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## **Contagion Effect of Financial Crisis on OECD Stock Markets**

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**Abstract** In this paper we investigate the contagion effect between stock markets of U.S and sixteen OECD countries due to Global Financial Crisis (2007-2009). We apply Dynamic Conditional Correlation GARCH model Engle (2002) to daily stock price data (2002-2009). In order to recognize the contagion effect, we test whether the mean of the DCC coefficients in crisis period differs from that in the pre-crisis period. The identification of break point due to the crisis is made by Bai-Perron (1998, 2003) structural break test. We find a significant increase in the mean of dynamic conditional correlation coefficient between U.S and OECD stock markets under study during the crisis period for most of the countries. This proves the existence of contagion between the US and the OECD stock markets.

**JEL** E44, F15, F36, F41

**Keywords** Financial crisis; integration; contagion, multivariate GARCH-DCC model

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## 1 INTRODUCTION

Almost all economies of the world go through some tremors and shocks during the complex interplay of their economic activity. In the case of The United States of America (USA), these tremors and shocks play a greater role as its economy is the largest in the world, and its propagation throughout the world could bring the financial life to stagnation. The global financial Crisis of 2007-2009 is generally recognized as one of the most severe since the Great Depression of 1929 and will be well-known in the books of history and finance. Former Chief Economist at International Monetary Fund and Professor of Economics and Public Policy at Harvard University, Kenneth Rogoff, described the global financial crisis as "*a once in a 50-year event*". This tsunami of financial catastrophe could be traced back to the beginning of the US housing boom and an inevitable burst (also known as Subprime Crisis). Like other crises in history, the seeds for the Subprime Crisis were also sown in good times. The Federal Reserve reduced the Fed fund rate from 6.5 in May 2000 to 1.75% in December 2001. This led to a flood of liquidity and the money washed through the economy like water rushing through a broken dam (Commission 2011). Lower interest rates supported by large inflows of foreign capital created easy credit conditions which helped fuel the boom. On one hand, the bankers and other lenders were busy in lending to any one in search of a mortgage loan; and on the other hand, these lenders were busy in repackaging these loans into securities (CBOs and MBOs) and reselling to investors around the world. This included securitization firms and investment banks such as Merrill Lynch, Bear Stearns, and Lehman Brothers, and commercial banks and thrifts such as Citibank, Wells Fargo, and Washington Mutual. In October 2004, the Securities Exchange Commission reduced the capital requirement for 5 investment banks including Lehman Brothers, Bear Stearns and Morgan Stanley which helped these banks to leverage their investments by 30 to 40 times. These hey days came to an end when the Fed Reserve Bank decided to raise Fed fund rate on 30 June, 2004. Till mid-2006 this rate reached a level of 5.25%. Down-turns in the housing industry can cause ripple effects almost everywhere. But this is what was not predicted, as in the words of Warren Buffet, "very, very few people could appreciate the bubble" which he called "a mass delusion" shared by "300 million Americans"(Commission 2011). By early 2004, the Subprime Crisis started showing signs in the form of declining housing prices, higher interest rates, and many of the mortgage loan borrowers were in no position to pay for their liabilities and started to default on their loans. Consequently, in the year 2007, bankruptcy applications were filed by subprime lenders. This severely affected banks and other financial institutions around the globe. Largest banks around the globe started writing down their holdings of sub-prime mortgage-backed securities. And ultimately, this housing bubble burst in August of 2007 and the Northern Rock failed in UK which gave birth to the global financial crisis. On October 15, 2007 the president of Federal Reserve in speech admitted that the small US Subprime Crisis was having a large impact on global financial markets. This view strengthens our argument for the selection of structural break date of 01/10/2007 using Bai Perron(1993) Structural Break test. Equity markets play an important role in the economic growth of any nation. These markets are generally recognized as the barometer of the economic health of any nation. Problems with the underlying economic factors are readily indicated by the country's equity markets. The objective of our research is to look into the phenomenon of contagion among the OECD countries due to the US Financial Crisis (2007-2009). Therefore, we have taken representative country indices of the USA and the rest of sixteen OECD countries. We use Bai Perron (1998) for the identification of the structural break and locate the period before and after the Crisis. To achieve our task of identification of the contagion effect, we use Dynamic Conditional Correlation (DCC) Garch Model of Engel (2002) for estimating time-varying correlation coefficients. Then we test if there is contagion effect of the financial crisis on OECD equity markets.

The rest of the paper is organized as follows. Section 2 presents literature review on equity market contagion, cointegration, and empirical studies. Section 3 gives the methodology to estimate both

structural change and the time varying correlation. Section 4 presents data analysis and the empirical results. Finally, section 5 provides conclusions.

## 2 REVIEW OF THE LITERATURE

In this section, we recall the main research papers on co-integration and contagion effect. Co-integration has become a common econometric tool for empirical analysis in numerous areas where long-run relationships affect currently observed value. In our research, we focus on studies on equity market integration. The idea behind analyzing linkages among international equity markets is to determine common forces driving the long-run movement of the data series, or to determine if each individual stock index is driven only by its own fundamentals. The existence of co-integration would indicate correlation among markets in a long term period and this could be captured by using co-integration analysis.

The relationship among national equity markets has been analyzed in a series of studies since the seminal work of Granger and Morgenstern (1970) where they studied market interdependence. Then, other researchers followed on national stock indices to study correlations : Ripley (1973), Lessard (1974,1976), Panton and *al.* (1976) where they noticed stock price co-movements due to factors such as geographical proximity, institutional currency relationships, partnerships in trade and on cultural and economic grounds.

