Return and Volatility Spillovers in the Moroccan Stock Market During The Financial Crisis

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Abstract

The aim of this paper is to investigate the return and volatility linkages among Moroccan stock market with that of U.S. and three European countries (France, Germany and U.K.) before and during the financial crisis. More specifically, we use stock returns in MASI, CAC, DAX, FTSE and NASDAQ as representatives of Moroccan, French, German, British and U.S. markets respectively. The data sample frequency is daily and spans from January 2002 to December 2012 excluding holidays. Using the estimation results of bivariate VAR-BEKK GARCH model, we analyze the return and volatility spillover effects between the Moroccan market and the other considered markets. Moreover, the identification of break point due to the subprime crisis is made by Lee-Strazicich (2003,2004) and Bai-Perron (1998, 2003) structural break tests. The empirical findings provide clear evidence of stronger linkages between the Moroccan market and the four other considered stock markets have been created during the subprime financial crisis period.

Key-words : Return and volatility spillovers; multivariate GARCH model; financial crisis; stock markets; break identification; conditional correlation.

JEL Classification : C5, C22, G1, G01, G15.

1 Introduction

The global subprime financial crisis and its consequences to international markets attracted great attention from academics, investors and policy makers. Already, there is a large literature investigating the theoretical

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and empirical mechanisms of international volatility transmission of crises. The volatility spillover effect states that volatility of asset prices in one market can be explained or predicted by innovations in other markets; in other words, two or more markets are interdependent in terms of their price volatility. Extant literature usually examines volatility spillover among national equity markets. On the theoretical side, King and Wadhwani (1990), and Kaminsky and Schukler (1999) suggested an analysis based on revision of expectations and herding behaviour, respectively. Furthermore, more recently, Stevens (2008) has documented two types of channels for international transmission of crises: Firstly, there are the common shocks, whereby financial sectors in different countries are concurrently affected by the same shock. Secondly, there are the spillover effects that are transmitted among economies. Didier et al. (2008) proposed two types of spillover effects. The first type is transmitted via real economy effects such as international transmission of aggregate demand and trade flow effects. The second type of spillover effects is due to the interaction of capital markets. These effects are transmitted by asset market adjustments or by financial institutions, e.g. banks. On the empirical side, Wang and Lee (2009) report evidence that after the 1997 Asian crisis, spillover effects of the stock returns and stock return volatilities in nine Asian stock markets increased while Baig and Goldfajn (1999) report evidence of spillover effects for four Asian financial markets. For the recent 2008 crisis an empirical study of Angkinand et al. (2010) indicates that the degree of interdependence and spillover effects peaked after the US subprime mortgage meltdown between USA and seventeen other developed economies.

An understanding of the magnitude and direction of linkages and spillover effects is an essential part of financial managers and policy makers' information set. From the financial managers' point of view, knowledge of markets interdependence is important in determining hedging and diversification of their international investment. Furthermore, from a policy maker's point of view, financial instability, such as a bank collapse and stock market crashes, are major issues that directly influence a country's welfare.

Other recent research has considered to the linkages between developed markets and emerging markets, as pointed out by economists and financial analysts the benefits of international diversification rely increasingly on investment in emerging markets (Goetzmann et al., 2005). Worthington and Higgs (2004) explore the transmission of stock returns and volatility in Asian developed markets and emerging markets during the period 1988-2000. They identify the source and magnitude of spillovers by using the multivariate GARCH model and demonstrate that the mean spillovers from the developed to the emerging markets are not homogenous across the emerging markets, and direct spillovers are generally higher than indirect spillovers, especially for the emerging markets. At the same time, researchers have also investigated the extent of the transmissions across different markets during a specific event such as a financial crisis (e.g. Caporale et al., 2006; Neaime, 2012).

Our paper focuses on VAR-GARCH approach to study the spillover effects and equity volatility transmission empirically on the Moroccan market due to 2008 US subprime crisis. At the best of our knowledge, this is the first study of its kind to focus on spillovers effects and interdependences between the Moroccan equity market and those of U.S., U.K., France, Germany. To explore these effects, we apply a bivariate VAR-GARCH framework with the BEKK representation proposed by Engle and Kroner (1995) to model and test for cross-market spillovers in means and variances of stock returns. This approach builds and expands on the methodologies adopted in earlier studies such as Ng (2000), and Bekaert et al. (2005).

In order to do this study, we will investigate to study whether the US subprime financial turmoil has had any statistically significant effect on the conditional return and volatility of stock prices in the Moroccan stock market, for which the VAR-BEKK GARCH methodology is adopted. Further, we analyze the volatility linkages between the Moroccan stock market and the U.S., France, U.K. and Germany stock markets before and after the US subprime crisis. Therefore, we contribute to the literature of volatility spillovers and contagion among the financial markets around the financial crisis of 2008. Firstly, we use the Bai-Perron's (1998, 2003) and Lee-Strazicich's (2003, 2004) tests for the identification of the structural break and locate the period before and after the crisis. Then, we investigate VAR-BEKK GARCH models to study the volatility transfers, i.e. how different volatilities influence each other. It is thus possible to show how significantly the different foreign volatilities have influenced the volatility of Moroccan stock prices. The multivariate VAR(p)-GARCH$(1,1)$ models enables us to explain the impact of return (volatility) spillover on the conditional mean (variance) of each time series. Furthermore, we use Wald tests to examine several hypotheses about spillovers in means and variances between the four foreign markets and the Moroccan one.

The structure of our paper is presented as follows. Section 1 briefly reviews the literature on volatility transmission. Special emphasis is given to research focussing on spillovers. In Section 2, we outline the methodology used to develop our empirical analysis. The data is described in Section 3, followed by structural break detection. Section 4 is devoted to our empirical results and discussions. Section 5 concludes.

2 Methodology

In this section we present the econometric tools we use to develop our empirical analysis. We intend to study whether the US subprime financial turmoil has had any statistically significant effect on the conditional volatility of stock prices in the Moroccan stock market, for which the BEKK methodology is adopted, developed by Engle and Kroner (1995). In order to do this study, we will test the spillover effects between the Moroccan stock market and the U.S., France, U.K. and Germany stock markets considering the pre- and post crisis periods. Therefore, we contribute to the literature of volatility spillovers and contagion among the financial markets around the financial crisis of 2007-2009. Firstly, we use the Bai-Perron's (1998, 2003) and Lee-Strazicich's

(2003, 2004) tests for the identification of the structural break and locate the period before and after the crisis. Secondly, we employ the VAR-BEKK GARCH approach to analyze the return and volatility spillover effects between the Moroccan market and the other considered markets.

