Spring 5-17-2013

European Stock Market Contagion during Sovereign Debt Crisis and the Effects of Macroeconomic Announcements on the Correlations of Gold,Dollar and Stock Returns

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A Dissertation

Submitted to the Graduate Faculty of the
University of New Orleans
in partial fulfillment of the
requirements for the degree of

Doctor of Philosophy
in
Financial Economics

by
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May, 2013

Acknowledgement

This research has reached this point because of the help of many people I'd like to extend the deepest appreciation. I owe a great deal of thanks to the chair of my dissertation committee, Dr. Atsuyuki Naka. He earned my special gratitude and respect for his deep knowledge of the subject and the extended hours he spent to help me. I would like also to thank my dissertation committee members, Dr. Gerald Whitney, Dr. James R. Davis, Dr. Wei Wang, Dr. Duygu Zirek for their valuable comments and suggestions.

I also would like to extend special thanks to Dr. Walter Lane, the Chair of the Department of Economics and Finance, for his continuous support throughout my life as a Ph.D. student at UNO, and many thanks to all faculty members at the department and all students of the Ph.D. program.

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Abstract

The first part of this dissertation examines the presence of the financial contagion across European stock markets with respect to the Greece sovereign debt crisis by estimating the time-varying conditional correlations of stock returns between Greece and other European countries over 2001 to 2012. We find that the correlations vary over time and reach the peaks in the late 2008 during the U.S. subprime crisis, and in the beginning of 2010 of the height of European debt crisis. Further, the correlations between stock index returns of Greece and Spain, France, Ireland, Netherlands are significantly increased by Greek sovereign credit rating downgrade announcements.

The second part of this dissertation examines the correlations of gold, dollar and U.S. stock returns over 2001 to 2012 using ADCC-GARCH model. The conditional correlations of gold-dollar returns are negative during all sub-sample periods and significantly increase in magnitude during both subprime crisis and sovereign debt crisis. The conditional correlations of gold-stock returns are positive on average over time. However, gold-stock correlation falls below zero during subprime crisis and sovereign debt crisis. Gold-stock correlation is significantly negatively affected by positive CPI announcements. And gold-dollar correlation is significantly negatively affected by negative GDP announcements and positive unemployment announcements. The effects of macroeconomic announcements are stronger during economic recessions.

Key words: Financial Contagion, Sovereign Debt Crisis, Macroeconomic Announcements, Conditional Correlation

Chapter 1

Introduction

The European sovereign debt crisis is an ongoing financial crisis that has made it difficult or impossible for some countries in the Euro area to re-finance their government debt without the assistance of third parties. Since the end of 2009, fears of a sovereign debt crisis developed among investors with a wave of downgrading of government debt levels in some European states. While the European debt crisis has its origin in Greece, problems have now spread to several other European countries as well.

Previous studies find spillover effects of Greek sovereign credit rating downgrades on other European countries' bond markets during sovereign debt crisis (Missio and Watzka 2011, Arezki and Candelon 2011, De Haan and Mink 2012). However no research has been done on the stock market contagion during debt crisis. A sovereign credit rating downgrade can affect stock markets by negatively affecting securities' price and investors' confidence. Some researchers argue that sovereign debt rating announcements do not only affect bond market, but also spill over to stock markets. And this effect is stronger during financial crisis (Kaminsky and Schmukler 2002). Thus the first research question in dissertation is whether stock market contagion exists in Euro-zone during the European sovereign debt crisis. The second research question is whether and how the contagion effect is affected by sovereign rating news, such as downgrades. Based on previous literature, financial contagion refers to the spread of market disturbance or market shocks from one country or market to another. Contagion may occur through fundamental causes and investors' behavior. For example, the “wake-up call” hypothesis proposed by Goldstein (1998) states that a crisis in one country may serve as a “wake-up call” for markets participants in other countries if it causes them to take a closer watch on their own countries’ fundamentals. Contagion occurs if this leads them to detect any problems or risks. Contagion is defined as a significant increase in correlations by Forbes and Rigobon (2002). To overcome the heteroskesdasticity problem and to incorporate asymmetry effects, I apply DCC-GJR-GARCH model to obtain dynamic conditional correlation of stock returns and test financial contagion.

In the second chapter of this dissertation, I examine the existence of financial contagion across European stock markets during sovereign debt crisis and then I test whether and how the sovereign credit rating downgrades affected the cross-country correlations of stock index returns during debt crisis.

Gold is usually considered to serve as a hedge against a falling dollar and a safe haven for stock, especially during financial crisis period. During the subprime crisis, we observed a substantial decline in the S&P stock index and the trade weighted value of dollar. But during the same period, the spot gold price increased by 38.45%. The performance of gold is very impressive given the losses suffered in other asset classes. The recent financial crisis and the strength of gold price present a strong motivation to test the ability of gold as a hedge or safe haven for losses in financial markets. Previous literature shows the hedging, diversifying and safe haven properties of gold. For example, Capie, Mills and Wood (2005) found that there exists an inverse correlation based relationship between fluctuations in gold prices and the U.S. dollar. Baur and McDemott (2010) argue that gold is used as a safe haven for stock during economic recessions. Hillier, Draper & Faff (2006) suggest the diversification benefits of gold in portfolio settings.

Previous studies also show that the asset returns and volatilities are affected by the macroeconomic announcements (Flannery and Protopapadakis 2002, Roache and Rossi 2009). Some papers suggest that asset returns and volatilities respond differently to news announcements in recessions and expansions (Boyd et al. 2005, Andersen et al., 2004). But the research on how macroeconomic announcements affect the correlations of asset returns is scarce. So the research questions in my dissertation are as follows: how do markets adjust to important news arrivals? Do macroeconomic announcement affect the correlations of gold, dollar and stock returns? Does the current economic business cycle characterize the markets' price reactions to macroeconomic news? In this paper, I attempt to shed new lights on these important issues.

In the third chapter, I study if gold is a hedge against change in the value of dollar and if gold is a safe haven or just a diversifier for stock. Second, I examine the effect of macroeconomic announcements on the correlations of gold-stock and gold-dollar returns. Third, I test if the correlations of the asset returns respond differently to news announcements under different economic conditions.

Chapter 2

European Stock Market Contagion During Sovereign Debt Crisis

I. Introduction

Since the end of 2009, the European area faces a severe sovereign debt crisis. Rising government deficits and debt levels triggered rating agencies to downgrade several European countries' debt repayment probabilities, thereby creating a loss of confidence in financial markets. The European sovereign debt crisis has its origin in Greece. The research on the contagion effect of European sovereign debt crisis so far is very limited. Most papers focus on the contagion effect in European bond market. Missio and Watzka (2011) found the presence of contagious effects during the European sovereign debt crisis. Their results show that Spanish, Italian and Beglian yield spreads increase along with their Greek counterpart. Arezki and Candelon (2011) examined the impact of rating news on credit markets by focusing on Credit Default Swap markets during 2007-2010. They found that one country's rating downgrade has a significant negative effect on the Credit Default Swap spreads of other countries. De Haan and Mink (2012) found that the sovereign bond prices of Ireland and Spain respond to both news about Greece and news about a Greek bailout. And news about Greece does not lead to abnormal returns while news about a bailout does, even for banks without any exposure to Greece or other highly indebted euro countries.