Hilliard (1979) used spectrum analysis focusing on contemporaneous lagged correlations of daily stock prices, and found significant correlations for intercontinental stock prices but weak ones for intra-continental prices.

Engle and Granger (1987) developed statistical theories and techniques for testing, and parameter estimation for linear system with co-integration. In their paper, they summed up and extended the theory of co-integrated variables.

A group of researchers have used co-integration to assess the international integration of financial markets such as Johansen (1988) and Johansen and Juselius (1990), numerous studies beginning with Taylor and Tonks (1989), Kasa (1992) and, subsequently, Masih and Masih (1997, 2002), Chowdhry (1994) and Chowdhry and al (2007). Errunza and Losq (1987), Bekaert and Harvey (1995), and Heston and al. (1995) applied statistical models to study the time-varying co-integration property of different equity markets.

Some research was made to study the interdependence structure by focusing on the transmission mechanism. Engle and Granger (1987) opened the gates for a flood of applications. They enhanced the popularity of VAR models developed by Sims (1980) to offer an alternative to simultaneous equation models. Sims had emphasized the use of unrestricted VAR models as a means of modeling economic relationships. A VAR model with co-integration is often based on the idea of a "long-run" or moving equilibrium, defined by economic theory.

Moreover, Kumar and Mukhopadhyay (2002) used a two-stage GARCH model and an ARMA-GARCH model. Then Agarwal (2000) concluded that there is lots of scope for the Indian equity markets to integrate with the world market after having found a correlation coefficient of 0.01 between India and developed markets. By using Granger causality relationship and the pair wise, multiple and fractional co-integration, Wong, Agarwal and Du (2005) observe that the Indian equity markets are integrated with the matured markets of the World.

Similar to co-integration, there exists a large body of literature on contagion. It will not be wrong to say that the innovation of dynamic correlations for time series stimulated studies on the subject of contagion. Many events have occurred on the equity markets over the last three decades. The 1987 Crash, known as Black Monday, was a worldwide phenomenon. This crash was the greatest single-day loss that Wall Street had ever suffered in continuous trading. Between the start of trading on October 14 to the close on October 19, the DJIA lost 760 points, a decline of over 31%. As a consequence, in the month of October, all major world markets declined substantially. Out of 23 major industrial countries, 19 had a decline greater than 20%. This crash affected major equity

markets around the world. Hamao and *al.* (1990) examine equity markets around the 1987 U.S. Equity Markets Crash and find evidence of significant price-volatility spillovers from New York to London and Tokyo, and from London to Tokyo. In December 1994, the Mexican Market dropped significantly; this fall was quickly reflected in other Latin American Markets. In October 1997, the Hong Kong Equity Market declined sharply and then partially rebounded. This movement affected markets in North and South America, Europe, and Africa. Longin and Solnik (1995) further developed the work of Koch and Koch (1991) and Von Furstenberg and Jeon (1989). They considered seven OECD countries from 1960 to 1990 and report that average correlations in equity markets returns between the United States and other countries rose by about 0.36 over the period of 30 years. These cases show that dramatic movements in one equity market can have a powerful impact on markets of very different sizes and structures across the globe.

These cases lead us to think of the existence of a contagion effect. The definition of the term contagion varies widely across the literature. In our research, we assume that contagion appears if cross-market co-movement increases significantly after one shock. This is the restrictive definition of contagion given by Forbes and Rigobon (2000, 2002). We refer to this definition as it is widely used in the literature. It also allows us to define contagion as a positive shift in the degree of co-movement between asset returns.

There are many studies examining the existence of contagion effect of various crises on different equity markets in the world. Different methodologies have been utilized to measure how shocks are transmitted internationally: cross-market correlation coefficients, ARCH and GARCH models, co-integration techniques, and direct estimation of specific transmission mechanisms.

The initial empirical literature on financial contagion was the simple comparative analysis of Pearson' correlation coefficients between markets in calm and in crisis periods. Contagion was found when significant increases in correlations occurred in periods of crisis. King and Wadhvani (1990), and Lee and Kim (1993) employed the correlation coefficient between stock returns to test for the impact of the US stock crash in 1987 on the equity markets of several countries. Empirical findings show that the correlation coefficients between several markets significantly increased during the crash. Hamao and *al.* (1990) employed the conditional variance estimated under the GARCH model to test for correlations between market volatilities for the crisis of 1987. Edward and Susmel (2001) used switching ARCH model. They found that many Latin American equity markets, during the times of high market volatility, were significantly correlated which proved the existence of contagion effects.

Forbes (2000) studied the impact of the Asian and Russian crises on stock returns for a sample of over 10,000 companies around the world. It was observed that the trade linkages were important predictors of firms' stock returns to these crises.

In our paper, as already indicated, we formalize the idea of contagion by testing if there is a positive shift in the degree of co-movement between asset returns; we apply a Dynamic Conditional Correlation GARCH model Engle (2002) to daily stock price data (2002-2009). In order to recognize the contagion effect, we test whether the mean of the DCC coefficients in the crisis period differs from that in the pre-crisis stable period. The identification of break point due to the crisis is made by Bai-Perron (1998, 2003) structural break test.