2.1 Structural break tests

To identify the possible structural changes, we use two reliable tests which have been widely used on financial and macroeconomic time series for analysis of structural breaks : The first one is due to Bai and Perron (1998, 2003) who have pioneered the development of the endogenous method for multiple structural change models. Their method was superior and statistically sophisticated as compared to the exogenous method as it allowed simultaneous estimation of multiple break points. The second one is the Lee and Strazicich (2003, 2004) test which allows for two structural breaks in the trend under both the null and the alternative hypothesis of a unit root, and does not suffer from spurious rejection of the null.

2.1.1 Bai and Perron tests

First, we address the issue of estimating the number of breaks and their locations in the NASDAQ daily stock index series using Bai-Perron tests (1998, 2003). This approach allows the estimation of multiple structural shifts in a linear model estimated by least-squares. It is a selection procedure based on a sequence of tests to estimate consistently the number of changes. It focuses on the instability problem in the time.
When considering the standard linear regression model as following :

$$Y_t = X_t'\beta + Z_t^{'}\delta_j + u_t; \quad \text{for} \quad t = T_j + 1, \dots, T_{j+1} \quad \text{and} \quad j = 0, ..., m. \tag{1}$$

with Y_t is the observed dependent variable, X_t and Z_t are vectors of covariates, and β and δ_j are the corresponding vectors of coefficients. The parameter m is the number of breaks. The break points $(T_1, ..., T_m)$ are explicitly treated as unknown and for $j = 1, ..., m$, we have $\lambda_j = T_j/T$ with $0 < \lambda_1 < \lambda_2 < \cdots < \lambda_m < 1$. Note that in this structural change model, only δ_j coefficients are subject to change over time. The hypothesis that the regression coefficients remain constant is as follows :

$$H_0 : \quad \delta_j = \delta_0 \quad \text{for} \quad j = 1, \dots, m. \tag{2}$$

against the alternative that at least one coefficient varies over time.
The purpose is to estimate the unknown regression coefficients and the break dates $(\beta, \delta_0, \delta_1, \dots, \delta_m, T_1, \dots, T_m)$ when T observations on (Y_t, X_t, Z_t) are available.
Bai and Perron (1998) impose some restrictions on the possible values of the break dates. Indeed, they define

the following set for some arbitrary small positive number ϵ as following :

$$\lambda_\epsilon = \{(\lambda_1, \ldots, \lambda_m) \; ; \; |\lambda_{i+1} - \lambda_i| \geq \epsilon, \lambda_1 \geq \epsilon, \lambda_m \geq \epsilon\} \tag{3}$$

This condition is made to restrict each break date to be asymptotically distinct and bounded from the boundaries of the sample.

The estimation method considered by Bai and Perron (1998) is based on the least-squares. For each m- partition $(T_1, \ldots, T_m)$, the associated least-squares estimate of β and δ_j are obtained by minimizing the sum of squared residuals denoted $S_T(\hat{T}_1, \ldots, \hat{T}_m)$. Then the estimated break dates $(\hat{T}_1, \ldots, \hat{T}_m)$ are obtained as given below :

$$(\hat{T}_1, \ldots, \hat{T}_m) = arg \min_{(T_1, \ldots, T_m)} S_T(T_1, \ldots, T_m). \tag{4}$$

2.1.2 Lee and Strazicich tests

The LM unit-root tests proposed by Lee and Strazicich (2003, 2004) allow for until two breaks in the deterministic trend under both the null and the alternative hypotheses in a consistent manner. The tests employ a data generating process (DGP) as follows:

$$Y_t = \delta' Z_t + e_t, \qquad e_t = \beta e_{t-1} + \epsilon_t \tag{5}$$

where Z_t is a vector of exogenous variables and $(\epsilon_t) \sim iidN(0, \sigma^2)$. We consider two structural breaks as follows: Model A allows two changes in levels so that $Z_t = [1, t, D_{1t}, D_{2t}]'$, where D_{jt} is a dummy variable equal 1 if $t \geq T_{Bj} + 1$; and 0 otherwise and T_{Bj} represents the date the break. Model C allows two changes in both levels and trend, so that $Z_t = [1, t, D_{1t}, D_{2t}, DT_{1t}, DT_{1t}]'$, where $DT_{jt} = t - T_{Bj}$ if $t \geq T_{Bj} + 1$, $j = 1, 2$, and 0 otherwise.

Lee and Strazicich (2003) demonstrate that the asymptotic distribution of the null hypothesis of the endogenous structural two-breaks LM unit root test for model A is invariant to the location and size of the structural breaks. Although the invariance property does not hold strictly for the model C, the minimum LM test statistic, in contrast to the Lumsdaine and Papell (1997) test, does not diverge in the presence of structural breaks in the null, even when the breaks magnitude is large.

2.2 VAR(p)-GARCH($1,1$) model using the BEKK method

We consider a VAR(p)-GARCH($1,1$) model in a BEKK form. The BEKK kind of multivariate GARCH models (Engle and Kroner, 1995) allows to keep the interactions in the variances of multiple series. This is useful to show the volatility transfers from one market to another. Moreover, the BEKK kind of multivariate GARCH can be used in association with a VAR specification, allowing a computation of VAR-coefficients that are efficient and consistent even if the residuals of the classical VAR do not present a Gaussian distribution and a constant variance.

The mean equation is given by the following representation :

$$r_t = \alpha + \sum_{i=1}^{p} \beta(i) r_{t-i} + \epsilon_t \tag{6}$$

with $\epsilon_t \sim N(0, H_t)$, where the variance equation is given as follows :

$$H_t = C^{'}C + A_1^{'}(\epsilon_{t-1}\epsilon_{t-1}^{'})A_1 + B_1^{'}H_{t-1}B_1 \tag{7}$$

where the matrices $\beta(i)$, C, A_1 and B_1 are of dimension $d \times d$ (C is higher triangular), with d equals the number of equations. Because of paired matrices, symmetry and non negative definiteness of the conditional variance matrix H_t is assured (see Engle and Kroner, 1995).

In the case with 2 dimensions, we have :

1. For the mean equation (6):

$$r_t = \begin{pmatrix} r_{1t} \\ r_{2t} \end{pmatrix}, \alpha = \begin{pmatrix} \alpha_1 \\ \alpha_2 \end{pmatrix}, \beta(i) = \begin{pmatrix} \beta_{11}(i) & \beta_{12}(i) \\ \beta_{21}(i) & \beta_{22}(i) \end{pmatrix}_{\{i=1,\ldots,p\}}, \epsilon_t = \begin{pmatrix} \epsilon_{1t} \\ \epsilon_{2t} \end{pmatrix}$$

2. For the variance equation (7):

$$A_1 = \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix}, B_1 = \begin{pmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{pmatrix}, C = \begin{pmatrix} c_{11} & c_{12} \\ 0 & c_{22} \end{pmatrix}.$$

We note that in this BEKK model, a_{21} and a_{12} are different from each other, as are b_{21} and b_{12}.

