in Section 5. The paper ends with concluding observations in Section 6.

2. Literature review

The relationship between real estate securities and general financial markets has been extensively explored. Empirical studies on the performance of REITs in the US generally have suggested that REITs have similar risk and return characteristics to those of stocks over the period prior to the 1990s. Smith and Shulman (1976) in their paper covering the period 1963-1974, have found that REITs provide returns that are comparable to those of diversified portfolios of common stocks. Han and Liang (1995), and Liang et al. (1998) also have reported that REIT returns behave far closer to those of stock returns than those of returns on direct properties. For the period 1978-1994, Brueggeman and Fisher (1997) have reported correlation coefficient of 0.69 between equity REITs and shares, and 0.41 between REITs and bonds. Mull and Soenen (1997) analyzed the correlation between US REITs, domestic stock and domestic bonds for the time period 1985-94. They found that REITs have moderate positive correlation coefficient (0.61) with stocks and low correlation coefficient (0.28) with bonds. It is also evidenced by Heaney and Srinanthkumar (2012) that the correlation between real estate returns and share market returns is time-varying in case of Australian financial market. Bertero and Mayer (1990), King and Wadhwani (1990), Longin and Solnik (2001), Ang and Bekaert (2002) and Baele (2005) have shown that during periods of high volatility correlation between markets is higher than that of low volatile periods. Kundu and Sarkar (2016) and Bouri et al. (2018) both have argued that the spillover effect is varying with market condition like 'up' and 'down' or 'bull' and 'bear' market condition respectively. The determinants of REIT returns have also been analyzed by using asset pricing model. Chen et al., (1990) employed the capital asset pricing model (CAPM) and arbitrage pricing theory (APT) to examine equity REIT returns. Asset pricing models have been applied to investigate integration *versus* segmentation between real estate market and general financial markets. Liu et al. (1990) who were the first to do so, used a single factor model and reported that the US private securitized real estate market is integrated with the stock market, while the US private commercial real estate market is segmented from the stock market. Peterson and Hsieh (1997) showed that risk premiums on equity REITs are significantly related to common stock returns. Using a series of commonly used multi-factor asset pricing models, Ling and Naranjo (1999) found that US REITs are integrated with the stock markets and the degree of such integration had significantly increased during the 1990s, while there is little evidence of integration between real estate and stock markets when appraisal based real estate returns are used. However, while this evidence is supportive of strong relationship between REITs and general stock markets, a number of studies have found contrasting evidence as well. For instance, Wilson and Okunev (1996) in their study involving REITs, the indirect traded real estate markets and stock markets have found no ebidence of cointegration among themselves. In addition, Clayton and MacKinnon (2001) found that the sensitivity of REIT returns to stock market in the USA declined significantly in the 1990s. As regards studies on this relationship between REIT returns and stock returns with consideration to volatility in the modeling framework, there are only very few. Using a bivariate generalized autoregressive conditional heteroscadastic (GARCH) model, Cotter and Stevenson (2006) found that correlation between returns on daily REIT and stock indices generally increased during the period from 1990 to 2005. Applying a multivariate dynamic conditional correlation (DCC)-GARCH model to a group of seven assets, Huang and Zhong (2006) argued that during the period from 1999 to 2005 in the USA, conditional correlation between REITs and US equity using daily – level data was always positive, but the same with US bond fluctuated around zero. Feng et al. (2006) and Ambrose et al. (2007) found that, starting in October 2001, the coefficient attached to REIT betas relative to that of stocks increased following the inclusion of REITs in S&P 500 and other broad stock market indices. Using a DCC-GARCH model, Case et al. (2014) examined the monthly conditional correlations between returns from the US stock market and REIT market over the period 1972 to 2008, and explored the implications of these correlations in portfolio allocation.

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3. Model and Methodology

In this section, we briefly represent the econometric model used to examine the spillover of return and volatility of REIT and stock in 'bull' and 'bear' market as stated in the previous section. We employed the bivariate threshold-GARCH with dynamic conditional correlation to model asymmetric nature of volatility and its interconnection. The STVAR specification for conditional mean duly captures the transition from one market condition to the other, in which the 'in-mean' component measures the impact of volatility on returns. Overall, the STVAR-BTGARCH-M model allows asymmetry in volatility and return spillover as well as asymmetric nature of risk-return relationship.