The stock market should be expected to react to a sovereign rating downgrade because a downgrade can affect a country's ability to borrow in international markets, and thus contribute to a credit crunch, which negatively impacts the stock market. Other mechanisms as well reveal a link between sovereign rating and stock market. Sovereign rating can provide information on the future economic health of the rated country that is not available to stock market participants, and government can take policy actions that directly affect companies' future prospects (for example, raising corporate taxes to compensate for increased debt service following a downgrade). In addition, since many institutional investors can hold only investment-grade instruments, rating downgrade may have a negative impact on security prices. Rising government deficits and debt levels triggered rating agencies to downgrade several European countries' debt repayment probabilities. It brought about a dramatic loss of confidence for investors who had intended to invest in European markets. Such a shift in the attitudes of investors may produce prolonged damage to portfolio investments because their concerns may not subside until another successful story of economic growth in the region develops. Thus sovereign debt crisis is a negative shock to the stock markets in the European area. Some researchers examined the effect of sovereign credit-rating changes on stock market. Kaminsky and Schmukler (2002) show that sovereign debt ratings do not only affect bond market but also spill over into the stock market. This effect is stronger during crisis. Pukthuanthong, Elayan and Rose (2007) studied the impact of changes in sovereign ratings on international capital markets using a database of 34 countries during 1990-2000. They find that the sovereign credit ratings announcements affect not only bonds but also stocks. Downgrade has a significant negative impact on equity returns.

The Euro-zone stock markets are very unique to study the financial contagion effect due to the high integration suggested by many researchers (Fratzscher, 2002, Bartram, Taylor and

Wang, 2007). Forbes and Rigobon (2002) defines contagion as significant increases in cross-market co-movement. And thus, contagion must involve a dynamic increment in correlation. The earliest studies on financial contagion focus on simple correlation. However, some researchers argue that tests for financial contagion using simple correlation coefficients give us biased results due to heteroskesdasticity. To overcome the heteroskesdasticity problem of tests for financial contagion, Chiang, Jeon and Li (2007) applied a Dynamic Conditional Correlation (DCC)-GARCH model. But DCC-GARCH model doesn't incorporate the presence of asymmetric responses in conditional variances to negative returns. In order to obtain more accurate conditional correlations of stock returns, we need to consider the asymmetry effect. To test financial contagion, I use DCC-GJR-GARCH model.

This paper has two main objectives: First, to determine the existence of financial contagion across European stock markets during the sovereign debt crisis, and second, to examine whether and how the sovereign credit rating changes and affected the cross-country correlations of stock market returns during the European sovereign debt crisis.

This paper makes three important contributions to the literature on financial contagion. First, it examines financial contagion during the most recent crisis, that is the European sovereign debt crisis. Previous literature on the existence of financial contagion largely focuses on 1990's Asian crisis and 2007-2009 U.S. subprime crisis. This paper provides a broad understanding of the European debt crisis in terms of financial contagion. Second, I use the DCC-GJR-GARCH model to examine the time-varying conditional correlations of stock returns by permitting conditional asymmetries in volatilities. The DCC-GJR-GARCH specification is well suited to investigate the presence of asymmetric responses in conditional variance to negative returns. Third, I examine the response of conditional correlations to sovereign credit rating changes.

II. Literature Review and Hypotheses

Researchers have become more and more interested in the contagious effect of financial crisis. It provides us important guide of monetary policy, asset allocation, asset pricing and risk management. It's widely accepted that during financial crisis, market participants seem to perceive financial contagion. However we still need to investigate financial contagion effect empirically. Nowadays there is little consensus on the definition of financial contagion and the existence of financial contagion.

Based on recent academic researches, financial contagion in general is referred to as the co-movement of exchange rates, stock prices, and sovereign spreads in one market as a result of a market disturbance in another market. In other words, financial contagion refers to the spread of market disturbance or market shocks from one country or market to another. Forbes and Rigobon (2002) defines contagion as significant increases in cross-market co-movement. Some researchers find significant evidence of financial contagion using simple correlations (King and Wadhwani (1990), Baig and Goldfajn (1999)).

There are a number of theories why contagion can occur. Based on Claessens and Forbes (2004), the theories can be divided into two types: fundamental causes (including common shocks, trade and financial linkages) and investors' behavior (including informational asymmetries, and investor reassessment).

Many different fundamental causes may lead to contagion. Masson (1999) and Calvo (1996) proposed theoretical models of common shocks. Take European sovereign debt crisis for example, a downgrade in one countries' sovereign debt credit rating can trigger debt crisis and lager capital outflows. Thus the shock can lead to increased co-movements in asset prices and capital flows. Contagion can also occur through financial and trade linkages (Gerlach and Smets, 1995; Forbes 2002). In a world or region that is highly integrated, a crisis in one country can have direct financing effects on other countries, through reductions in imports or exports, foreign direct investment, and other capital flows. A well-known theory based on fundamental causes is the "Globalization Theory". Contagion during crises hits hardest those economies that are highly integrated globally, such as through trade and financial linkages To explain cross-country propagation of shocks not related to or explained by economic fundamentals, we need to resort to market imperfections, including information effects and domino effects. Information effects involve a crisis in one country that triggers a crisis in others as agents take the crisis as a signal to update information. In a domino effect, a crisis in one country leads to crisis in others because of financial connectivity.

The other major group of theories explaining contagion is based on investors' behavior. The two main theories are wake-up call theory and information asymmetry theory. Goldstein (1998) and Masson (1999) proposed "wake-up call" hypothesis. It states that a crisis initially restricted a one market segment or country provides new information that may prompt investors to reassess the vulnerability of other market segments or countries, which spreads the crisis across markets and borders. A crisis in one country could lead to a reassessment of objectively unchanged fundamentals in other countries. Thus a crisis in one country may serve as a “wake-up call” for market participants if it causes them to take a closer look at fundamentals similar to those in the crisis country. Contagion occurs if this leads them to detect problems or risks they failed to see before.

Another theory that is based on investors’ behavior is information asymmetry theory. Investors usually do not have a complete picture of the conditions in every country that can affect their portfolio’s returns due to imperfect information. So a financial crisis in one country may lead investors to believe that other countries could face similar problems. Then investors would sell securities in other countries, especially those with similar conditions to those in the country where the crisis originated.