The variance system has 11 parameters for two equations (24 for three equations). The parameters of the mean and the variance equation are estimated by maximum likelihood.

We estimate a series of bivariate models based on the equations 6 and 7 above in order to capture cross market return and volatility spillovers :

$$r_{1t} = \alpha_1 + \sum_{i=1}^{p} \beta_{11}(i) r_{1t-1} + \sum_{i=1}^{p} \beta_{12}(i) r_{2t-1} + \epsilon_{1t} \tag{8}$$

$$r_{2t} = \alpha_2 + \sum_{i=1}^{p} \beta_{21}(i) r_{1t-1} + \sum_{i=1}^{p} \beta_{22}(i) r_{2t-1} + \epsilon_{2t} \tag{9}$$

The simultaneous estimation of the parameters in the mean and in the variance equations is reached by maximum likelihood.

To explain the volatility transfers between markets in the framework of a BEKK-kind of VAR(p)- GARCH(1,1) model for 2 variables, we consider the following variance equations :

$$\begin{aligned}
h_{11t} &= a_{11}\big(a_{11}\epsilon^2_{1t-1} + a_{21}\epsilon_{1t-1}\epsilon_{2t-1}\big) + a_{21}\big(a_{11}\epsilon_{1t-1}\epsilon_{2t-1} + a_{21}\epsilon^2_{2t-1}\big) \\
&\quad + b_{11}\big(b_{11}h_{11t-1} + b_{21}h_{12t-1}\big) + b_{21}\big(b_{11}h_{21t-1} + b_{21}h_{22t-1}\big) + c^2_{11} \\
h_{12t} &= a_{11}\big(a_{12}\epsilon^2_{1t-1} + a_{22}\epsilon_{1t-1}\epsilon_{2t-1}\big) + a_{21}\big(a_{12}\epsilon_{1t-1}\epsilon_{2t-1} + a_{22}\epsilon^2_{2t-1}\big) \\
&\quad + b_{11}\big(b_{12}h_{11t-1} + b_{22}h_{12t-1}\big) + b_{21}\big(b_{12}h_{21t-1} + b_{22}h_{22t-1}\big) + c_{11}c_{12} \\
h_{21t} &= a_{12}\big(a_{11}\epsilon^2_{1t-1} + a_{21}\epsilon_{1t-1}\epsilon_{2t-1}\big) + a_{22}\big(a_{11}\epsilon_{1t-1}\epsilon_{2t-1} + a_{21}\epsilon^2_{2t-1}\big) \\
&\quad + b_{12}\big(b_{11}h_{11t-1} + b_{21}h_{12t-1}\big) + b_{22}\big(b_{11}h_{21t-1} + b_{21}h_{22t-1}\big) + c_{11}c_{12} \\
h_{22t} &= a_{12}\big(a_{12}\epsilon^2_{1t-1} + a_{22}\epsilon_{1t-1}\epsilon_{2t-1}\big) + a_{22}\big(a_{12}\epsilon_{1t-1}\epsilon_{2t-1} + a_{22}\epsilon^2_{2t-1}\big) \\
&\quad + b_{12}\big(b_{12}h_{11t-1} + b_{22}h_{12t-1}\big) + b_{22}\big(b_{12}h_{21t-1} + b_{22}h_{22t-1}\big) + c^2_{12} + c^2_{22}
\end{aligned}$$

The presence of return and volatility spillovers is examined by testing the validity of restrictions on the above model. So, we test spillovers in means and variances by placing restrictions on the relevant parameters and computing the following Wald test :

$$W = [R\hat{\theta}]^{'}[R\,Var(\hat{\theta})R^{'}]^{-1}[R\hat{\theta}] \tag{10}$$

where R is the $q \times k$ matrix of restrictions with q equal to the number of restrictions and k equal to the number regressors ; $\hat{\theta}$ is a $k \times 1$ vector of the estimated parameters, and $Var(\hat{\theta})$ is the heteroscedasticity robust consistent estimator for the covariance matrix of the parameter estimates. The tests involve joint hypotheses at 2, p, $2p+4$ degrees of freedom (k). Specifically, hypotheses that allow for no spillovers in mean, no spillovers in variance and no spillovers in both were tested :

Hypotheses: No Spillovers in mean

$$H_1 : \beta_{12}(1) = \beta_{12}(2) = \cdots = \beta_{12}(p) = 0\,, \qquad H_2 : \beta_{21}(1) = \beta_{21}(2) = \cdots = \beta_{21}(p) = 0$$

Hypotheses: No Spillovers in variance

$$H_3 : a_{12} = b_{12} = 0\,, \qquad H_4 : a_{21} = b_{21} = 0$$

Hypothesis : No Spillovers

$$H_5 : \beta_{12}(1) = \cdots = \beta_{12}(p) = \beta_{21}(1) = \cdots = \beta_{21}(p) = a_{12} = b_{12} = a_{21} = b_{21} = 0.$$

3 Data and structural break detection

In this section, we firstly present the description of the different data used in our analysis. Secondly, we apply the tests discussed in the previous section for structural break detection.

3.1 Data description

The Casablanca Stock Exchange (CSE), which achieves one of the best performances in the region of the Middle East and North Africa (MENA), is Africa's third largest Bourse after Johannesburg Stock Exchange (South Africa) and Nigerian Stock Exchange in Lagos. Originally, CSE had the "Indice General Boursier" (IGB) as an index. IGB was replaced on January 2002 by two indices: MASI (Moroccan All Shares Index) and MADEX (Moroccan Most Active Shares Index). The Open Market Days are Monday-Friday and the financial market trading hours are 9:00 AM to 03:30 PM (GMT/GMT+1 in the summer).

In our empirical studies, we consider the stock market indices, namely, MASI (Morocco), NASDAQ 100 (Unites States), CAC 40 (France), FTSE 100 (United Kingdom), and DAX 30 (Germany). These indices are extensively based on financial and econometric literature and are considered as the most comprehensive index for the above countries. The sample sets of data used are daily closing prices of the five indices from January 2002 to December 2012 excluding holidays (2869 observations).

We compute the returns (Stock return, R_{it} is measured as logarithmic difference of the price series, P_{it} as follows: $R_{it} = 100 * ln(P_{it}/P_{i(t-1)})$) for each index. Panel 1 displayed in the Appendix shows the dynamics of all return series.