### **3 DATA AND METHODOLOGY**

#### **3.1 DATA**

The dataset includes daily data for 17 OECD countries : USA (Nasdaq 100), Canada (TSX), Finland (Helsinki General), France (CAC 40), Germany (DAX 30), Ireland (ISEQ), Italy (Milan MIB), Netherlands (AEX), Spain (Madrid General Index), Denmark (KFX Copenhagen), Norway(Oslo Stock Exchange), Sweden (Stockholm Index), Switzerland (Zurich Swiss Market Index), UK (FTSE 100), Australia (All ordinaries Index), Japan (Nikkei 225), New-Zealand (New

Zealand Stock Exchange 50) from 02/01/2002 to 01/06/2009. We compute the growth rates<sup>1</sup> and remove the mean from each series. Our dataset is primarily drawn from *Ecwin* database.

### 3.2 METHODOLOGY

In this section we present the different econometric tools we use to develop our analysis.

First, we address the issue of estimating the number of breaks and their locations in the daily U.S. stock indexes series using Bai-Perron test (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:

$$y_t = x_t \beta_j + u_t \quad \text{for } t = T_{j-1} + 1, \dots, T_j \quad \text{and } j = 1, \dots, m+1 \quad (1)$$

with  $y_t$  is the observation of the dependent variable,  $x_t$  is a  $k \times 1$  vector of regressors' and  $\beta_j$  is the  $k \times 1$  vector of regression coefficients.

Note that in this structural change model, all the coefficients are subject to change over time.

The hypothesis that the regression coefficients remain constant is as follows:

$$H_0 : \beta_i = \beta_0 \quad \text{for } i = 1, \dots, n \quad (2)$$

against the alternative that at least one coefficient varies over time.

The parameter  $m$  is the number of breaks. The break points  $(T_1, \dots, T_m)$  are explicitly treated as unknown and for  $i = 1, \dots, m$ , we have  $\lambda_i = T_i / T$  with  $0 < \lambda_1 < \dots < \lambda_m < 1$ .

The purpose is to estimate the unknown regression coefficients and the break dates  $(\beta_1, \dots, \beta_{m+1}, T_1, \dots, T_m)$  when  $T$  observations on  $(y_t, x_t)$  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  $\varepsilon$  as following:

$$\lambda_\varepsilon = \{(\lambda_1, \dots, \lambda_m); |\lambda_{i+1} - \lambda_i| \geq \varepsilon, \lambda_1 \geq \varepsilon, \lambda_m \geq 1 - \varepsilon\} \quad (3)$$

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  $(T_1, \dots, T_m)$ , the associated least-squares estimate of  $\beta_j$ , noted  $\hat{\beta}(T_1, \dots, T_m)$  are obtained by minimizing the sum of squared residuals noted  $S_T$ . Then the estimated break dates  $(\hat{T}_1, \dots, \hat{T}_m)$  are obtained as given below:

$$(\hat{T}_1, \dots, \hat{T}_m) = \arg \min_{(T_1, \dots, T_m)} S_T(T_1, \dots, T_m) \quad (4)$$

To measure the degree of co-movement time-varying correlation coefficients, we apply DCC-GARCH model of Engle (2002). Engle (2002) and Tse and Tsui (2002) attempted to model both variances and conditional correlations of several series using the DCC-GARCH process. The multivariate model is defined as follows:

$$X_t = \mu_t + H_t^{1/2} \varepsilon_t \quad (5)$$

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<sup>1</sup> Stock return,  $R_{i,t}$ , is computed as the logarithmic difference of closing stock price index,  $P_{i,t}$  as follows :

$$R_{i,t} = \log(p_{i,t} / p_{i,t-1}) \times 100$$

$$\begin{cases} H_t = D_t R_t D_t' \\ R_t = (\text{diag}(Q_t))^{-1/2} Q_t (\text{diag}(Q_t))^{-1/2} \\ D_t = \text{diag}(\sqrt{h_{11,t}}, \sqrt{h_{22,t}}, \dots, \sqrt{h_{NN,t}}) \end{cases} \quad (6)$$

With  $X_t = (X_{1t}, X_{2t}, \dots, X_{Nt})$  is the vector of the past observations,  $\mu_t = (\mu_{1t}, \mu_{2t}, \dots, \mu_{Nt})$  is the vector of the conditional returns,  $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t}, \dots, \varepsilon_{Nt})$  is the vector of the standardized residuals,  $R_t$  is a  $(N \times N)$  symmetric dynamic correlations matrix and  $D_t$  is a diagonal matrix of conditional standard deviations for each of the returns series, obtained from estimating a univariate GARCH process in equation (5).

$$\sigma_{ii,t} = \omega_i + \alpha_i \varepsilon_{ii,t-1}^2 + \beta_i \sigma_{ii,t-1}^2 \quad (7)$$

$Q_t$  is a  $(N \times N)$  variance-covariance matrix of standardized residuals ( $u_t = \frac{\varepsilon_t}{\sqrt{h_t}}$ ) which is defined as follows :

$$Q_t = (1 - \theta_1 - \theta_2) \bar{Q}_t + \theta_1 u_{t-1} u_{t-1}' + \theta_2 Q_{t-1} \quad (8)$$

Where  $\bar{Q}_t = E(u_{t-1} u_{t-1}')$  refers to a  $(N \times N)$  symmetric positively-defined matrix of the unconditional variance-covariance of standardized residuals.

$\theta_1$  and  $\theta_2$  are the unknown parameters to be estimated. The sum of these coefficients must be less than one in order to insure positivity of the matrix  $Q_t$ .