In many studies, financial contagion is measured by simple historical correlation of asset returns, for example, stock returns. If there exists a significant change in the correlations between before-crisis and after-crisis periods, financial contagion is verified. Researchers obtain different empirical evidence of the existence of financial contagion. Some researchers find significant evidence of financial contagion using simple correlations, for example King and Wadhwani (1990), Baig and Goldfajn (1999), Calvo and Reinhart (1996). They find significant changes in historical correlations of stock returns in different markets and they suggest that financial contagion effect exists. For example, King and Wadhwani (1990) find a significant increase in the cross-country correlation coefficients of stock returns during the 1987 U.S. market crash. They suggest that "contagion" between markets occurs as the result of attempts by rational agents to infer information from price changes in other markets. In addition, Calvo and Reinhart (1996) suggest that Mexico's economic crisis in December 1994 gave renewed importance to the issue of "spillover" or "contagion" effects in other emerging market economies. They find the evidence of increased comovement across weekly equity and Brady bond returns for emerging markets in Latin America after the Mexican crisis. And they suggest that contagion may be more regional than global - the degree of comovement after the crisis increased in both Asia and Latin America, but regional patterns differed. Baig and Goldfain (1999) test contagion between the financial markets of Thailand, Malaysia, Indonesia, Korea, and the Philippines. Cross-country correlations among currencies and sovereign spreads are found to increase significantly during the crisis period, whereas the equity market correlations offer mixed evidence.

However, some researchers argue that tests for financial contagion using simple correlation coefficients give us biased results due to heteroskesdasticity. So the previous evidence of the existence of financial contagion has to be re-examined. For example, Forbes and Rigobon (2002) points out that heteroskedasticity biases tests for contagion based on correlation coefficients. This paper shows that correlation coefficients are conditional on market volatility. Using volatility–adjusted correlations, there was virtually no contagion during the 1997 Asian crisis, 1994 Mexican devaluation, and 1987 U.S. market crash.

To overcome the heteroskesdasticity problem of tests for financial contagion, Chiang, Jeon and Li (2007) applied a Dynamic Conditional Correlation (DCC)- GARCH model. They did a dynamic correlation analysis of financial contagion of Asian crisis and their evidence confirms a contagion effect. By analyzing the correlation-coefficient series, they also identify two phases of the Asian crisis. The first shows an increase in correlation (contagion) and the second shows a continued high correlation (herding).

DCC-GARCH model assumes that both negative and positive news have symmetric effects on variance and conditional correlations. However, Cappiello, Engle and Sheppard (2006) find the presence of asymmetric responses in conditional variances to negative returns. In order to obtain more accurate conditional correlations of stock returns, we need to take into account the asymmetry effect. Thus I use DCC-GJR-GARCH model to test the financial contagion effect in this paper.

Some studies show that the European stock markets are very unique to study the financial contagion effect due to the high integration suggested by many researchers. For example, Fratzscher (2002) analyses the integration process of European equity markets since the 1980s. The author found that European equity markets have become highly integrated since 1996 and the integration of European equity markets is in large part explained by the drive towards EMU, and in particular the elimination of exchange rate volatility. In addition, Bartram, Taylor and Wang (2007) use a time-varying copula model to investigate the impact of the introduction of the Euro on the dependence between seventeen European stock markets during the period 1994-2003. The results show that, within the Euro area, market dependence increased after the introduction of the common currency only for large equity markets, such as in France, Germany, Italy, the Netherlands and Spain. Structural break tests indicate that the increase in financial market dependence started around the beginning of 1998 when Euro membership was determined and the relevant information was announced. So the study of Euro-zone stock markets is important for us to test the existence of financial contagion during the sovereign debt crisis. Imad and Schwienbacher (2011) explore the relationship between institutional investors and funds managers, a relatively little studied field in private equity. They study this relationship within the context of international investment flows. They build the research using a two-level analysis. They first look at which US LPs are more likely to invest in funds focusing on Europe (regardless of whether a US or European fund) to identify the active global players. And second, using only the subsample of LPs investing in Europe-focused funds, they study which types of LPs are more likely to provide capital to European funds investing locally as opposed to US funds with a European focus. They find that financial institutions with facilities in Europe, such as banks and insurance companies, are more prone to invest directly in European funds. This is consistent with the transaction cost hypothesis whereby LPs may benefit from lower costs to access valuable information to screen European funds. The presence of local facilities may further capture size effects. They also find that pension funds often invest directly in European funds although those funds do not possess local facilities in Europe. This may be due to the larger size that drives them to invest abroad or their increased experience in investing in private equity.

Previous studies show some impacts of European sovereign debt crisis on financial markets. Drenovak, Urosevic and Jelic (2012) examine the tracking performance of 31 eurozone sovereign debt exchange traded index funds (ETFs) during 2007–2010. The tracking performance is assessed by four different tracking error models. Overall, funds underperform their respective benchmarks. Active returns (net of fees) vary substantially (from +46.74 to −30.36 basis points) and are of considerable economic interest. The significant differences in the performance of swap-based and in-kind funds highlight the importance of appropriate (e.g. correlation vs. cointegration based) metrics required for the assessment of funds adopting different replication methods. They also document important changes in the tracking performance due to the changing characteristics of EU sovereign bonds since the start of the sovereign debt crisis. Grammatikos and Vermeulen (2012) test for the transmission of the 2007–2010 financial and sovereign debt crises to fifteen EMU countries. They use daily data from 2003 to 2010 on country financial and non-financial stock market indexes to analyze the stock market returns for three country groups within EMU: North, South and Small. They find that for both the North and South European countries, while the smallest countries seem to be relatively isolated from international events. First, they find strong evidence of crisis transmission to European non-financials from US non-financials, but not for financials. Second, in order to test how the sovereign debt crisis affects stock market developments they split the crisis in pre- and post-Lehman sub periods. Results show that financials become significantly more dependent on changes in the difference between the Greek and German CDS spreads after Lehman's collapse, compared to the pre-Lehman sub period. However, this increase is much smaller for non-financials. Third, before the crisis euro appreciations coincide with European stock market decreases, whereas this relationship reverses during the crisis. Finally, this reversal seems to be triggered by Lehman's collapse.

In this paper, I examine the effects of changes in sovereign credit ratings on stock return correlation. Gande and Parsley (2005) suggest two theories to illustrate this issue, "common information effect" and "differential effect". "Common information effect" suggests that a sovereign credit rating downgrade in one country may be perceived as a widespread common trend by other countries. Thus the stock return correlation may rises. "Differential effect" suggests that a sovereign credit rating downgrade in one country implies the countries poor ability to borrow in international market, which would cause investors move away from the downgraded country's stock market and move towards other stock markets. Thus, the stock return correlation would decline. The final result depends on which effect dominates. If the "common information effect" dominates, a sovereign credit rating downgrade would lead to an increase in stock return correlation. If "Differential effect" dominates, a sovereign credit rating would lead to a decline in stock return correlation. Some researchers studied the news spillover effects in European bond markets. Christiansen (2007) studies volatility spillover from the US and aggregate European bond markets into individual European bond markets using a GARCH volatility-spillover model. Strong statistical evidence of volatility spillover from the US and aggregate European bond markets is found. For EMU countries, the US volatility-spillover effects are rather weak (in economic terms) whereas the European volatility-spillover effects are strong. The bond markets of EMU countries have become much more integrated after the introduction of the euro, and in recent years they have become close to being perfectly integrated.