3.2 Testing for the structural breaks

In order to analyze the spillover effects between Moroccan market and the four other considered markets before and after the subprime crisis, we first estimate the break point due to the subprime crisis on NASDAQ index using the unit root tests with multiple structural breaks of Bai-Perron (1998, 2003) and Lee-Strazicich (2003, 2004). It figures out from our analysis that September 26, 2008 is break date which occurred due to the US subprime crisis[1].

First, we use the methodology proposed by Lee-Strazicich. Thus, the one lag (k=1) included in the Equation (5) is chosen to eliminate residuals autocorrelations. According to the results, the unit root null is rejected. The break dates March 10, 2003 and September 26, 2008 which minimize the LM statistics correspond respectively to the reverse of the U.S. economy after the stock market downturn of 2002 and the starting of the great recession of 2008. The Panel 3 displayed in the Appendix (figure in RHS) shows the NASDAQ index series

[1] Lehman Brothers, fourth-largest investment bank in the U.S. filed for Chapter 11 bankruptcy protection on September 15, 2008.

and its broken deterministic trend.

Further, we use the methodology proposed by Bai-Perron (1998, 2003) to identify the change dates in the mean of NASDAQ in order to confirm the break point due to the 2008 crisis identified by Lee-Strazicich tests. Our results show that five breaks occurred in the mean of NASDAQ between 2002 and 2012 including the same date related to the second break (September, 26, 2008) initially identified by Lee-Strazicich test[2]. Based on the Bai-Perron test results, the estimated time-varying mean is shown the Panel 3 (figure in LHS), displayed in the Appendix, along with observed NASDAQ index series. Between September 26, 2008 and July 22, 2009, the NASDAQ has crashed down around the mean 1,294 points.

We thus obtain evidence that September 26, 2008 can be used as break date due to the subprime crisis. In the following, we divide the overall sample data into two sub-periods: the pre-crisis (January 2, 2002-September 26, 2008: 1758 observations) and the post-crisis (September 29, 2008 - December 31, 2012: 1111 observations). Following the NASDAQ crash, the MASI and the three other European markets indices, shown in the Panel 2 displayed in the Appendix, appear to decrease dramatically around September 26, 2008.

3.3 Data preliminary analysis

Table A.1 given in the Appendix contains the summary statistics of the market returns in the full and two defined sub-periods. The kurtosis of all return series is much larger than three. Further, the Jarque-Berra normality test ($p<0.0001$) reveals a statistically significant deviation of the data form normality. The Ljung-Box test Q statistics confirm the presence of autocorrelation on the return series. The Ljung-Box test for heteroscedasticity, Q^2 statistics, is significant ($p<0.0001$) for all squared returns, which confirm the presence of heteroscedasticity in all return sample series. The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) test statistics for all return series are less than their critical values at the 1%. This clearly shows that the return series have no unit roots. Thus, there is no need to differentiate the data to use the VAR-GARCH model approach.

The Unrestricted Bivariate VAR-BEKK model outlined above is estimated in pre- and post-crisis periods for the countries pairs (1) Morocco-U.S., (2) Morocco-France, (3) Morocco-U.K. and (4) Morocco-Germany. To identify the most appropriate lag order for the VAR model, we use information criteria including Akaike Information Criterion (AIC), the Schwarz Bayesian Criterion (SBC) and the Hannan-Quinn Criterion (HQ). For the pre-crisis period, we choose respectively 1, 1, 3 and 2 as lag lengths for the pairs (1) to (4). For the post-period crisis, we adopt for the same pairs the lags 1, 2, 5 and 2 respectively.

Granger causality tests of the previous lag orders indicate evidence concerning the existence of spillover effects

[2] Using Bai-Perron structural break test we find 8/28/2003, 10/11/2006, 9/26/2008, 7/22/2009, 11/30/2010 as break points occurred between 2002 and 2012.

from the considered economic partners to Morocco in the pre-crisis period and from the U.S. and the U.K. in the post-crisis period. Moreover, the tests show also that there is also spillover effects from Morocco to France and U.K. in the same period (See Table A.4 in the Appendix).

4 Empirical results

Using the VAR-GARCH framework with the BEKK representation, we examine in our empirical analysis the return and volatility spillover effects between four matures stock markets (U.S., France, U.K. and Germany) and the local Moroccan stock market before and during the global crisis period. In the Appendix, we present in the Tables A2-A3 the estimation results of the bivariate VAR-BEKK GARCH model in pre- and post-crisis periods for each pair: Morocco-U.S., Morocco-France, Morocco-U.K. and Morocco-Germany.

To analyze the phenomenon of return and volatility spillovers between the foreign stock markets and the Moroccan stock market, we propose in the following two subsections. In the first one, we interpret the significance of our estimated BEKK persistence parameters. In the second, we analyze the return and volatility spillover effects between the four considered foreign markets and the Moroccan market in the pre- and post-crisis periods.

4.1 Shocks and volatility persistence

According to Tables A2-A3, all a_{ii} and b_{ii} estimated coefficients of BEKK model in the pre- and post-crisis periods are statistically significant at 1% level. The significance of estimated coefficients a_{ii} means that news/shocks in a specific market are of great importance for future volatility in that specific market. In absolute value, the estimated coefficients a_{11} are higher than a_{22}. This means that the news/shocks have more impact on the volatility in Moroccan market compared to U.S. and European markets. Furthermore, the significantly high estimated coefficients b_{11} and b_{22} indicate the highly persistence of volatility in all the five markets. The estimated coefficients b_{22} are higher than b_{11}. That is, the own past volatility effects the conditional variance in the foreign equity markets persist more compared to the Moroccan one.
Note that for all countries pairs, the estimated coefficient a_{11} was negative in pre-crisis period and positive in post-crisis period. So it means that the Moroccan market volatility is more sensitive to market events in the post-crisis period.

4.2 Spillover effects of U.S. financial crisis on the Moroccan stock market

As generally used in the literature, the existence of volatility spillovers implies that one large shock increases the volatility not only in its own asset or market but also in other assets or markets. The study of volatility spillovers can be helpful when considering the importance and extend of financial volatility linkages across countries. In this sub-section, we compare the return and volatility spillover effects between the four considered foreign stock markets and Moroccan stock market during the crisis and tranquil periods. In the Appendix, Tables A2-A3 give estimation results of the bivariate VAR-BEKK GARCH model in pre- and post-crisis periods for each pair: Morocco-U.S., Morocco-France, Morocco-U.K. and Morocco-Germany.