Therefore, for a pair of markets  $i$  and  $j$ , their conditional correlation at time  $t$  can be written as :

$$\rho_{ij,t} = \frac{(1 - \theta_1 - \theta_2) \bar{q}_{ij} + \theta_1 u_{i,t-1} u_{j,t-1} + \theta_2 q_{ij,t-1}}{\left[ (1 - \theta_1 - \theta_2) \bar{q}_{ii} + \theta_1 u_{i,t-1}^2 + \theta_2 q_{ii,t-1} \right]^{1/2} \left[ (1 - \theta_1 - \theta_2) \bar{q}_{jj} + \theta_1 u_{j,t-1}^2 + \theta_2 q_{jj,t-1} \right]^{1/2}} \quad (9)$$

Where  $q_{ij}$  is the element on the  $i^{\text{th}}$  line and  $j^{\text{th}}$  column of the matrix  $Q_t$ .

The parameters are estimated using quasi-maximum likelihood method (QMLE) introduced by Bollerslev and Wooldridge (1992). This method permits to obtain, for each variable, the conditional variance and the conditional covariance. Under the Gaussian assumption, the likelihood function can be rewritten as:

$$L(\theta) = -\frac{1}{2} \sum_{t=1}^T (n \log(2\pi) + 2 \log|D_t| + \log|R_t| + u_t' R_t^{-1} u_t) \quad (10)$$

$$\text{with } u_t = \varepsilon_t / \sqrt{h_t} = D_t^{-1} \varepsilon_t$$

The estimation of the vector of unknown parameters ( $\theta$ ) is carried out by QMLE method which and Wooldridge, 1992).

## 4 MAIN RESULTS OF THE ANALYSIS

To examine the evolution of different dynamic correlations, analyze their ability to track important events, and the co-movements between the series we will start by considering the Bai and Perron test for testing structural changes. This approach focuses on the instability problem in time series. We use the U.S stock returns, the Nasdaq 100, from 02/01/2002 to 01/06/2009.

We choose to estimate a single break model. In the presence of multiple breaks, the estimate of the break fraction will converge to one of the true break fractions, the one that is dominant in the sense that taking it into account allows the greatest reduction in the sum of squared residuals. The break date found is 01/10/2007. This break point clearly appears in figure 1. It corresponds to the financial crisis (2007-2009).

We divide our sample into two periods. The first period, contains the observations before the crisis and the second one, during the financial crisis.

When computing the descriptive statistics as indicated in table 1, we notice that the mean in the OECD indices returns decrease during the crisis period compared to the pre-crisis and the entire period under study. During the crisis period mean return is negative for all of the OECD's stock markets. The variance increases significantly during the financial crisis compared to the pre-crisis and the entire period under study. Note that the skewness coefficients are negative for most of the countries, except for U.S, France, Germany, Sweden and Switzerland. So left-skewed distributions are predominant. For the kurtosis coefficients, all are greater than 3. All the stock returns are in a leptokurtic distribution which is a common characteristic of financial variables.

The mean and variance analysis indicate the possible existence of contagion effects. To study this assumption, we estimate a multivariate GARCH-DCC model. The coefficients of GARCH (1,1) in table 2, are observed to be significant and positive which clearly exhibit that the volatility is captured by the Garch model. All the estimated parameters are statistically significant at 5% significance level. The Garch error parameter,  $\alpha$ , measures the reaction of conditional volatility to market shocks. When  $\alpha$  is relatively large (e.g. above 0.1) then volatility is very sensitive to market events (Carol Alexander 2008). In our case  $\alpha$  is above 0.1 for most of the countries except USA, Canada, and Italy. The GARCH lag parameter,  $\beta$ , measures the persistence in conditional volatility irrespective of anything happening in the market. When  $\beta$  is relatively large (e.g. above 0.9) then volatility takes a long time to die out following a crisis in the market (Carol Alexander 2008). In our case  $\beta$  for all the countries is equivalent or very close to 0.9 except Japan and Netherlands.

Then we estimate a multivariate GARCH-DCC model for the period under study. Figure 3, depicts the time-varying conditional correlations of the U.S stock market index versus one of the OCDE stock market index under study. These graphs clearly show variation in the dynamic conditional correlations across time. As predicted, a shift is observed in the final quarter of 2007, which reach at its' peak by the end of 2008 for most of the countries under study. This phenomenon further strengthens the identification of structural break in the final quarter of 2007.

We compute the unconditional correlations and the mean of DCC coefficients in the pre-crisis and crisis periods for comparison purpose as detailed in table 3. For all countries the unconditional correlations and the mean of DCC coefficients increase in the crisis period compared to the correlations in the pre-crisis period as expected. This result is in accordance with the finding of Forbes and Rigobon (2002), where they prove that the unconditional correlation coefficient is an important instrument to identify the contagion effect. With respect to dynamic conditional correlations, it is observed that the highest correlation exist between US and Germany for the period before and during crisis of around 0.589 and 0.685 respectively whereas the lowest correlation exist between US and Japan for the period before and during crisis of around -0.0543 and -0.0395 respectively. We also observe that for most of the countries dynamic conditional correlations better predict the contagion effect than the traditional correlation, as the difference between the crisis and pre-crisis is found to be greater using DCC for all the countries except Germany, Italy and Japan.



We then apply t-test to statistically verify if the dynamic conditional correlation coefficients are same during the crisis and pre-crisis periods. The null hypothesis tests for zero hypothesized mean difference. We observe that t-test fails to support the null hypothesis of zero hypothesized mean difference considering one tail at 5% significance level for all the countries except Germany and Italy. In case of two tail t-test at 5% significance level, the test fails to support null hypothesis of zero hypothesized mean difference for all the countries except Germany, Italy and U.K. Therefore we support the phenomenon of contagion effect of global financial crisis on most of the OECD countries.