Based on the globalization and wake-up call theory illustrated in literature review, I developed my hypotheses as follows:

Hypothesis 1:

The correlations of stock market returns between Greece and other sample European countries are time-varying.

Hypothesis 2:

There exist asymmetric responses in conditional variance to negative returns.

Hypothesis3:

There is a significant increase in correlations of stock market returns between Greece and other sample European countries during the sovereign debt crisis. (Financial contagion effect)

Hypothesis 4:

The sovereign credit ratings announcements have significant impact on the dynamic conditional correlations of stock returns.

The first two hypotheses test if the correlations of stock returns between Greece and other sample European countries are time-varying and asymmetrically respond to negative returns. The third hypothesis is on the existence of financial contagion effect across Euro-area stock markets. Many researchers find that the Euro-area is highly integrated. Based on the "globalization" theory, in a highly integrated region such as Euro-area, the sovereign debt crisis in Greece can have direct financing effects on other countries, through reductions in trade, FDI and other capital flows. So a crisis in one country can lead to crisis in others due to financial connectivity. Based on the "wake-up call" theory, debt crisis initially restricted in Greece provides news information that may prompt investors to reassess the vulnerability of other European markets, which spread the debt crisis across borders. Information asymmetry may also lead to contagion effect. The debt crisis in Greece may lead investors to believe that other Euro-area countries could face similar problems. Since financial contagion is studied by stock returns correlation, we expect to see a significant increase in stock returns correlation during European sovereign debt crisis.

The last hypothesis is on the effect of sovereign credit rating changes on the stock return correlations. Since the European sovereign debt crisis is triggered by the sovereign credit rating downgrades. The sovereign debt credit rating agencies played an important role in the spread of the debt crisis. The previous literature shows that the sovereign debt credit rating changes have significant impact on the stock returns and volatilities. Thus, we expect to see that the sovereign debt credit rating changes would lead to significant changes in correlations of stock returns within the Euro-zone.

III. Methodology

DCC-GJR-GARCH model is a developed model based on DCC-GARCH model proposed by Engle (2002). First, univariate GARCH models are estimated for each single stock and the standardized residuals from the models for the conditional variance are used to calculate the conditional correlations.

The returns equation is specified as

$$r_t = \gamma_0 + \gamma_1 r_{t-1} + \varepsilon_t$$

$$\varepsilon_t / \xi_{t-1} \sim N(0, H_t) \quad (1)$$

Where r_t is an n*1 vector of stock returns, and ξ_{t-1} is the information set at time t-1. The AR(1) term is used to take into account the autocorrelation of stock returns.

We'll also examine the effect of the value of Euro,

$$r_t = \gamma_0 + \gamma_1 r_{t-1} + r_{t-1}^{Euro} + \varepsilon_t \quad (2)$$

All DCC-GARCH models use the fact that H_t can be decomposed as

$$H_t \equiv D_t R_t D_t \quad (3)$$

Where $D_t = diag\{\sqrt{h_{it}}\}$ is the n*n diagonal matrix of time-varying standard deviations from the univariate GARCH models, and R_t is the n*n time-varying correlation matrix. The DCC-GARCH model is designed to allow for a two-stage estimation of the conditional covariance matrix H_t. In the first stage, univariate volatility models are fitted to each of the stock return residuals and estimates of $\sqrt{h_{it}}$ are obtained. In the second stage, stock returns are transformed by their estimated standard deviations as $u_{it} = \varepsilon_{it} / \sqrt{h_{ii,t}}$. $u_{i,t}$ is used to estimate the correlation parameters. The evolution of the correlation in the standard DCC-GARCH model is given by

$$Q_t = (1-a-b)\overline{Q} + a u_{t-1} u_{t-1}^{'} + b Q_{t-1} \quad (4)$$

$$R_t = Q_t^{*-1} Q_t Q_t^{*-1} \quad (5)$$

Where $Q_t = \left[q_{ij,t}\right]$ is the n*n time-varying covariance matrix of u_t, $\overline{Q} = E\left[u_t u_t^{'}\right]$ is the n*n unconditional variance matrix of u_t, and a and b are scalars such as that a+b<1. $Q_t^* = \left[q_{ii,t}^*\right] = \left[\sqrt{q_{ii,t}}\right]$ is a diagonal matrix with the square root of the ith diagonal element of Q_t on its ith diagonal position. As long as Q_t is positive definite, Q_t^* guarantees that R_t is a correlation matrix with ones on the diagonal and the absolute values of all the other elements less than 1.

Following Engle (2002), the DCC-GARCH model can be estimated by a two-stage approach to maximize the log-likelihood function. Let the parameters D be denoted by θ and the additional parameters in R be denoted by φ. The log likelihood function can be written as the sum of a volatility part and a correlation part:

$$L(\theta,\varphi) = L_V(\theta) + L_C(\theta,\varphi)$$
$$= \left[-\frac{1}{2}\sum_t (n\log(2\pi) + \log|D_t|^2 + \varepsilon_t^{'} D_t^{-2}\varepsilon_t)\right] \quad (6)$$
$$+ \left[-\frac{1}{2}\sum_t (\log|R_t| + u_t^{'} R_t^{-1} u_t - u_t^{'} u_t)\right]$$

The volatility part of the likelihood is the sum of individual GARCH likelihoods. In the first stage, the volatility part of the likelihood is maximized to find,

$$\hat{\theta} = \arg\max[L_V(\theta)] \quad (7)$$

And the correlation part is then maximized in the second stage,

$$\max_{\varphi}\left[L_C(\hat{\theta},\varphi)\right] \quad (8)$$

To incorporate the asymmetries in volatilities:

The variance equation is the asymmetric GJR (1,1):

$$h_{ii,t} = c + (\alpha + \theta I_t[\varepsilon_{t-1} < 0])\varepsilon_{ii,t-1}^2 + \beta h_{ii,t-1} \quad (9)$$

Where $I_t = 1$, if $\varepsilon_{t-1} < 0$; $I_t = 0$, if $\varepsilon_{t-1} \geq 0$

$$R_t = diag[Q_t]^{-1} Q_t diag[Q_t]^{-1} \quad (10)$$

$$Q_t = \overline{Q}(1 - a - b) + a\varepsilon_{t-1}\varepsilon_{t-1}^{'} + bQ_{t-1} \quad (11)$$

Where α,β and θ are scalar parameters.