3.1. Basic framework of the model

The basic framework of the model considered in this article is

$$r_t = \mu_t(\theta) + \varepsilon_t \tag{1}$$

where r_t is an $N \times 1$ vector of returns at time t on N equity indices, $\mu_t(\theta)$ is the $N \times 1$ conditional mean vector which also include the 'in-mean' component. $\varepsilon_t = H_t^{1/2}(\theta)\eta_t$, with $E(\eta_t) = 0$ and $V(\eta_t) = I_N$, I_N is the identity matrix of order N, and θ is a finite vector of parameters. Further $H_t^{1/2}(\theta)$ is assumed to be a $(N \times N)$ positive definite matrix such that $H_t(\theta)$ is the conditional variance-covariance matrix of r_t. Both $H_t(\theta)$ and $\mu_t(\theta)$ depend on the unknown vector θ. Under this assumption on $H_t^{1/2}(\theta)$, $H_t(\theta)$ is also positive definite given by the DCC matrix. Following Kundu and Sarkar (2016) and Bouri et al. (2018) the conditional mean is specified as the smooth transition VAR model along with MGARCH-in-mean. To capture the switching nature of the relationship between equity and REIT return and the risk return relationship in bull and bear market, we specified a smooth transition model in conditional mean. In the next subsections we are briefly describing the CCC and DCC specification of the MGARCH model followed by STVAR model.

3.2. CCC and DCC representations

The constant conditional correlation (CCC) model proposed by Bollerslev (1990) considers the conditional covariances are proportional to the conditional variance such that the conditional correlations are constant over time. Here, conditional variances are specified as any univariate generalized autoregressive conditional heteroskedasticity (GARCH) model and the conditional correlations are considered as unknown parameters to be estimated. These restrictions greatly reduce the number of unknown parameters and thus simplify the estimation of the model. In CCC model, time varying covariance matrix, H_t based on N equity returns, is defined as:

$$H_t = D_t R D_t = (\rho_{ij}\sqrt{h_{ii,t}\, h_{jj,t}}) \tag{2}$$

where $D_t = diag(h_{11,t}^{1/2}, \ldots.., h_{NN,t}^{1/2})$, $h_{ii,t}$ is any univariate GARCH model for the i^{th} equity return. The original CCC model has symmetric GARCH(1,1) specification i.e., each conditional variance in D_t is given as -

$$h_{ii,t} = \omega_i + \alpha_i \varepsilon_{i,t-1}^2 + \beta_i h_{ii,t-1}, \qquad i = 1, \ldots \ldots., N. \tag{3}$$

The asymmetric GARCH specification like the EGARCH by Nelson (1991) or the GJR-GARCH model by Glosten et al. (1993) can as well be taken, especially in case of financial market in which leverage effect has been found to be more prominent. In this context, the GJR GARCH(p,q) specification, is defined as

$$h_{ii,t} = \omega_i + \sum_{j=1}^{q} \alpha_{ij} \varepsilon_{i,t-j}^2 + \sum_{j=1}^{q} d_{ij} I(\varepsilon_{i,t-j} < 0)\varepsilon_{i,t-j}^2 + \sum_{j=1}^{p} \beta_{ij} h_{i,t-j} \tag{4}$$

where the indicator function, $I(\cdot)$ takes the value unity when the argument $\varepsilon_{i,t-j}^* < 0$ holds, and $I(\cdot) = 0$ otherwise. The parameter d_{ij} measures the leverage effect. Finally, $R = (\rho_{ij})$ is a symmetric positive definite matrix whose elements are the constant conditional correlation, ρ_{ij}.

The H_t matrix defined in equation (2) is positive definite if and only if all the N conditional variances are positive and R is a positive definite matrix. The unconditional variances are easily obtained, as in the univariate case, but the unconditional covariances are difficult to compute because of the nonlinearity involved in the elements of H_t. He and Terasvirta (2002) used a VEC-type formulation for $(h_{11t}, h_{22t}, \ldots\ldots, h_{NNt})'$, to allow for interactions between the conditional variances, and they called the resultant model as the extended CCC model.

It has been established in the financial econometrics literature that the integration of several asset market is time varying. Hence, the conditional correlation being a constant is unrealistic and considered as a major limitation of the CCC model. Christodoulakis and Satchell (2002), Engle (2002), and Tse and Tsui (2002) have generalized the CCC model by making time varying conditional correlation matrix in different ways. Accordingly, the dynamic conditional correlation (DCC) model is defined as

$$H_t = D_t R_t D_t = (\rho_{ij,t}\sqrt{h_{ii,t}\, h_{jj,t}}) \tag{5}$$

where $R_t = (\rho_{ij,t})$, $\rho_{ij,t}$ being the time varying conditional correlations. The requirement that this H_t is positive definite is guaranteed under simple conditions on the parameters, as stated in Bauwens et al. (2006).