Furthermore, Table A.5 summarises the results obtained from the outlined above testing methodology about mean and volatility spillovers between foreign stock markets and Moroccan stock market. These results are consistent with the above Granger causality tests (see Table A.4). It is interesting to note that the test statistics for the hypothesis of no spillovers during the Turmoil period always have high values than during the calm period except for the pair Morocco-U.S. This indicates that the 2008 financial crisis led to increase of market linkages between European considered countries and Morocco.

4.2.1 Pre-crisis period

The off-diagonal elements of matrices $\beta(i)$ ($\beta_{12}(i)$, $\beta_{21}(i)$), A (a_{12}, a_{21}) and B (b_{12}, b_{21}) of the VAR-BEKK GARCH model capture the cross-market effects, such as, return and volatility spillovers among the four pairs. Regarding the shock transmissions between the Moroccan market and others in the pre-crisis period, the results displayed in first half of Table A.5 suggest that unidirectional mean spillover effects exist from U.S., France, U.K. and Germany to Morocco (H_1). On the second hand, there is no significant volatility spillover between the foreign markets and the Moroccan market (H_3 and H_4). These results give clear evidence that, before the subprime crisis, mean spillovers existed from the U.S., France, U.K. and Germany markets to Moroccan Market.

4.2.2 Post-crisis period

As it was pointed out in the existing literature, the correlations among the markets and countries show an increasing trend in the crisis period. To analyze the shock and volatility transmission in the post-crisis between the Moroccan market and the four foreign markets, we refer to the second half of Table A.5 displayed in the Appendix. Hypothesis 1 does not accept the restrictions on the coefficients $\beta_{12}(i)$ for the pair Morocco-U.K. at 1% level. This indicates that, during the crisis period, unidirectional mean spillover effects exist from the U.K. market to the Moroccan market. This provides evidence supporting return spillover from U.K. to Morocco. On other hand, Hypothesis 4 is rejected at 1% level for the pairs Morocco-France and Morocco-Germany. The results indicate that the parameters, capturing volatility spillovers from moroccan market, change during the turbulent period in the French and German markets[3]. This consistent finding is in favor of increasing volatility

[3]The results for France and Germany are in line with those obtained by Beirne et al. (2008)

linkage between the Moroccan stock market and the European considered stock markets (France, U.K. an Germany) during the last financial crisis.

5 Conclusion

The current international financial crisis which started in U.S. has revealed a high interdependence between financial markets worldwide. The aim of this paper focuses to empirically investigate the return and volatility spillover effects between the Moroccan stock market and the France, U.S., U.K. and Germany stock markets over the period of 2002-2012. The paper contributes to the literature of volatility spillovers among the financial markets around the financial crisis of 2007-2009. Firstly, we use the Bai-Perron's (1998, 2003) and Lee-Strazicich's (2003, 2004) tests to estimate the break point, due the subprime crisis, found equals to 09/26/2008. Secondly, the flexible multivariate VAR-BEKK model was applied to examine the return and volatility spillovers between the four foreign markets (U.S., France, U.K. and Germany) and the Moroccan market in the pre- and post-crisis periods.

The presence of a significant return and volatility spillovers between the considered economic partners and Morocco was pointed. We find that in the pre-crisis period there was positive return spillover effects from the four considered foreign markets to Moroccan stock market. The same spillover effects was also significantly present from the British stock market to the Moroccan one in the post-crisis period. Moreover, we found that such volatility spillover effects are present in the post-crisis period from Moroccan stock market to French and German stock markets.

Given these latter findings, it is apparent that the recent global financial crisis leads to increase the financial linkages between Moroccan market and the other considered markets. This rising integration can be usefully considered by the international investors in their trading strategy which consists of taking a position in one market following the signals given by the volatility of another market. A good understanding of the volatility spillover effect is an important ingredient for designing trading and hedging strategies and optimizing portfolios.