The DCC-GJR-GARCH process extends previous specifications by permitting conditional asymmetries in volatilities. The DCC-GJR-GARCH specification is well suited to examine correlation dynamics among different stocks and investigate the presence of asymmetric responses in conditional variance to negative returns. We use DCC-GJR-GARCH model because that correlation may be higher after a negative innovation than after a positive innovation of the same magnitude.

Two economic theories explain asymmetric volatility: the leverage effect and time-varying risk premia (volatility feedback). The leverage effect, based on Christie (1982), state that after an unexpected drop in a stock value, the debt-to-equity ration of a firm increases. Thus, the volatility of the whole firm, which is assumed to be constant, must be reflected by an increase in volatility in the nonleveraged part of the firm. Campbell and Hentschel (1992) suggest that the larger increase in volatility after a negative shock is because that news that volatility will be higher in the future will induce risk-adverse investors to sell positions today until the expected return rises to compensate for the risk. Hence, markets decline in advance of volatility increases. Another explanation is that after a negative return shock and variance increase, the required rise in expected return creates more volatility (volatility feedback effect).

IV. Data

For the investigation of stock market contagion during the European debt crisis I use a sample of nine countries: Greece (ATHEX 20), Germany (DAX), Spain (IBEX35), Netherlands (AEX), Austria (ATX), Belgium (BEL20), Ireland (ISEQ-OVERALL), France (CAC40), UK (FTSE100). A dataset consisting of stock returns data from Yahoo. Finance for a time period from 01/01/2001 until 10/31/2012 is applied in the analysis. In this paper, the beginning date of the sovereign debt crisis is defined as December 8th, 2009 (Since December 8th, 2009, the Greek sovereign credit rating has been downgraded. 12/08/2009: A- to BBB+

by Fitch, 12/16/2009: A- to BBB+ by S&P, 12/22/2009: A1 to A2 by Moody's).

Table 1: Summary statistics of stock returns

Panel A: Entire time period (1/1/2001-10/31/2012)									
	Austria	Belgium	France	Germany	Greece	Ireland	Netherlands	Spain	UK
Mean	0.022	-0.007	-0.009	0.011	-0.073	-0.012	-0.015	-0.006	-0.007
Variance	2.411	1.931	2.575	2.74	4.285	2.277	2.568	2.567	1.708
Skewness	-0.319	0.125	0.131	0.057	0.139	-0.554	0.004	0.067	-0.180
Kurtosis	11.289	8.595	7.628	6.734	8.125	10.084	8.854	7.633	8.754
Panel B: Before the subprime crisis (1/1/2001-07/31/2007)									
	Austria	Belgium	France	Germany	Greece	Ireland	Netherlands	Spain	UK
Mean	0.076	0.020	0.012	0.02	-0.006	0.031	-0.001	0.023	-0.001
Variance	0.956	1.402	2.028	2.577	2.169	1.107	2.207	1.75	1.234
Skewness	-0.663	0.319	-0.032	-0.044	0.187	-0.498	0.023	-0.052	-0.158
Kurtosis	7.622	8.733	5.737	5.473	8.12	5.969	7.504	4.841	6.785
Panel C: During the subprime crisis (08/01/2007-12/07/2009)									
	Austria	Belgium	France	Germany	Greece	Ireland	Netherlands	Spain	UK
Mean	-0.104	-0.099	-0.074	-0.048	-0.127	-0.193	-0.093	-0.039	-0.055
Variance	6.915	3.833	4.542	4.089	5.817	6.528	4.956	4.127	3.522
Skewness	-0.1	-0.006	0.338	0.329	-0.083	-0.329	0.056	-0.024	-0.134
Kurtosis	6.231	6.394	7.856	8.092	5.222	5.603	7.681	6.871	7.246
Panel D: During the sovereign debt crisis (12/08/2009-10/31/2012)									
	Austria	Belgium	France	Germany	Greece	Ireland	Netherlands	Spain	UK
Mean	-0.021	-0.006	-0.011	0.034	-0.204	0.019	0.009	-0.056	0.016
Variance	2.676	1.821	2.47	2.112	8.616	1.983	1.642	3.49	1.318
Skewness	-0.051	0.267	0.12	-0.09	0.309	-0.117	-0.035	0.327	-0.112
Kurtosis	5.112	6.737	5.715	4.954	5.688	5.173	5.129	7.536	4.628

Table 1 presents the summary statistics of stock returns of the 9 European countries. Panel A reports the summary statistics for the entire sample period and Panel B reports the summary statistics before subprime crisis and Panel C presents the summary statistics during subprime crisis. Comparing Panel C with Panel B, we can see that during the subprime crisis, all the 9 countries have lower stock returns and higher volatilities. Panel D reports the summary statistics for the stock index returns for the nine countries during sovereign debt crisis. During the sovereign debt crisis, all countries, except Germany, Netherlands and UK, have lower returns and higher volatilities compared to the precrisis period. These results suggest that the sub-prime crisis and sovereign debt crisis are negative shocks to the European stock markets. Both the subprime crisis and sovereign debt crisis depressed the stock returns and increased volatility of European stock markets. Greece shows the largest negative mean returns and the largest variance. During the sovereign debt crisis, Greece has been frequently downgraded by rating agencies. The downgrade announcements affected Greek stock markets by decreasing Greek stock returns and increasing Greek stock market volatilities.

V. Empirical results

A.Estimation of Conditional Correlations

Table 2: Tests of changes in unconditional correlations

	Correlation before crisis	Correlation during subprime crisis	Z-statistics	Correlation during sovereign debt crisis	Z-statistics
GREECE-AUSTRIA	0.306	0.682	-10.761	0.445	-3.704
GREECE-BELGIUM	0.335	0.651	-8.894	0.416	-2.163
GREECE-FRANCE	0.355	0.671	-9.177	0.41	-1.464
GREECE-GERMANY	0.334	0.674	-9.769	0.391	-1.493
GREECE-IRELAND	0.343	0.609	-7.267	0.396	-1.399
GREECE-NETHERLANDS	0.361	0.67	-8.989	0.406	-1.196
GREECE-SPAIN	0.324	0.673	-9.992	0.402	-2.059
GREECE-UK	0.388	0.637	-8.716	0.337	1.227

I start with investigating the changes in unconditional correlations of stock index return between Greece and other 8 European countries. I construct a Z-test to study if there exists any significant changes in unconditional correlations during sub-prime crisis and sovereign debt crisis.

Table 2 reports the tests of changes in unconditional correlations of stock returns before the crisis, during the subprime crisis, and sovereign debt crisis. From Table 2, we can see that all the eight pair-wise conditional correlations significantly increase during the subprime crisis. During the sovereign debt crisis, the unconditional correlations decline but still higher than the correlations during the period before subprime crisis for all countries except UK. The changes in the pairwise correlations lead us to investigate the time-varying conditional correlation approach.