The DCC model of Engle, denoted by $DCC_E(1,1)$ is given as

$$R_t = diag\left(q_{11,t}^{-1/2}, \dots, q_{NN,t}^{-1/2}\right) Q_t\, diag\left(q_{11,t}^{-1/2}, \dots, q_{NN,t}^{-1/2}\right) \tag{6}$$

where the $N \times N$ symmetric positive definite matrix $Q_t = (q_{ij,t})$ is given by

$$Q_t = (1 - \varphi_1 - \varphi_2)\bar{Q} + \varphi_1 \varepsilon_{t-1}^* \varphi_1 \varepsilon_{t-1}^{*\prime} + \varphi_2 Q_{t-1} \tag{7}$$

where $\varepsilon_t^* = (\varepsilon_{1t}^*, \dots, \varepsilon_{Nt}^*)'$, $\varepsilon_{it}^* = \varepsilon_{it}/\sqrt{h_{ii,t}}$, $i = 1, \dots, N$ and ε_{it} is the random error term associated with the given conditional mean model for r_t, , $\bar{Q}$ is the $N \times N$ unconditional variance-covariance matrix of ε_t^*, and φ_1, and φ_2 are non-negative scalar parameters satisfying $(\varphi_1 + \varphi_2) < 1$. It may be noted that unlike the DCC model of Tse and Tsui (2002), this model has the advantage that it does not formulate the conditional correlation as a weighted sum of past correlations. Note that when $\varphi_1 = \varphi_2 = 0$, the DCC_E model reduces to the CCC model. This condition can, therefore, be tested for checking if imposing conditional correlations to be constant is empirically relevant for a given series.

In our analysis we consider $h_{ii,t}$ to be a univariate GJR-GARCH model and imposed following conditions on the parameters for H_t to be positive definite for all $t: (i)\omega_i > 0, (ii) h_{ii,0} > 0, (iii)$ α_i and β_i are such that $h_{ii,t}$ will be positive with probability one. (iv) the roots of the polynomial of GARCH equation lie outside the unit circle, (v) $\varphi_1 > 0$, (vi) $\varphi_2 > 0$, and (vii) $(\varphi_1 + \varphi_2) < 1$.

3.3. STVAR-BTGARCH-M model

In coherence with two market situations *viz., bull* and *bear* and the transition from one market condition to other, we have employed the STVAR-BTGARCH-M model proposed by Kundu and Sarkar (2016). In this model the conditional mean equation is given by smooth transition VAR (STVAR) along with volatility 'in-mean' component, where H_t as given in equation (5). A logistic transition function $\boldsymbol{G}\left[\bar{r}_{it}^k, \gamma\right]$, which changes smoothly from 0 to 1 as $\bar{r}_{it}^{\boldsymbol{k}}$ increases (see, Terasvirta (1994), for details), has been considered representing a smooth transition from bear to bull market. The transition function depending on two parameters $\bar{r}_{it}^{\boldsymbol{k}}$ and γ, where $\bar{r}_{it}^{\boldsymbol{k}} = \frac{\sum_{j=1}^{k} r_{i,t-j}}{k}$ is the average of the past k returns on the i^{th} equity market $(i = 1, 2)$ characterizing bull (bear) market as $\bar{r}_{it}^{\boldsymbol{k}} > 0$ $(\bar{r}_{it}^{\boldsymbol{k}} \leq 0)$ and γ is the smoothness parameter. The two regimes are associated with very small and large values of the transition variable, $\bar{r}_{it}^{\boldsymbol{k}}$. The threshold value has been taken to be zero for both the returns to define the bull and bear market conditions, as suggested by Chen (2009). In order to choose the appropriate value of k for the threshold variable $\bar{r}_{it}^{k}$, several choices of k were considered and opted the value for which the maximized log-likelihood value is found to be the highest. The volatility-in-mean component in the conditional mean explicitly incorporates the direct and indirect impact of risk on return in both the market conditions. Accordingly, the STVAR-BTGRACH-M model for $N = 2$ in this study is given by

$$r_t = \left(a^1 + B^1 r_{t-1} + \Lambda^1 vech\,(H_t(\theta))\right) \odot (\mathbf{1} - \boldsymbol{G}[\cdot]) + \left(a^2 + B^2 r_{t-1} + \Lambda^2 vech\,(H_t(\theta))\right) \odot \boldsymbol{G}[\cdot] + \varepsilon_t \tag{8}$$