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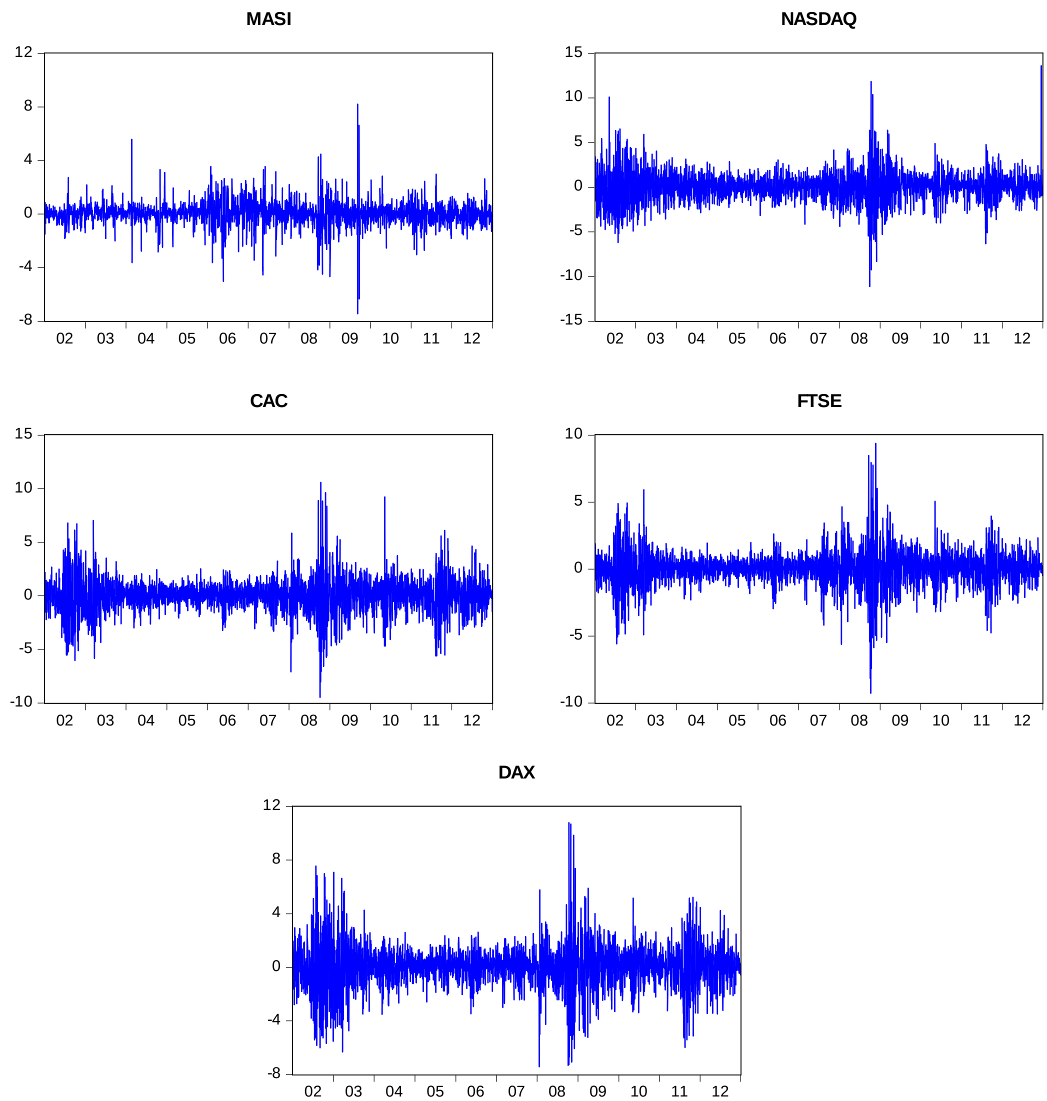
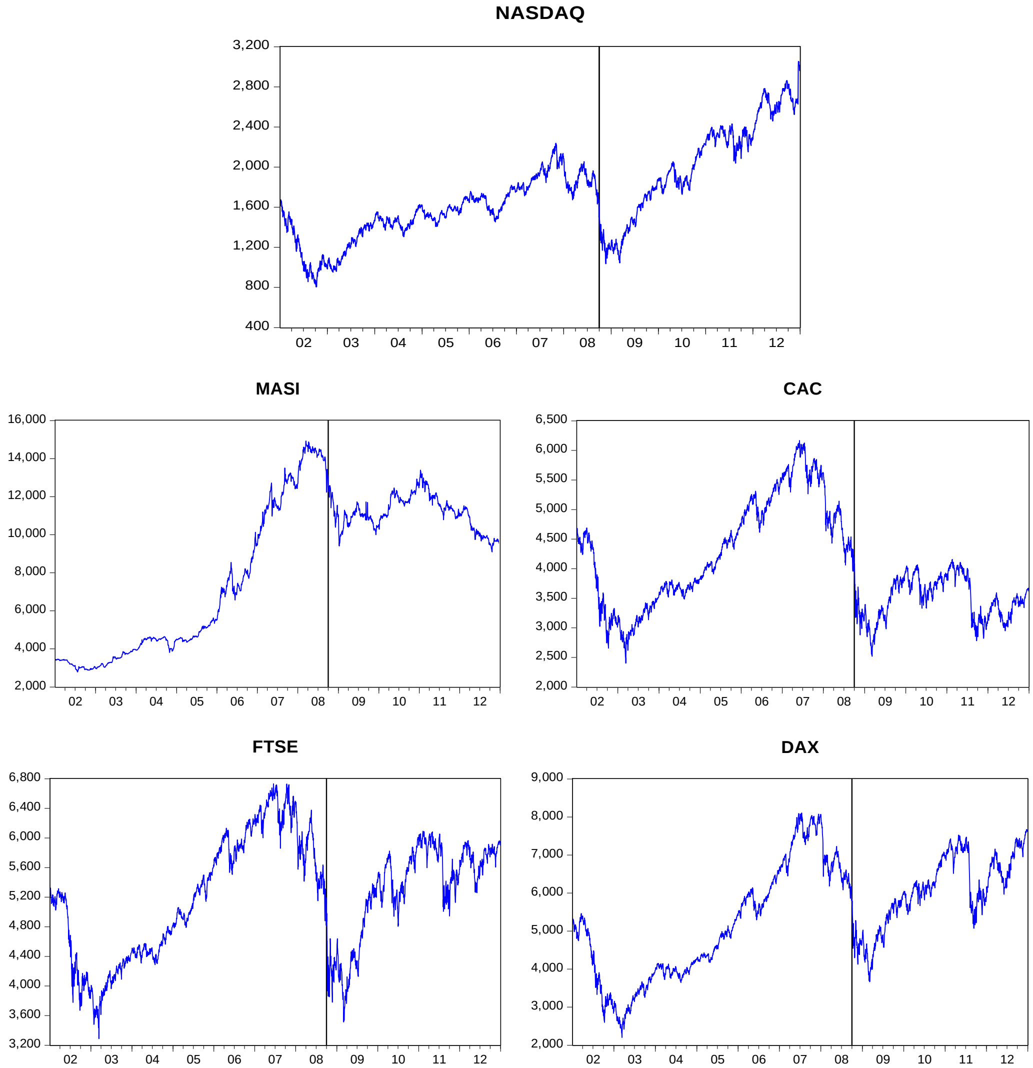
6 Appendix

Panel 1 : Stock Index returns



Panel 2 : Daily Stock Market Indices with the crisis break line (09/26/2008)



Panel 3 : Structural changes in the NASDAQ series

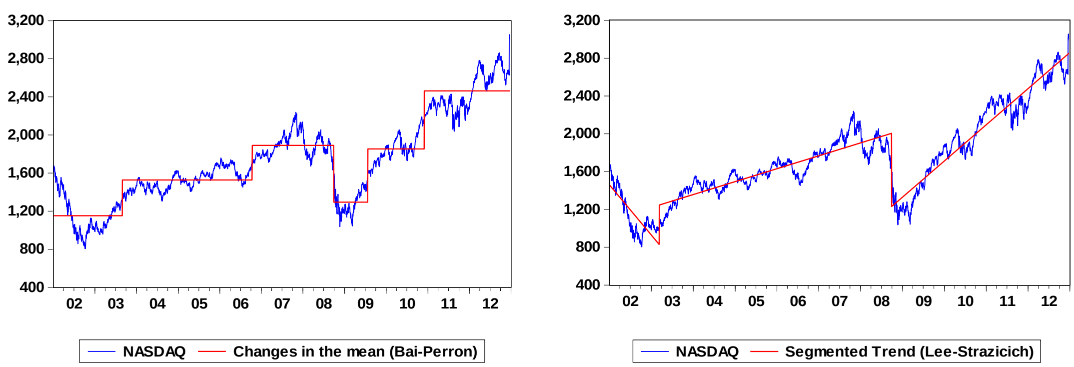


Table A.1 : Descriptive statistics of return series

	Full Period (January 3, 2002 to December 31, 2012)				
	MASI	**NASDAQ**	**CAC**	**FTSE**	**DAX**
Mean	0.035	0.022	-0.008	0.004	0.014
Median	0.019	0.044	0.000	0.000	0.044
Maximum	8.192	13.588	10.595	9.384	10.797
Minimum	-7.435	-11.115	-9.472	-9.265	-7.433
Std. Dev.	0.859	1.617	1.556	1.280	1.595
Skewness	-0.163	0.259	0.084	-0.122	0.059
Kurtosis	14.235	9.392	8.275	9.864	7.688
Jarque-Bera	15096.8***	4914.3***	3328.9***	5637.3***	2627.4***
Ljung-Box Q(24)	169.1***	47.8***	70.4***	92.0***	35.6*
Ljung-Box $Q^2(24)$	820.4***	1991.7***	2856.7***	3702.1***	3118.2***
ADF	-42.6***	-58.5***	-26.8***	-26.0***	-54.9***
PP	-42.3***	-58.9***	-56.4***	-57.1***	-55.1***
(Observations : 2868)	Significance level: *** 1%, ** 5%, *10%				