During 2007-2009 subprime crisis, the unconditional correlations of stock index returns between Greece and Austria, Germany and Spain exhibit most significant rises. During European sovereign debt crisis, the unconditional correlations between Greece and Austria, Belgium, and Spain exhibit the most significant rises. And Z-statistics show that the changes in correlations between Greece and the other 5 European countries are not significant. It may suggest that Austria, Belgium and Spain are affected most by the sovereign debt crisis. This is the primary result I obtain using unconditional correlations. I'll examine the effect of both sub-prime crisis and sovereign debt crisis using conditional correlations in a later section.Before I conduct DCC- GJR-GARCH model, I apply DCC-GARCH model first.

Table 3 presents the estimation results for the DCC-GARCH model. In Panel A, the coefficient of AR(1) term in the mean equation is significant and negative for only Austria and is significant and positive for all the other 8 countries. This finding is consistent with the evidence in the literature that AR(1) is positive due to price friction or partial adjustment and AR(1) is negative due to positive feedback trading in markets (as discussed in Antoniou, Koutmos, Percli, 2005, Chiang et al., 2007).

Table3: Estimation results of DCC-GARCH model

PanelA Mean Equation						
	r0	t-statistics	P-value	r1	t-statistics	P-value
Greece	3.5703	56.1452	0.0000	2.2453	59.1862	0.0000
France	0.0212	36.9803	0.0000	0.1039	18.2958	0.0000
Austria	2.0598	59.4347	0.0000	-0.2775	-27.1907	0.0000
Belgium	0.6006	47.7185	0.0000	0.1026	16.1857	0.0000
Netherlands	0.2802	32.3222	0.0000	0.2792	32.024	0.0000
Spain	0.6135	38.3144	0.0000	0.4013	37.2726	0.0000
Germany	1.673	59.5678	0.0000	0.2608	26.3829	0.0000
Ireland	0.8639	40.1951	0.0000	0.4633	37.6545	0.0000
UK	0.5192	43.5071	0.0000	0.6676	45.9623	0.0000
PanelB Variance Equation						
	alpah	t-statistics	P-value	beta	t-statistics	P-value
Greece	0.6265	78.2814	0.0000	0.9881	68.4362	0.0000
France	0.2683	102.1642	0.0000	0.5126	108.9243	0.0000
Austria	0.2907	97.3792	0.0000	0.4502	70.9184	0.0000
Belgium	0.2766	100.8979	0.0000	0.632	77.4487	0.0000
Netherlands	0.2948	99.5791	0.0000	0.6757	95.4944	0.0000
Spain	0.2711	82.4468	0.0000	0.6027	78.6556	0.0000
Germany	0.2607	60.5474	0.0000	0.6674	95.0992	0.0000
Ireland	0.4104	89.3714	0.0000	0.7545	114.5039	0.0000
UK	0.3015	85.1087	0.0000	0.6086	88.1421	0.0000
PanelC DCC equation						
		Coefficient	t-statistics	p-value		
	a	0.0353	58.9649	0.0000		
	b	1.0812	27.7759	0.0000		

Notes: Return equation: $r_t = \gamma_0 + \gamma_1 r_{t-1} + \varepsilon_t$

Variance equation: $h_{ii,t} = c_i + \alpha_i \varepsilon_{i,t-1}^2 + \beta_i h_{ii,t-1}, i = 1,2.......8.$

The evolution of the correlation in the DCC model is given by:

$$Q_t = (1 - a - b)\overline{Q} + a u_{t-1} u_{t-1}^{'} + b Q_{t-1}$$

In Panel B, the coefficients of GARCH parameters for all of the countries are highly significant, which support time-varying volatility and justify the use of GARCH specification and confirm the presence of conditional heteroskedasticity in the time series.

Panel C of Table3 reports the estimation results for the evolution equation of the correlation in DCC model. Both a and b coefficients are significant at one percent level indicating strong time-varying conditional correlations of the returns of these stock markets. These findings are consistent with the evidence presented by Hwang et al. (2010), in which the contagion effect of the U.S. subprime crisis on international stock markets is examined. Hwang et al. (2010) also find significant a and b during both Asian crisis and U.S. subprime crisis periods, implying that the correlations of U.S. and other major international stock markets are strongly time-varying.

Table 4 reports the estimation results for the DCC-GJR-GARCH model. In Panel A, the coefficients of AR(1) are significantly positive for Greece, Austria and Ireland and are significantly negative for France, Netherlands, Germany and UK. In Panel B, the parameter theta are significant and positive, implying that the conditional variance of stock returns is affected more significantly by negative shocks than by positive shock. The results indicate that the volatility of the European stock markets increase more by bad news than by good news, e.g., showing the leverage effects. The finding is consistent with the existing literature such as the evidence presented by Cappiello et al. (2006). Panel C of Table4 shows the estimation results for the evolution equation of the correlation in the DCC-GJR-GARCH model. Consistent with the DCC-GARCH model, the coefficients of a and b are significant indicating that conditional correlations of these stock markets are highly dynamic and time-varying.

Table 4: Estimation results of DCC-GJR-GARCH model

PanelA: Mean Equation						
	r0	t-statistics	P-value	r1	t-statistics	P-value
Greece	0.0288	0.9974	0.3186	0.0581	4.3754	0.0000
France	0.0251	1.3240	0.1855	-0.0365	-5.6679	0.0000
Austria	0.0708	3.2973	0.0010	0.0525	4.5864	0.0000
Belgium	0.0398	2.2461	0.0247	0.0091	1.1323	0.2575
Netherlands	0.0190	1.0549	0.2915	-0.0141	-1.9294	0.0537
Spain	0.0417	2.1484	0.0317	-0.0131	-1.4077	0.1592
Germany	0.0457	2.3442	0.0191	-0.0246	-3.0561	0.0022
Ireland	0.0411	1.9430	0.0520	0.0252	2.1007	0.0357
UK	0.0208	1.3029	0.1926	-0.0571	-6.7349	0.0000
PanelB: Variance Equation						
	constant	t-statistics	P-value	alpah	t-statistics	P-value
Greece	0.0108	2.5740	0.0101	0.0368	7.7972	0.0000
France	0.0140	8.0259	0.0000	0.0139	3.2103	0.0013
Austria	0.0179	5.5939	0.0000	0.0262	4.9839	0.0000
Belgium	0.0148	6.8393	0.0000	0.0216	3.9831	0.0001
Netherlands	0.0109	7.0051	0.0000	0.0105	2.2937	0.0218
Spain	0.0131	6.1213	0.0000	0.0172	4.3247	0.0000
Germany	0.0127	6.3200	0.0000	0.0076	1.5675	0.1170
Ireland	0.0209	5.1851	0.0000	0.0491	7.2095	0.0000
UK	0.0094	6.5113	0.0000	0.0038	0.8474	0.3968
	beta	t-statistics	P-value	theta	t-statistics	P-value
Greece	0.9444	170.4022	0.0000	0.0383	5.8211	0.0000
France	0.9510	302.5256	0.0000	0.0582	10.3114	0.0000
Austria	0.9424	183.0530	0.0000	0.0448	5.9857	0.0000
Belgium	0.9410	196.3562	0.0000	0.0583	8.9890	0.0000
Netherlands	0.9510	278.7036	0.0000	0.0662	11.0132	0.0000
Spain	0.9463	230.8391	0.0000	0.0617	11.4025	0.0000
Germany	0.9527	257.9858	0.0000	0.0651	10.0229	0.0000
Ireland	0.9288	136.6221	0.0000	0.0293	2.9226	0.0035
UK	0.9524	254.3143	0.0000	0.0719	11.5438	0.0000
PanelC: ADCC Equation						
		Coefficient	t-statistics	p-value		
	a	0.0143	15.8339	0.0000		
	b	0.9824	814.8835	0.0000		