## 5 CONCLUSION

The aim of this paper was to investigate empirically the co-movements between US equity market and the OCDE equity markets over the period of 2002-2009, and to study the contagion effect in the case of global financial crisis. In that way, we have characterized contagion as a pandemic process: it happens once a local shock originating from a national market spread out to other local markets. We refer to Forbes and Rigobon (2002) by defining contagion as a positive shift in the degree of co-movement between asset returns.

First, we used DCC-GARCH model to study the dynamic correlations for a panel of 17 OECD's countries observed over the period 02/01/2002 to 01/06/2009. We use the Bai and Perron's test to estimate the break point found equals to 01/10/2007. This break point reflects the financial crisis (2007-present). Then we move by estimating a multivariate GARCH(1,1)-DCC model for the period of study and also for the periods of the financial crisis and before crisis. The obtained coefficients were economically significant.

As pointed out in our empirical findings, there is upward trend in the dynamic conditional correlations since October 2007 and onward in all the sample markets. This evidence is strengthened by the fact that the cross-market correlation coefficients exceed by 50% during the global financial crisis in most of the cases.

Further, the presence of frequent structural breaks in the time-path of cross-market correlation series as evidenced in our results encourage assessment and follow up of major stock markets and the stock market co-movements in implementing investment strategy in US and around the world.

Finally, high co-movement of stock markets in the times of crisis evidence contagion effect as confirmed by a number of previous studies.

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**Figure 1: Nasdaq 100 Index**