where $r_t = \begin{pmatrix} r_{1t} \\ r_{2t} \end{pmatrix}$, $a^1 = \begin{pmatrix} a_1^1 \\ a_2^1 \end{pmatrix}$, $a^2 = \begin{pmatrix} a_1^2 \\ a_2^2 \end{pmatrix}$, $B^1 = \begin{pmatrix} b_{11}^1 & b_{12}^1 \\ b_{21}^1 & b_{22}^1 \end{pmatrix}$, $B^2 = \begin{pmatrix} b_{11}^2 & b_{12}^2 \\ b_{21}^2 & b_{22}^2 \end{pmatrix}$, $\Lambda^1 = \begin{pmatrix} \lambda_{11}^1 & \lambda_{12}^1 & \lambda_{13}^1 \\ \lambda_{21}^1 & \lambda_{22}^1 & \lambda_{23}^1 \end{pmatrix}$, $\Lambda^2 = \begin{pmatrix} \lambda_{11}^2 & \lambda_{12}^2 & \lambda_{13}^2 \\ \lambda_{21}^2 & \lambda_{22}^2 & \lambda_{23}^2 \end{pmatrix}$, $H_t = \begin{pmatrix} h_{11t} & h_{12t} \\ h_{12t} & h_{22t} \end{pmatrix}$, $vech(H_t) = \begin{pmatrix} h_{11t} \\ h_{12t} \\ h_{22t} \end{pmatrix}$, $\varepsilon_t = \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{pmatrix}$, $\boldsymbol{G}[\cdot] = \begin{pmatrix} g(\bar{r}_{1t}^{k},\ \gamma_1) \\ g(\bar{r}_{2t}^{k},\ \gamma_2) \end{pmatrix}$, and $g(\bar{r}_{it}^{k},\ \gamma_i), i = 1,2,$ are the usual logistic functions with parameters γ_1 and $\gamma_2$respectively. H_t is the conditional variance-covariance matrix of the DCC model as given in equation (5). Superscripts 1 and 2 refer to 'bear' and 'bull' markets in that order. In consent to potentially asymmetric response of volatility to positive and negative shocks, we opted the GJR-GARCH (1,1) process of Glosten et al. (1993) given in equation (4). The reason for considering asymmetric volatility is that the market risk reflects asymmetrically in case of positive and negative shocks due to 'leverage effect' in asset markets (see, Kundu and Sarkar (2016), for details). Further, it is likely that REIT returns also would have 'leverage effect' which reflect an asymmetry in volatility with respect to positive and negative shocks.

The parameters of STVAR-BTGARCH-M model has been estimated by the method of maximum likelihood (ML) assuming bivariate normality for the conditional distribution of the error term, $\varepsilon_t|\psi_{t-1}$, where ψ_{t-1} is the set of past information on all variables up to time $t-1$. In short, $\varepsilon_t|\psi_{t-1} \sim N\,(0, H_t)$. The log-likelihood function (up to a constant), based on T observations, is given as:

$$L(\theta) = -\frac{1}{2}\sum_{t=1}^{T}(\ln|H_t| + \varepsilon_t' H_t^{-1}\varepsilon_t). \tag{10}$$

Obviously, obtaining the ML estimate of the parameter vector θ requires maximizing this log-likelihood function with respect to θ.

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4. Tests of hypotheses

In this section, we briefly describe the statistical tests carried out in this paper. Before discussing the different hypotheses of interests pertaining to STVAR-BTGARCH-M model, we first mention about a test for linearity against non-linearity in the data generating process using a bivariate framework. This test, proposed by Camacho (2004), is described below. It is worthwhile to note that this test also enables us to find which of the two standard transition functions – logistic and exponential – is appropriate for the underlying model. After testing nonlinearity as well as the appropriate type of transition function, we carry out a set of tests based on the Wald test to conclude on the different kinds of spillovers in mean, volatility, and BTGARCH-in-mean effects based on this model.

4.1. Nonlinearity and model selection tests

Granger and Terasvirta (1993) developed a test of linearity under null against STAR type nonlinearity. The null hypothesis of linearity can be obtain if smooth transition parameter γ is equal to zero, i.e., $H_0 : \gamma = 0$, and the alternative hypothesis is $H_1 : \gamma > 0$. Since the model is not identified under the null hypothesis, any statistical test for regime switching model as an alternative involve the problem of nuisance parameter. To avoid this, a standard Lagrange Multiplier (LM)-type test based on an auxiliary regression, obtained from a suitable Taylor series expansion of the transition function around the point $\gamma = 0$, is used (see, Granger and Terasvirta (1993), for details). In line with this procedure for the univariate case, Camacho (2004) has generalized the testing of nonlinearity in the VAR model with a smooth transition specification. In this context, one single-regime linear VAR model under the null is specified against the alternative of smooth transition between regimes. Camacho (2004) proposed the following two auxiliary regressions for the bivariate case:

$$r_{1t} = \tau_1 + \sum_{h=0}^{3} \xi'_{1h} X_t w^h + u_{1t} \tag{11}$$

and

$$r_{2t} = \tau_2 + \sum_{h=0}^{3} \xi'_{2h} X_t w^h + u_{2t} \tag{12}$$

where $X'_t = (r_{1\,\overline{t-1}}, r_{2\,\overline{t-1}})$, ξ_{1h} and ξ_{2h} are (1×2) coefficient vectors, and the variable w is the transition variable which is the lag value of returns. The null hypothesis of linearity thus corresponds to $\xi_{11} = \xi_{12} = \xi_{13} = \xi_{21} = \xi_{22} = \xi_{23} = 0$.