Notes: Return equation: $r_t = \gamma_0 + \gamma_1 r_{t-1} + \varepsilon_t$

Variance equation (GJR-GARCH): $h_{ii,t} = c + (\alpha + \theta I_t[\varepsilon_{t-1} < 0])\varepsilon^2_{ii,t-1} + \beta h_{ii,t-1}$

Evolution of correlations: $Q_t = \overline{Q}(1 - a - b) + a\varepsilon_{t-1}\varepsilon'_{t-1} + bQ_{t-1}$

We also estimate DCC-GJR-GARCH model with the changes in the value of Euro, and reported in Table 5. From Table 5, the coefficients of own AR(1) processes are significant for all countries except Belgium and Spain, and the coefficients of changes in the value of Euro are significantly positive for four countries: Greece, Austria, Spain and UK. These results suggest that an increase in the value of Euro leads to an increase in the stock index returns for these four countries. The appreciation of Euro is a positive shock to the European stock markets. The significant coefficients of changes in the value of Euro we found could be due to the high integration among the European markets, and thus these markets are significantly affected by the Euro value changes. This finding is consistent with previous study on the impact of foreign exchange rate on stock markets. Hui and Chung (2011) shows that not only the creditworthiness of the euro-area countries with weaker fiscal positions but also that of the member countries with more sound fiscal positions are important determinants of the deep out-of-the-money euro put option prices, which embedded information on the euro crash risk during the sovereign debt crisis of 2009–2010. The authors also find evidence of information flow from the sovereign credit default swap market to the currency option market during the crisis. Mylonidis and Kollias (2010) assesses the dynamic process of convergence among four major European stock markets in the first euro-decade. Using tests that allow for endogenously determined breaks in cointegrating relationships and rolling cointegration analysis, they find that although some convergence has been taking place over time, it is very much an ongoing process. There is also evidence that the German and French markets appear to be the ones with a higher degree of convergence.

Table5: Estimation results of DCC-GJR-GARCH model with changes in Euro value

PanelA Mean Equation						
	r1	t-statistics	P-value	r2	t-statistics	P-value
Greece	0.0568	4.3325	0.0000	0.1303	2.8599	0.0042
France	-0.0378	-6.3602	0.0000	0.0018	0.0594	0.9526
Austria	0.0537	5.0989	0.0000	0.1511	5.0120	0.0000
Belgium	0.0081	0.9872	0.3235	0.0305	1.1908	0.2337
Netherlands	-0.0153	-2.1959	0.0281	-0.0393	-1.3845	0.1662
Spain	-0.0138	-1.5188	0.1288	0.0631	2.0396	0.0414
Germany	-0.0263	-3.4280	0.0006	0.0064	0.1964	0.8443
Ireland	0.0252	2.2182	0.0265	-0.0246	-0.8132	0.4161
UK	-0.0582	-6.8748	0.0000	0.0762	3.1182	0.0018
PanelB: Variance Equation						
	constant	t-statistics	P-value	alpah	t-statistics	P-value
Greece	0.0107	2.5887	0.0096	0.0362	6.1221	0.0000
France	0.0141	7.7170	0.0000	0.0142	3.2133	0.0013
Austria	0.0186	5.5176	0.0000	0.0279	5.9745	0.0000
Belgium	0.0151	6.8480	0.0000	0.0221	4.7033	0.0000
Netherlands	0.0110	7.0616	0.0000	0.0104	2.3642	0.0181
Spain	0.0133	6.1375	0.0000	0.0180	3.6270	0.0003
Germany	0.0128	6.2915	0.0000	0.0075	1.5106	0.1309
Ireland	0.0208	5.6816	0.0000	0.0498	8.0115	0.0000
UK	0.0099	6.8214	0.0000	0.0032	0.7541	0.4508
	beta	t-statistics	P-value	theta	t-statistics	P-value
Greece	0.9449	160.1449	0.0000	0.0384	5.7192	0.0000
France	0.9508	293.6004	0.0000	0.0579	10.4060	0.0000
Austria	0.9408	192.8751	0.0000	0.0437	6.4112	0.0000
Belgium	0.9404	201.1758	0.0000	0.0583	9.3115	0.0000
Netherlands	0.9510	297.5704	0.0000	0.0664	11.4765	0.0000
Spain	0.9459	222.5448	0.0000	0.0609	9.7927	0.0000
Germany	0.9527	249.2416	0.0000	0.0652	9.7299	0.0000
Ireland	0.9287	145.6662	0.0000	0.0287	3.7397	0.0002
UK	0.9518	254.7112	0.0000	0.0734	11.8750	0.0000
PanelC ADCC Equation						
		Coefficient	t-statistics	p-value		
	a	0.0143	15.9315	0.0000		
	b	0.9823	805.1866	0.0000		

Notes: Return equation: $r_t = \gamma_0 + \gamma_1 r_{t-1} + \gamma_2 Euro_{t-1} + \varepsilon_t$

Variance equation: (GJR-GARCH): $h_{ii,t} = c + (\alpha + \theta I_t[\varepsilon_{t-1} < 0])\varepsilon^2_{ii,t-1} + \beta h_{ii,t-1}$

Evolution of the correlation: $Q_t = \overline{Q}(1 - a - b) + a\varepsilon_{t-1}\varepsilon'_{t-1} + bQ_{t-1}$

Figure1 through Figure8 describe the conditional correlations of stock returns between Greece and each of other eight countries. These correlations are constructed from equation (5). From these graphs, we observe that first, prior to the sovereign debt crisis that occurred in late 2009, the Greek stock market's correlations with other countries had varied over time, and reached its peak in the late 2008 after Lehman Brothers filed for bankruptcy in September 2008. It shows the evidence of financial contagion effect caused by the subprime financial crisis. Second, we see an obvious rise in correlations in the first quarter of 2010 after the debt crisis. Then the conditional correlations start to decline. From the figures, we conjecture some evidence of contagion effect of sovereign debt crisis but the contagion effect triggered by subprime crisis is larger. Contagion can be identified with Greece infecting the other countries. This doesn't mean that Greece alone caused the refinancing difficulties of the other countries, but that potentially existing fundamental problems were further worsened to at least some extent. If countries are under investors' close watch for some reasons, the sudden downturn in financing conditions of one observed country can cause spillover effects exaggerating the actual fundamental problems.