USA

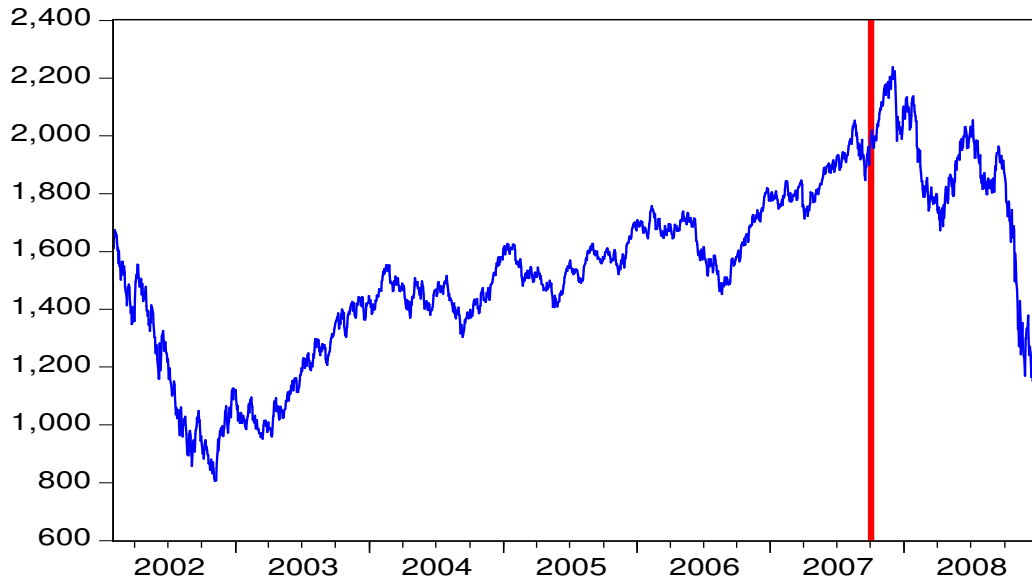
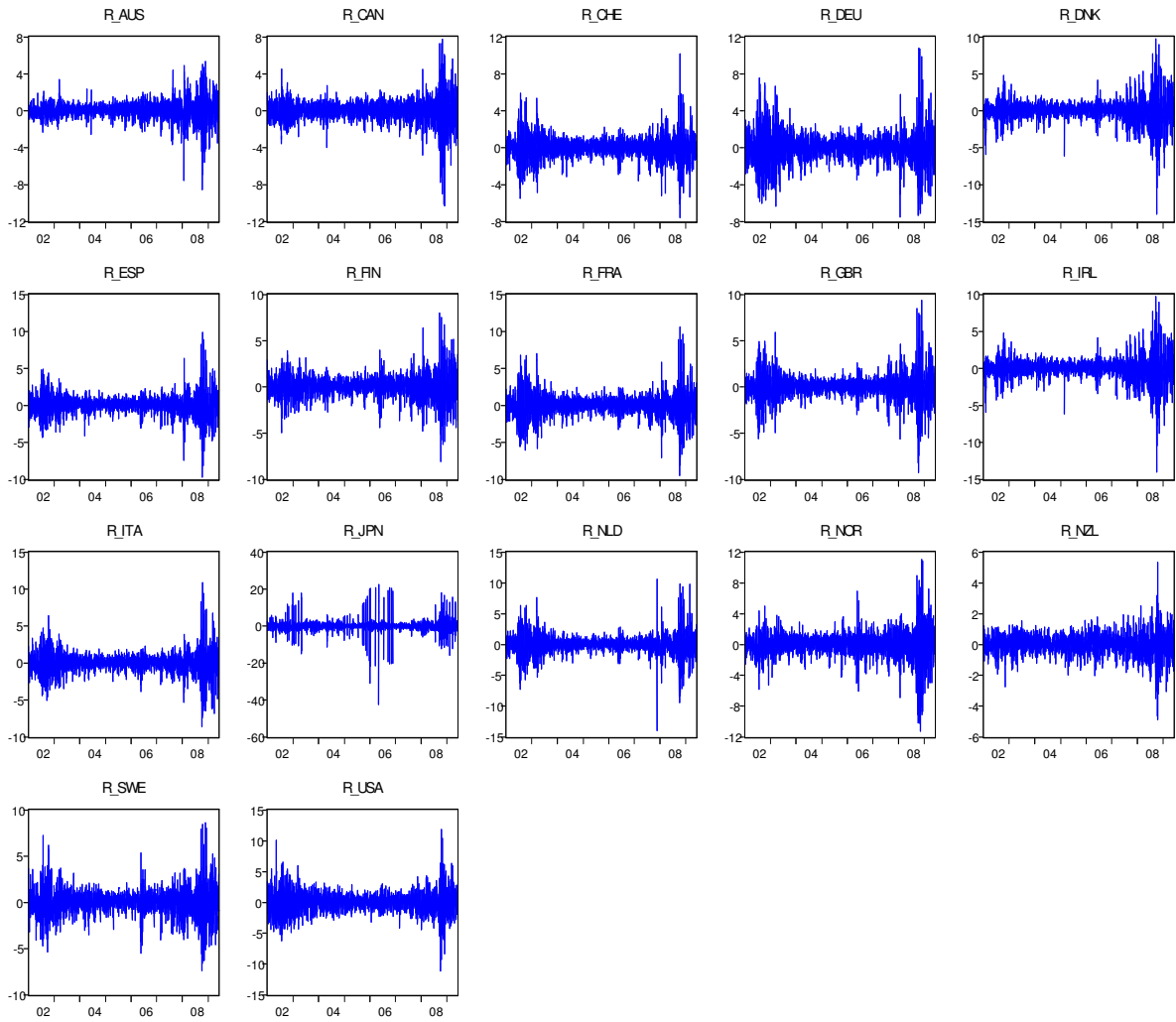
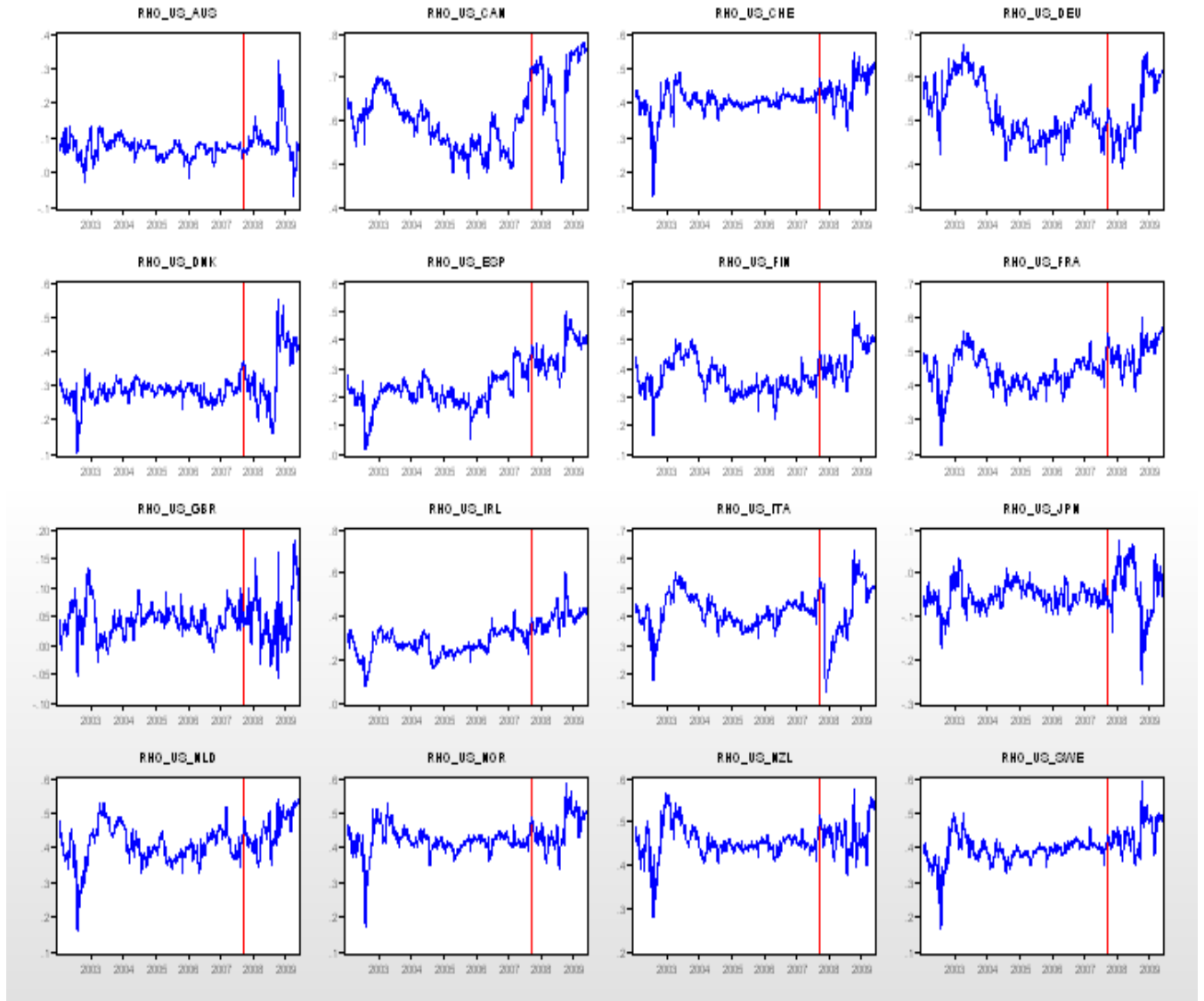