	Pre-Crisis Period (January 3, 2002 to September 26, 2008)				
	MASI	**NASDAQ**	**CAC**	**FTSE**	**DAX**
Mean	0.076	0.002	-0.005	-0.001	0.009
Median	0.054	0.022	0.000	0.000	0.045
Maximum	5.564	10.097	8.868	8.469	7.553
Minimum	-5.017	-6.191	-7.077	-5.637	-7.433
Std. Dev.	0.824	1.544	1.379	1.148	1.498
Skewness	-0.268	0.191	0.093	0.041	-0.049
Kurtosis	9.459	5.579	7.366	8.058	6.684
Jarque-Bera	3075.0***	497.5***	1397.9***	1873.1***	994.5***
Ljung-Box Q(24)	199.2***	41.3**	78.5***	102.9***	57.4***
Ljung-Box $Q^2(24)$	634.5***	1605.1***	1950.4***	1394.7***	2815.4***
ADF	-30.2***	-45.8***	-44.2***	-27.8***	-44.7***
PP	-30.0***	-46.0***	-44.9***	-47.1***	-44.8***
(Observations : 1757)	Significance level: *** 1%, ** 5%, *10%				

	Post-Crisis Period (September 29, 2008 to December 31, 2012)				
	MASI	**NASDAQ**	**CAC**	**FTSE**	**DAX**
Mean	-0.031	0.052	-0.013	0.011	0.019
Median	0.000	0.062	0.000	0.001	0.041
Maximum	8.192	13.588	10.595	9.384	10.797
Minimum	-7.435	-11.115	-9.472	-9.265	-7.336
Std. Dev.	0.908	1.725	1.801	1.466	1.738
Skewness	-0.001	0.324	0.078	-0.247	0.167
Kurtosis	19.310	13.033	7.904	10.019	8.243
Jarque-Bera	12325.4***	4683.5***	1115.4***	2293.9***	1278.8***
Ljung-Box Q(24)	39.6**	28.3	41.8**	52.6***	26.8
Ljung-Box $Q^2(24)$	318.1***	626.1***	785.2***	1269.1***	893.9***
ADF	-30.1***	-36.3***	-34.0***	-16.1***	-25.2***
PP	-29.9***	-36.5***	-34.5***	-34.1***	-32.6***
(Observations : 1111)	Significance level: *** 1%, ** 5%, *10%				

Table A.2 : Bivariate VAR BEKK-GARCH (1,1) model estimations
- Pre-Crisis Period –

	Morocco-USA		Morocco-France		Morocco-UK		Morocco-Germany	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
α_1	0.054***	(0.014)	0.058***	(0.014)	0.054***	(0.015)	0.055***	(0.015)
α_2	0.037	(0.031)	0.068***	(0.023)	0.06***	(0.02)	0.077***	(0.026)
$\beta_{11}(1)$	0.257***	(0.03)	0.254***	(0.029)	0.264***	(0.031)	0.250***	(0.030)
$\beta_{12}(1)$	0.021**	(0.008)	0.030***	(0.01)	0.053***	(0.012)	0.023***	(0.009)
$\beta_{21}(1)$	0.008	(0.035)	-0.006	(0.029)	-0.020	(0.024)	0.017	(0.033)
$\beta_{22}(1)$	-0.077***	(0.027)	-0.080***	(0.025)	-0.099***	(0.027)	-0.056**	(0.025)
$\beta_{11}(2)$	-	-	-	-	-0.004	(0.031)	0.006	(0.031)
$\beta_{12}(2)$	-	-	-	-	0.004	(0.013)	-0.005	(0.009)
$\beta_{21}(2)$	-	-	-	-	0.014	(0.026)	0.001	(0.033)
$\beta_{22}(2)$	-	-	-	-	-0.002	(0.027)	0.037	(0.026)
$\beta_{11}(3)$	-	-	-	-	0.009	(0.028)	-	-
$\beta_{12}(3)$	-	-	-	-	0.011	(0.013)	-	-
$\beta_{21}(3)$	-	-	-	-	-0.005	(0.024)	-	-
$\beta_{22}(3)$	-	-	-	-	-0.053**	(0.026)	-	-
c_{11}	0.184***	(0.021)	0.201***	(0.026)	0.194***	(0.022)	0.195***	(0.023)
c_{21}	-0.002	(0.029)	0.051**	(0.021)	0.045**	(0.018)	0.040	(0.024)
c_{22}	0.045	(0.037)	0.103***	(0.022)	0.073***	(0.019)	0.119***	(0.023)
a_{11}	-0.497***	(0.029)	-0.485***	(0.033)	-0.489***	(0.032)	-0.479***	(0.033)
a_{12}	-0.049*	(0.030)	-0.043	(0.027)	-0.020	(0.024)	-0.040	(0.031)
a_{21}	0.011	(0.010)	-0.009	(0.013)	-0.015	(0.016)	-0.013	(0.011)
a_{22}	-0.154***	(0.013)	-0.261***	(0.019)	-0.273***	(0.020)	-0.242***	(0.018)
b_{11}	0.855***	(0.017)	0.853***	(0.021)	0.855***	(0.018)	0.858***	(0.020)
b_{12}	-0.025*	(0.014)	-0.031**	(0.015)	-0.020*	(0.012)	-0.025	(0.016)
b_{21}	0.004	(0.003)	-0.003	(0.004)	-0.005	(0.005)	-0.003	(0.003)
b_{22}	0.988***	(0.002)	0.963***	(0.005)	0.961***	(0.005)	0.966***	(0.005)

Note: *, **, * denote significance at the 1%, 5% and 10% levels respectively.**

Table A.3 : Bivariate VAR BEKK-GARCH (1,1) model estimations
- Post-Crisis Period -