If linearity i.e., one single regime, is rejected in favor of additional regimes, the model selection test is then required to decide between logistic and exponential transition functions. To that end, a sequence of nested hypotheses is formulated for the two auxiliary regressions. Following Camacho (2004), the null and alternative hypotheses for the nested tests along with the choice of appropriate transition function are presented in the following tabular form. In this testing exercise, three test statistics are involved. These are denoted as Test 1, Test 2, and Test 3. Under the respective null hypothesis, these test statistics follow non-standard distributions, and their critical values are available in Camacho (2004).

Table 1: Model selection tests

Hypothesis	Test 1	Test 2	Test 3	Choice
Null	$\xi_{i3} = 0$	$\xi_{ij} = 0$, $j = 2,3$	$\xi_{ij} = 0$, $j = 1,2,3$	…….

Alternative	$\xi_{i3} \neq 0$	$\xi_{i2} \neq 0$ $\xi_{i3} = 0$	$\xi_{i1} \neq 0$ $\xi_{ij} = 0$ $j = 2,3$	…….
Test conclusion	Reject null Do not reject null Do not reject null Do not reject null	…… Reject null Do not reject null Reject null	……… Do not reject null Reject null Reject null	Logistic Exponential Logistic No conclusion

4.2. The Wald test

The above nonlinearity and model selection test confirm the existence of more than one regime in the dynamics of stock and REIT market. Hence, we have carried out several Wald test for testing the significance of own and cross spillover effects of returns, volatility and 'in-mean' component in REIT and stock markets in two market situations by placing appropriate restrictions on the relevant parameters in equation (8). The null hypotheses of absence of cross market spillover and equality of spillover in both market conditions have been given as follows--

1. *Tests of spillovers in conditional mean*
   (a) H_{01}^{a}: No spillovers in mean from stock market to REIT market in both bull and bear market movements i.e., $b_{12}^{1} = b_{12}^{2} = 0$.
   (b) H_{01}^{b}: No spillovers in mean from REIT market to stock market in both bull and bear market movements i.e., $b_{21}^{1} = b_{21}^{2} = 0$.
2. *Tests of equality of spillovers in bull and bear market movements for REIT and stock markets*
   (a) H_{02}^{a}: Equality of spillovers in mean in bull and bear market conditions form stock market to REIT market i.e., $b_{12}^{1} = b_{12}^{2}$.
   (b) H_{02}^{b}: Equality of spillovers in mean in bull and bear market conditions form REIT market to stock market i.e., $b_{21}^{1} = b_{21}^{2}$.
3. *Tests of no BTGARCH-in-mean effect from one market to another*
   (a) Equality of own volatility spillover on REIT returns in bull and bear markets i.e., H_{03}^{a}: $\lambda_{11}^{1} = \lambda_{11}^{2}$.
   (b) Equality of volatility spillover of stock market on REIT returns in bull and bear markets i.e., H_{03}^{b}: $\lambda_{13}^{1} = \lambda_{13}^{2}$.
   (c) Equality of own volatility spillover on stock returns in bull and bear markets i.e., H_{03}^{c}: $\lambda_{23}^{1} = \lambda_{23}^{2}$.
   (d) Equality of volatility spillover of REIT market on stock returns in bull and bear markets i.e., H_{03}^{d}: $\lambda_{21}^{1} = \lambda_{21}^{2}$.
4. *Test of equality of each of the parameters of BTGARCH-in-mean in bull and bear market movements*
   H_{04}: $\lambda_{11}^{1} = \lambda_{11}^{2};\ \lambda_{12}^{1} = \lambda_{12}^{2}; \lambda_{13}^{1} = \lambda_{13}^{2}; \lambda_{21}^{1} = \lambda_{21}^{2}; \lambda_{22}^{1} = \lambda_{22}^{2}; \lambda_{23}^{1} = \lambda_{23}^{2}$.
5. *Test of asymmetric volatility (due to leverage effect) of REIT and stock markets*

No asymmetric volatility i.e., H_{05}: $d_{1j} = d_{2j} = 0$ for all j.

6. *Test of equality of dynamic conditional correlation*
   No dynamic conditional correlation i.e., H_{06}: $\varphi_1 = \varphi_2 = 0$.

5. Empirical Analysis

In this section, we are reporting the results of linearity and model selection tests. Once the null hypothesis of linearity is rejected in favor of regime switching model with logistic transition function the STVAR-BTGARCH-M model have estimated and presented. Monthly data of both the markets have been taken for our analysis. The continuously compounded return of both REIT and stock defined by $r_t = \log\left(\frac{P_t}{P_{t-1}}\right) \times 100$, where P_t is the price index of the respective markets, are found to be stationary by the augmented Dickey-Fuller (ADF) test as require for the final model. Table 2 reports the results of ADF test for all the series. It has been found that all the return series are stationary. Further, Bai-Perron multiple structural break has been tested to check the stability of the time series. The results of multiple structural breaks are reported in table 3. The number of structural breaks in REIT returns and return of S&P 500 series for the USA has been found to have two structural breaks while REIT returns and FTSE ALL series for the UK has single break. These results also suggest that the relationship is not stable for all time period considered in this study.