Figure 2: Stock Index Returns



**Figure 3:** Dynamic Conditional Correlations between U.S and each OECD Country





**Table 1:** Descriptive Statistics

	<i>Mean</i>	<i>Mean Pre-Crisis</i>	<i>Mean Crisis</i>	<i>Variance</i>	<i>Variance Pre-Crisis</i>	<i>Variance Crisis</i>	<i>Skewness</i>	<i>Skew. Pre-Crisis</i>	<i>Skew. Crisis</i>	<i>Kurtosis</i>	<i>Kurt. Pre-Crisis</i>	<i>Kurt. Crisis</i>
USA	-0.0045	0.0174	-0.0797	3.0094	2.2672	5.5613	0.1271	0.2217	0.0831	7.7224	6.0142	6.6143
CAN	0.0199	0.0413	-0.0537	1.6956	0.6995	5.1181	-0.8505	-0.2839	-0.5872	13.2627	4.4500	6.1092
FIN	0.0040	0.0483	-0.1482	1.6398	0.9364	4.0328	-0.1344	-0.3887	0.1699	7.7122	5.2525	4.7258
FRA	-0.0157	0.0148	-0.1205	2.4969	1.7813	4.9497	0.0864	-0.0204	0.2433	9.2322	7.0527	7.3388
DEU	-0.0116	0.0186	-0.1152	2.7807	2.2664	4.5422	0.1185	-0.0484	0.3842	8.1152	6.3491	8.1495
IRL	-0.0381	0.0223	-0.2452	2.3948	1.0055	7.1226	-0.6847	-0.6976	-0.2655	12.4689	7.5611	5.6437
ITA	-0.0231	0.0146	-0.1525	2.0383	1.1869	4.9492	-0.0109	-0.1339	0.1743	10.5733	6.2088	6.7716
NLD	-0.0251	0.0123	-0.1537	2.6403	1.6605	5.9948	-0.2153	-0.0975	-0.1168	12.5643	7.8050	8.7419
ESP	0.0099	0.0444	-0.1087	1.8477	1.0808	4.4712	-0.0743	-0.1289	0.0929	10.5675	5.6403	6.8982
DNK	0.0319	0.1037	-0.2147	0.8933	0.4021	2.5058	-1.1224	-1.2789	-0.3828	15.7549	11.2786	7.5670
NOR	0.0175	0.0598	-0.1275	3.1404	1.5254	8.6745	-0.6503	-0.3829	-0.4106	10.2982	5.6158	5.3162
SWE	0.0031	0.0340	-0.1030	2.1514	1.4195	4.6590	0.0685	-0.0648	0.2357	7.5531	6.6292	5.0790
CHE	-0.0061	0.0262	-0.1170	1.6345	1.1609	3.2512	0.0178	-0.0986	0.2194	9.1047	7.4383	7.0060
GBR	-0.0076	0.0143	-0.0829	1.8293	1.1259	4.2454	-0.1099	-0.1901	0.0318	10.7046	7.8197	6.9483
AUS	0.0072	0.0444	-0.1207	1.1081	0.4854	3.2308	-0.6506	-0.2221	-0.3545	11.1478	6.1283	5.2286
JPN	-0.0041	0.0315	-0.1263	12.1797	12.0282	12.7092	-0.7904	-1.2135	0.5546	29.9614	36.7067	9.3949
NZL	-0.0038	0.0294	-0.1180	0.5058	0.3044	1.1829	-0.4065	-0.3417	-0.1167	8.1763	4.0996	5.6156

**Table 2:** Estimation Results for Garch(1,1)

<i>Country</i>	<i>C</i>	<i>A</i>	<i>β</i>
USA	0.01105* (0.003949)	0.05438* (0.006847)	0.94129* (0.007822)
CANADA	0.01215* (0.003972)	0.088438* (0.010689)	0.90242* (0.012329)
AUSTRALIA	0.00860* (0.002078)	0.10523* (0.009204)	0.88893* (0.010289)
CHE	0.00860* (0.002078)	0.10523* (0.009204)	0.88894* (0.010289)
GERMANY	0.02106* (0.004444)	0.09895* (0.010234)	0.89401* (0.010678)
DENMARK	0.02440* (0.003383)	0.13209* (0.012246)	0.86173* (0.011036)
SPAIN	0.01954* (0.003865)	0.11772* (0.011691)	0.87189* (0.012962)
FINLAND	0.01419* (0.003721)	0.09488* (0.010657)	0.89742* (0.011053)
FRANCE	0.01791* (0.004331)	0.09990* (0.010385)	0.89335* (0.010882)
UNITED KINGDOM	0.00951* (0.002722)	0.10979* (0.011338)	0.88768* (0.010411)
IRELAND	0.02440* (0.003383)	0.13209* (0.012246)	0.86173* (0.011036)
ITALY	0.01208* (0.002708)	0.08802* (0.008747)	0.90593* (0.009211)
JAPAN	2.84557* (0.077479)	0.25587* (0.025205)	0.52745* (0.014525)
NETHERLAND	0.02134* (0.004391)	0.16501* (0.012653)	0.84333* (0.012539)
NORWAY	0.04694* (0.010470)	0.11964* (0.013484)	0.86133* (0.014888)
NEWZEALAND	0.01485* (0.003327)	0.09596* (0.012591)	0.87142* (0.017031)
SWEDEN	0.02243* (0.004773)	0.10657* (0.010945)	0.88377* (0.010979)

Notes: This table presents the estimation results of GARCH (1, 1) from January 2, 2002 to June 1, 2009. The numbers in parenthesis represent associated standard errors. \* Indicate that the coefficients are significant at the 5% level.