	Morocco-USA		Morocco-France		Morocco-UK		Morocco-Germany	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
α_1	-0.011	(0.020)	0.001	(0.022)	-0.020	(0.020)	0.001	(0.021)
α_2	0.154***	(0.041)	0.035	(0.042)	0.068**	(0.034)	0.054	(0.037)
$\beta_{11}(1)$	0.169***	(0.036)	0.210***	(0.037)	0.153***	(0.038)	0.199***	(0.038)
$\beta_{12}(1)$	0.028*	(0.015)	0.018	(0.014)	0.035**	(0.017)	0.033**	(0.015)
$\beta_{21}(1)$	0.076*	(0.045)	0.017	(0.05)	0.048	(0.038)	0.008	(0.045)
$\beta_{22}(1)$	-0.074**	(0.034)	-0.019	(0.032)	-0.019	(0.032)	-0.001	(0.033)
$\beta_{11}(2)$	-	-	-0.038	(0.037)	0.017	(0.039)	-0.038	(0.037)
$\beta_{12}(2)$	-	-	-0.005	(0.013)	-0.01	(0.016)	-0.008	(0.013)
$\beta_{21}(2)$	-	-	-0.056	(0.046)	-0.038	(0.038)	-0.001	(0.047)
$\beta_{22}(2)$	-	-	-0.011	(0.034)	-0.032	(0.032)	-0.014	(0.033)
$\beta_{11}(3)$	-	-	-	-	-0.134***	(0.034)	-	-
$\beta_{12}(3)$	-	-	-	-	0.034**	(0.015)	-	-
$\beta_{21}(3)$	-	-	-	-	-0.002	(0.036)	-	-
$\beta_{22}(3)$	-	-	-	-	-0.076**	(0.031)	-	-
$\beta_{11}(4)$	-	-	-	-	-0.039	(0.034)	-	-
$\beta_{12}(4)$	-	-	-	-	0.051***	(0.017)	-	-
$\beta_{21}(4)$	-	-	-	-	0.004	(0.037)	-	-
$\beta_{22}(4)$	-	-	-	-	0.033	(0.032)	-	-
$\beta_{11}(5)$	-	-	-	-	-0.004	(0.033)	-	-
$\beta_{12}(5)$	-	-	-	-	-0.018	(0.016)	-	-
$\beta_{21}(5)$	-	-	-	-	-0.021	(0.035)	-	-
$\beta_{22}(5)$	-	-	-	-	-0.018	(0.031)	-	-
c_{11}	0.273***	(0.026)	0.295***	(0.031)	0.268***	(0.021)	0.287***	(0.028)
c_{21}	0.054	(0.041)	0.075	(0.074)	0.003	(0.033)	0.04	(0.045)
c_{22}	0.227***	(0.032)	0.243***	(0.058)	0.129***	(0.027)	0.163***	(0.04)
a_{11}	0.458***	(0.038)	0.41***	(0.035)	0.527***	(0.039)	0.411***	(0.037)
a_{12}	0.071*	(0.042)	-0.057	(0.043)	0.008	(0.038)	-0.038	(0.046)
a_{21}	-0.006	(0.021)	-0.118***	(0.025)	-0.027	(0.021)	-0.129***	(0.022)
a_{22}	0.255***	(0.027)	-0.345***	(0.054)	0.267***	(0.024)	-0.314***	(0.034)
b_{11}	0.843***	(0.020)	0.823***	(0.021)	0.814***	(0.018)	0.821***	(0.02)
b_{12}	-0.043**	(0.020)	0.017	(0.026)	-0.015	(0.019)	0.009	(0.032)
b_{21}	-0.002	(0.007)	-0.039**	(0.018)	0.009	(0.007)	-0.038***	(0.01)
b_{22}	0.955***	(0.008)	0.93***	(0.022)	0.958***	(0.007)	0.946***	(0.011)

Note: ***, **, * denote significance at the 1%, 5% and 10% levels respectively.

Table A.4 : Granger Test

Pre-Crisis Period (January 3, 2002 to September 26, 2008)

Null Hypothesis	F-statistic	Prob.	Conclusion
NASDAQ does not Granger Cause MASI	5.608**	0.018	NASDAQ → MASI
CAC does not Granger Cause MASI	8.984***	0.002	CAC → MASI
FTSE does not Granger Cause MASI	12.928***	0.005	FTSE → MASI
DAX does not Granger Cause MASI	6.985**	0.030	DAX → MASI
MASI does not Granger Cause NASDAQ	0.081	0.776	MASI ↛ NASDAQ
MASI does not Granger Cause CAC	2.050	0.152	MASI ↛ CAC
MASI does not Granger Cause FTSE	4.963	0.175	MASI ↛ FTSE
MASI does not Granger Cause DAX	4.188	0.123	MASI ↛ DAX

Significance level: *** 1%, ** 5%, *10%

Post-Crisis Period (September 29, 2008 to December 31, 2012)

Null Hypothesis	F-statistic	Prob.	Conclusion
NASDAQ does not Granger Cause MASI	12.450***	0.000	NASDAQ → MASI
CAC does not Granger Cause MASI	1.139	0.566	CAC ↛ MASI
FTSE does not Granger Cause MASI	11.553**	0.042	FTSE → MASI
DAX does not Granger Cause MASI	2.874	0.238	DAX ↛ MASI
MASI does not Granger Cause NASDAQ	0.135	0.713	MASI ↛ NASDAQ
MASI does not Granger Cause CAC	8.294**	0.016	MASI → CAC
MASI does not Granger Cause FTSE	16.856***	0.005	MASI → FTSE
MASI does not Granger Cause DAX	2.559	0.278	MASI ↛ DAX

Significance level: *** 1%, ** 5%, *10%

Table A.5 : Wald Tests

Period	Country	No spillovers in mean		No spillovers in variance		No spillovers
		H_1 : $\beta_{12}(1)=\ldots=\beta_{12}(p)=0$	H_2 : $\beta_{21}(1)=\ldots=\beta_{21}(p)=0$	H_3 : $a_{12}=b_{12}=0$	H_4 : $a_{21}=b_{21}=0$	H_5 : $\beta_{12}(1)=\ldots=\beta_{12}(p)=\beta_{21}(1)=\ldots=\beta_{21}(p)=0$ $a_{12}=b_{12}=a_{21}=b_{21}=0$
Pre-Crisis Period (January 3, 2002 to September 26, 2008)	U.S.	6.138**	0.048	3.179	2.254	11.279*
	France	9.147***	0.047	4.445	0.608	15.544**
	U.K.	18.765***	0.853	3.741	1.191	25.527***
	Germany	7.532**	0.324	2.471	1.626	12.511
Post-Crisis Period (September 29, 2008 to December 31, 2012)	U.S.	3.418*	2.894*	4.328	0.605	8.881
	France	1.741	1.553	2.184	32.650***	43.370***
	U.K.	20.516***	3.171	1.276	2.099	25.651**
	Germany	4.865*	0.035	1.247	34.098***	49.710***

Significance level: *** 1%, ** 5%, *10%