Table 2. Values of the ADF test statistic for stationarity

Country	REIT	SR
The USA	-6.77***	-16.28***
The UK	-11.19***	-14.65***

Note: '*', '**', and '***' denote significance at 10%, 5%, and 1% level, respectively.

Table 3. Bai-Perron tests for multiple structural breaks

	The USA		The UK	
Test	REIT	SR	REIT	SR

WD_{max} (Up to one break)	26.57***	20.73***	48.08***	17.75**
$Sup\ F_T(2\|1)$	25.92**	16.51**	6.64	4.08
$Sup\ F_T(3\|2)$	3.67	12.03		
Break dates	2005M04 & 2009M03	2005M06 & 2009M04	2007M01	2009M05

Note: ‘*’, ‘**’, and ‘***’ indicate significance at 10%, 5%, and 1% levels, respectively.

5.1. Results of the tests of model selection including linearity

The results of linearity and model selection tests stated in Section 3.1 are given in Table 4. As mentioned, the test has been done by taking two different choices of the transition variable *viz.*,$r_{1,t-1}$ and $r_{2,t-1}$. Based on the test results, it is concluded that the null hypothesis of linear specification against the alternative of regime-switching model which is regime-wise linear but overall non-linear, is rejected for both the countries at 1% level of significance. For instance, in case of $r_{1,t-1}$ being the transition variable, the test statistic values are 43.54 and 15.30 for the USA and the UK, respectively, both of which are higher than their respective critical values. Thus, the regime-switching nature in the relationship between REIT returns and stock returns is confirmed for both the USA and the UK. Further, as evident from the entries of this table, logistic transition function is appropriate for the USA in case $r_{2,t-1}$ is the transition variable, while no conclusive inference on this could be drawn for the other transition variable in the USA, and the same is the case for both the transition variables in case of the UK.

Table 4. Results of test of linearity and other model selection tests

	The USA		The UK	
	Transition variable		Transition variable	
	$r_{1,t-1}$	$r_{2,t-1}$	$r_{1,t-1}$	$r_{2,t-1}$
Test of linearity	43.54***	35.44***	15.30***	14.26***
Test 1	5.88	12.87***	2.42	3.87
Test 2	2087.75***		2143.98***	2146.46
Test 3	2125.41***		2156.86***	2156.85
Decision	No decision	LSTVAR	No decision	No decision

Note: ‘***’ indicates significance at 1% level.

5.2. Findings from STVAR-BTGARCH model

The model STVAR-BTGARCH as specified in equation (8) is based on DCC representation. The ML estimates of the parameters of this model for both the countries are reported in Tables 5 through 8. This section discusses the estimates of the parameters, given in Table 5, that capture the return spillover from one market to another in both bull and bear situations.

Table 5. Estimates of mean parameters

Parameter	The USA		The UK	
	Bear market (i.e., i =1)	Bull market (i.e., i =2)	Bear market (i.e., i =1)	Bull market (i.e., i =2)
a_1^i	-0.16***	-0.03	-0.07***	0.68***
b_{11}^i	0.06*	-0.13***	0.20***	-0.00
b_{12}^i	0.65***	0.17***	-0.42***	0.01
a_2^i	0.07***	0.43***	0.46***	0.44***
b_{21}^i	-0.00	-0.01	0.121***	0.05***
b_{22}^i	0.16***	-0.03	0.18***	0.06

Notes (1): '*', '**', and '***' indicate significance at 10%, 5% and 1% levels, respectively.

and (2): '1', '2' in the subscript stand for REIT returns and stock returns, respectively.

The relationship between REIT and stock has great importance in terms of portfolio diversification. It was believed in the literature that these two returns are highly uncorrelated as stock price are mainly driven by corporate profits and its expectation, REIT is mainly influenced by the earnings of property rents. However, the relationship significantly changed after the global recession in 2008. It is evident from the results that in case of the USA, the spillover effects from the stock returns to REIT returns in both bull and bear regimes i.e., b_{12}^i for $i = 1,2$, is significant and positive. An increase in stock return increases the income of the investors and due to positive income effect the investment in REIT also increases which leads to increase in REIT return. Similarly, an increase stock return increases the expected return for the future as the autocorrelation in stock return is positive. Hence, investor will prefer to invest in similar asset over the risk-free assets. Consequently, we are observing a positive spillover from stock market to REIT market. The first order autocorrelation parameters in bull regime for both the market in negative though it is significant only in REIT market. As the market is already in bull state, investor may think that the price will fall which leads to decrease in return. But the spillover from stock market to REIT is still positive. However, the positive return spillovers in both the market conditions are not the same. The causal relationship from stock market to REIT is higher in case of bear situation in REIT market. The estimated coefficient is 0.65 whereas the same coefficient in bull state is 0.17. Wald test result given in Table 8 confirms that the coefficients are significantly different. It is worth mentioning that in case of REIT an increase in lag return boost up the same market by 6% while an increase in past return of stock enhance the REIT return by 65% in case of bear state. In the bull state where lag return of REIT has a significant negative impact, increase in past stock return considerably improves the REIT market return. The return spillover from REIT returns to stock returns in both the regimes i.e., b_{21}^{i}, $i = 1{,}2$ is insignificant in both bull and bear regimes. In UK, an increase in stock market return in the previous period significantly reduces the return of the REIT market in bear state. In bear state of REIT market, increases in stock return attract the investor from REIT to stock market indicating a significant decrease in REIT return. Hence, the substitution effect is stronger than the positive income effect. The results are different in case of bull state in REIT. As REIT is already in bullish phase, investors are not diverting there investment though observe an increase in return from stocks. Hence, we have found insignificant impact from stock to REIT in bull state. The impact in the opposite direction is significant and positive in both the states.