Table 3: Comparative Analysis of Unconditional Correlation and DCC

UC AND DCC FOR THE PERIOD 02-01-2002 TO 01-06-2009							
	<i>UNCONDITIONAL CORRELATION</i>			<i>DYNAMIC CONDITIONAL CORRELATION</i>			
	Pre-crisis	Crisis	% Difference	Pre-Crisis	Crisis	% Difference	DCC IS GREATER THAN UC
CANADA	0.5803	0.663	14.2340	0.5892	0.685	16.23	YES
FINLAND	0.3422	0.375	9.4681	0.3622	0.437	20.76	YES
FRANCE	0.4232	0.427	0.8507	0.436	0.491	12.71	YES
GERMANY	0.5406	0.585	8.1946	0.5188	0.521	0.35	NO
IRELAND	0.2333	0.231	-1.0716	0.2713	0.393	45.01	YES
ITALY	0.4452	0.463	3.8859	0.4142	0.418	0.89	NO
NETHERLANDS	0.4043	0.406	0.4699	0.4059	0.452	11.41	YES
SPAIN	0.383	0.380	-0.8355	0.2174	0.352	62.05	NO
DENMARK	0.1658	0.141	-14.8372	0.2816	0.335	19.11	YES
NORWAY	0.2004	0.209	4.1916	0.4213	0.453	7.52	YES
SWEDEN	0.3847	0.408	5.9787	0.391	0.439	12.35	YES
SWITZERLAND	0.3455	0.353	2.2287	0.4028	0.445	10.38	YES
UK	0.3529	0.344	-2.4936	0.0423	0.047	9.93	NO
AUSTRALIA	0.0376	0.035	-6.6489	0.0691	0.094	36.47	YES
JAPAN	0.0473	0.071	49.0486	-0.0543	-0.039	-27.26	NO
NEW ZEALAND	0.0523	-0.077	-247.6099	0.4525	0.466	3.03	YES

Table 4: T-Test Estimation - Two-Sample Assuming Unequal Variances

	<i>Mean</i>	<i>Variance</i>	<i>Observations</i>	<i>H<sub>0</sub></i>	<i>t Stat</i>
<i>BC_RHO_US_CAN</i>	0.59	0.00	1497.00	0.00	-22.13**
<i>C_RHO_US_CAN</i>	0.68	0.01	436.00		
<i>BC_RHO_US_FIN</i>	0.36	0.00	1497.00	0.00	-23.04**
<i>C_RHO_US_FIN</i>	0.44	0.00	436.00		
<i>BC_RHO_US_FRA</i>	0.44	0.00	1497.00	0.00	-23.44**
<i>C_RHO_US_FRA</i>	0.49	0.00	436.00		
<i>BC_RHO_US_DEU</i>	0.52	0.00	1497.00	0.00	-0.46
<i>C_RHO_US_DEU</i>	0.52	0.01	436.00		
<i>BC_RHO_US_IRL</i>	0.27	0.00	1497.00	0.00	-46.49**
<i>C_RHO_US_IRL</i>	0.39	0.00	436.00		
<i>BC_RHO_US_ITA</i>	0.41	0.00	1497.00	0.00	-0.66
<i>C_RHO_US_ITA</i>	0.42	0.01	436.00		
<i>BC_RHO_US_NLD</i>	0.41	0.00	1497.00	0.00	-17.24**
<i>C_RHO_US_NLD</i>	0.45	0.00	436.00		
<i>BC_RHO_US_ESP</i>	0.22	0.00	1497.00	0.00	-42.94**
<i>C_RHO_US_ESP</i>	0.35	0.00	436.00		
<i>BC_RHO_US_DNK</i>	0.28	0.00	1497.00	0.00	-11.91**
<i>C_RHO_US_DNK</i>	0.34	0.01	436.00		
<i>BC_RHO_US_NOR</i>	0.42	0.00	1497.00	0.00	-12.47**
<i>C_RHO_US_NOR</i>	0.45	0.00	436.00		
<i>BC_RHO_US_SWE</i>	0.39	0.00	1497.00	0.00	-21.34**
<i>C_RHO_US_SWE</i>	0.44	0.00	436.00		
<i>BC_RHO_US_CHE</i>	0.40	0.00	1497.00	0.00	-17.76**
<i>C_RHO_US_CHE</i>	0.44	0.00	436.00		
<i>BC_RHO_US_GBR</i>	0.04	0.00	1497.00	0.00	-1.84*
<i>C_RHO_US_GBR</i>	0.05	0.00	436.00		
<i>BC_RHO_US_AUS</i>	0.07	0.00	1497.00	0.00	-8.98**
<i>C_RHO_US_AUS</i>	0.09	0.00	436.00		
<i>BC_RHO_US_JPN</i>	-0.05	0.00	1497.00	0.00	-4.61**
<i>C_RHO_US_JPN</i>	-0.04	0.00	436.00		
<i>BC_RHO_US_NZL</i>	0.45	0.00	1497.00	0.00	-6.67**
<i>C_RHO_US_NZL</i>	0.47	0.00	436.00		

Notes: \* Indicate that the t-stat is significant at 5% confidence level for one tail critical value ( $\pm 1.65$ ). \*\* Indicate that the t-stat is significant at 5% confidence level for one tail and two tail critical values of  $\pm 1.65$  and  $\pm 1.96$  respectively.

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