Now we discuss the estimation results of the volatility-in-mean parameters which are given in Table 6. It has been found that own risk-return relationship of REIT in bear market (λ_{11}^{1}) is positive and statistically significant for both the countries whereas the same relation in bull market is statistically insignificant. In case of stock market, the parameter indicating own risk return relationship in both the market conditions i.e., λ_{23}^{i} for $i = 1{,}2$, is insignificant in the USA. In case of UK the relationship is negative in the bear market condition and positive in the bull market situation. Kim and Zumwalt (1979) have argued that in the bear market situation investor would require a positive premium for taking downside risk of their investment, whereas they will pay a premium in the bull market. Thus, in the bear market situation, risk premium is positive. The negative risk-return relationship of stock market can also be explained by volatility feedback hypothesis which states that if there is a risk associated with an investment on an asset, then the investor will not be interested to invest on that asset. Thus, return would fall with the increase in risk.

Table 6. Estimates of the volatility-in-mean parameters

Parameters	The USA		The UK	
	Bear market	Bull market	Bear market	Bull market

	(i.e., i =1)	(i.e., i =2)	(i.e., i =1)	(i.e., i =2)
λ_{11}^{i}	0.04***	0.01	0.07***	-0.00
λ_{12}^{i}	-0.16***	0.06***	0.01	0.20***
λ_{13}^{i}	0.04*	0.02	-0.19***	-0.09***
λ_{21}^{i}	0.04***	-0.05***	-0.05***	0.00
λ_{22}^{i}	-0.18***	0.23***	0.5***	-0.35***
λ_{23}^{i}	0.03	-0.03	-0.19***	0.23***

Note: '*', '**', and '***' indicate significance at 10%, 5% and 1% levels, respectively.

In case of the cross risk-return relationship involving REIT returns and stock returns in the USA, the two relevant parameters i.e., λ_{21}^{i} and λ_{13}^{i} have been found to be positive in the bear market, while in the bull market only the risk in REIT market has significant negative effect on stock market returns. Considering the estimates of bear phase of USA as an example, we can explain the scenario as follows. As the own risk-return relationship is positive for both stock and REIT in bear phase, increase in risk in any market leads to higher return in that market. So, there must be a capital shift from the other market leads to a reduction in future return. Again, from the MGARCH specification it is clear that there is a positive spillover from one market to another. Hence, risk of the second market will also positively affect the risk of first market. Given the positive risk-return relationship return of both the market will increase. Hence the resultant impact of cross market risk-return relationship depends on the relative strength of two opposite forces. It has been found in our analysis that the effect of risk of stock on REIT in bear market is positive in US and negative in UK, whereas the same impact in bull phase is insignificant in US and negative in UK. Though the impact is negative in both regimes for UK, the absolute impact is higher in bear phase than bull. The cross market risk return relationship for the opposite direction, i.e., impact of risk of REIT market on the return of stock market in the US is significantly positive in bear phase and negative in bull phase. The same impact for the UK is negative and statistically insignificant respectively.

Now, looking at the parameters of smoothness i.e., γ_1 and γ_2, we find from Table 7 that these two parameters are positive. The values of these parameters have been found to be neither closed to zero nor very high, which implies that the transition from bear market situation to bull market situation is smooth. Hence, the validity of the smooth transition in the conditional mean model is empirically justified for both the countries. Insofar as the behavior of the conditional variance model i.e., BTGARCH, is concerned, we find that the parameters in the GARCH component of the model i.e., α_1, β_1, and β_2, are all significant except α_2 in the UK. Now, looking at d_{1j} and d_{2j}, the two coefficients capturing asymmetry in the conditional variance, we note that these two parameters are highly significant in both the countries. Thus, consideration of asymmetry in the risk-return relationship between REIT and stock markets is empirically established. Further, we find that the coefficients involved in the dynamic conditional correlation i.e., φ_1 and φ_2, are significant for both the USA and the UK, which justifies that the DCC modeling approach is useful in explaining the volatility dynamics between returns on REIT and stock markets.

Table 7 Estimates of the parameters of smoothness, GJR – GARCH and DCC models

Paremeters	The USA	The UK
γ_1	4.61***	4.65***
γ_2	5.22***	5.25***
c_1	1.18***	4.27***
c_2	1.44***	4.20***
α_1	0.29***	-0.07***
α_2	0.15***	0.01
d_1	-0.11***	0.15***
d_2	0.10***	0.39***
β_1	0.76***	0.86***
β_1	0.72***	0.46***
φ_1	0.08***	0.32***
φ_2	0.40***	0.45***

Note: '*', '**', and '***' indicate significance at 10%, 5% and 1% levels, respectively.

Finally, we report, in Table 8, the results of several tests of hypotheses of interest involving various kinds of spillover effects in bull and bear markets and also the dynamic nature of the conditional correlation in the BTGARCH model including the aspect of asymmetric effect of volatility. From the entries in row 1 and 2 of Table 8, we find that the null hypothesis of 'no spillover in mean' is rejected in case of both the USA and the UK except the case of mean spillover effect from REIT returns to stock returns in the USA.

Table 8. Results of the Wald test on equality of coefficients for bull and bear markets

Row No.	Null hypothesis	The USA	The UK

1	$b_{12}^1 = b_{12}^2 = 0$	64.56***	25.01***
2	$b_{21}^1 = b_{21}^2 = 0$	0.41	12.87***
3	$b_{12}^1 = b_{12}^2$	32.95***	8.68***
4	$b_{21}^1 = b_{21}^2$	0.18	1.28
5	$\lambda_{11}^1 = \lambda_{11}^2$	2.64	6.27***
6	$\lambda_{13}^1 = \lambda_{13}^2$	0.42	2.75
7	$\lambda_{21}^1 = \lambda_{21}^2$	15.34***	5.57***
8	$\lambda_{23}^1 = \lambda_{23}^2$	2.46	74.65***
9	$\lambda_{ij}^1 = \lambda_{ij}^2$	52.95***	107.02***
10	$d_1 = d_2 = 0$	20.33***	51.06***
11	$\varphi_1 = \varphi_2 = 0$	290.70***	312.87***

Note: '***' indicates significance at 1% level.

The null hypotheses of equality in the mean spillover effects from stock returns to REIT returns in the bull and bear markets are rejected at 1% level of significance for both the countries whereas the null hypothesis of equality in the mean spillover effect from REIT returns to stock returns cannot be rejected for both the countries.

As regards the null hypothesis of equality in volatility-in-mean components in the bull and bear market situations we find from rows 5 and 8 of Table 8, that the null hypothesis cannot be rejected in case of the own risk-return relationship for both REIT and stock markets in the USA while for the UK this null hypothesis is rejected at 1% level of significance. In rows 6 and 7, we have reported the results of the Wald test for testing the null hypotheses of equality of the cross risk-return relationship involving REIT returns and stock returns across bull and bear market conditions. The results suggest that the null hypothesis of equality of the effect of risk from REIT market to stock market returns in both bull and bear market situations is rejected for both the USA and the UK, while this null hypothesis in case of effect of risk from stock returns to REIT returns cannot be rejected for both the countries. Finally, we note that the results of the tests of the two null hypotheses *viz.*, 'no leverage effect' and 'no dynamic behavior' in the conditional correlation, respectively, suggest rejection of both these null hypotheses for both the countries. The rejection of the first null hypothesis is clear from the test statistic values of 20.33 and 51.06, respectively, for the USA and the UK, which are found to be significant at 1% level. Similar values for the null hypothesis of 'no dynamic behavior' are 290.70 and 312.87 for the USA and the UK, respectively, which also clearly suggests rejection of the null hypothesis at 1% level of significance.

6. Conclusions

In this paper, we have examined the volatility transmission between REIT returns and stock returns by applying a bivariate GARCH-M model in VAR framework with smooth transition nature of conditional mean, which also captures the asymmetric nature of mean and volatility spillovers in the bull and bear market situations. To that end, dynamic conditional correlation representations of bivariate GARCH and GJR-GARCH specification of volatility have been considered. We have empirically found that the mean spillover effect from stock returns to REIT returns is significant for both the countries while the same from REIT returns to stock returns is significant only in case of the UK. It is evident from the results that in both the countries own risk-return relationship of REIT market is positive and significant only in the bear market situation while for the stock market own risk-return relationship is insignificant for both the bull and bear markets in the USA, but it is negative in the bear market condition and positive in the bull market situation for the UK. We have also found the asymmetric nature in the conditional variance and dynamic behavior in the conditional correlation as well. Finally, several tests of hypotheses regarding equality of various kinds of spillover effects in the bull and bear market situations have shown that these spillover effects are not the same in these two market conditions in most of the aspects considered in this study.

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