Figure1: Dynamic conditional correlation coefficients of Greece and Austria (01/01/2001-10/31/2012)

Figure2: Dynamic conditional correlation coefficients of Greece and Belgium (01/01/2001-10/31/2012)

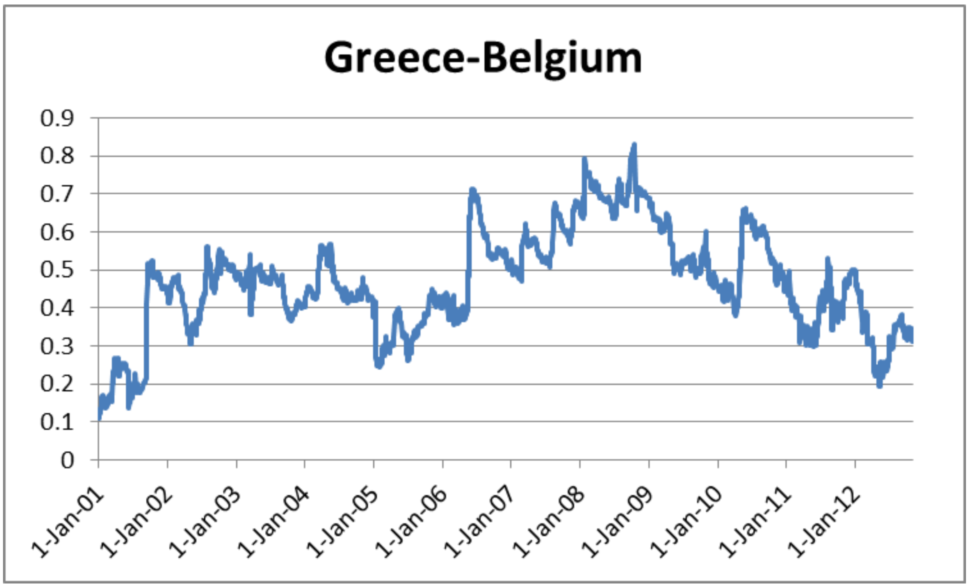


Figure3: Dynamic conditional correlation coefficients of Greece and Germany (01/01/2001-10/31/2012)

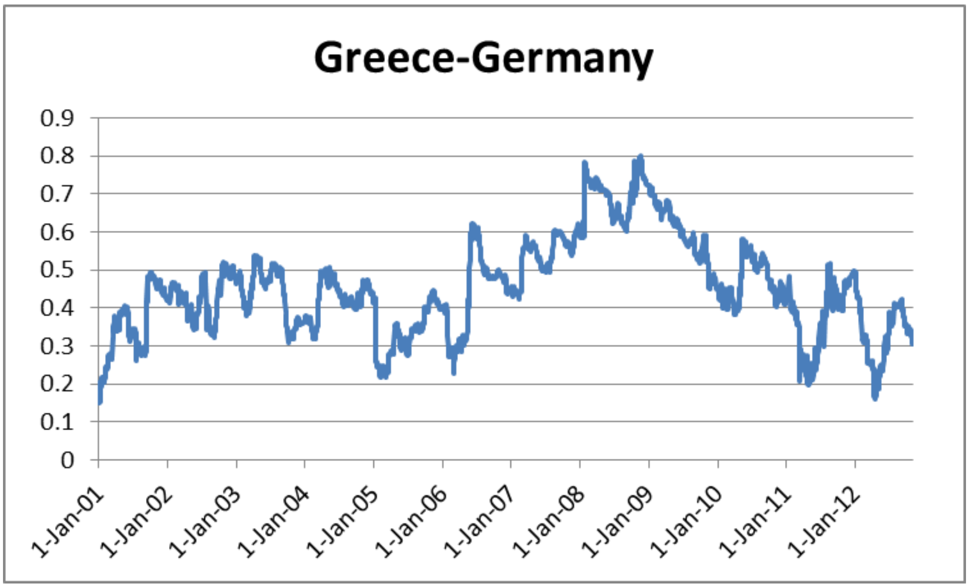


Figure4: Dynamic conditional correlation coefficients of Greece and Netherlands (01/01/2001-10/31/2012)

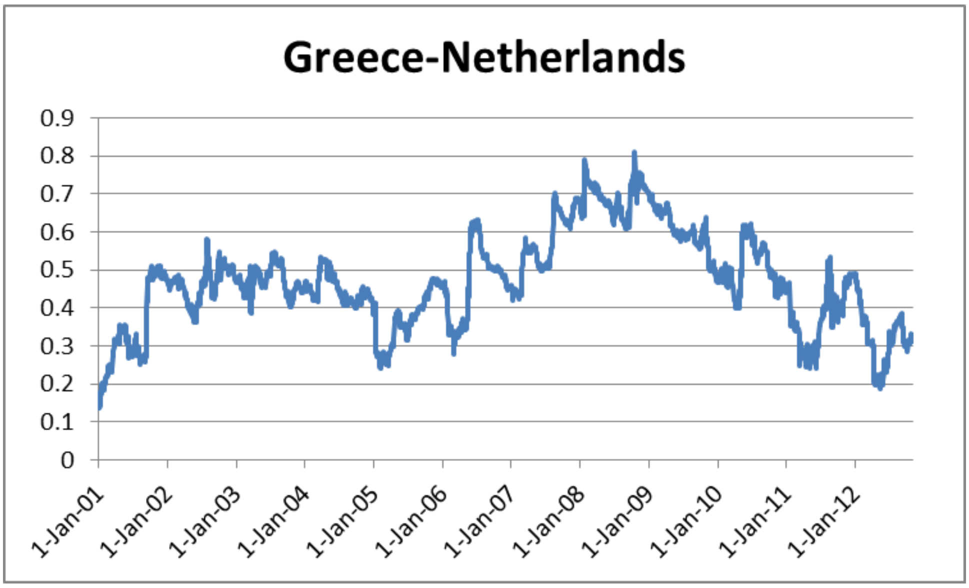


Figure5: Dynamic conditional correlation coefficients of Greece and Spain (01/01/2001-10/31/2012)

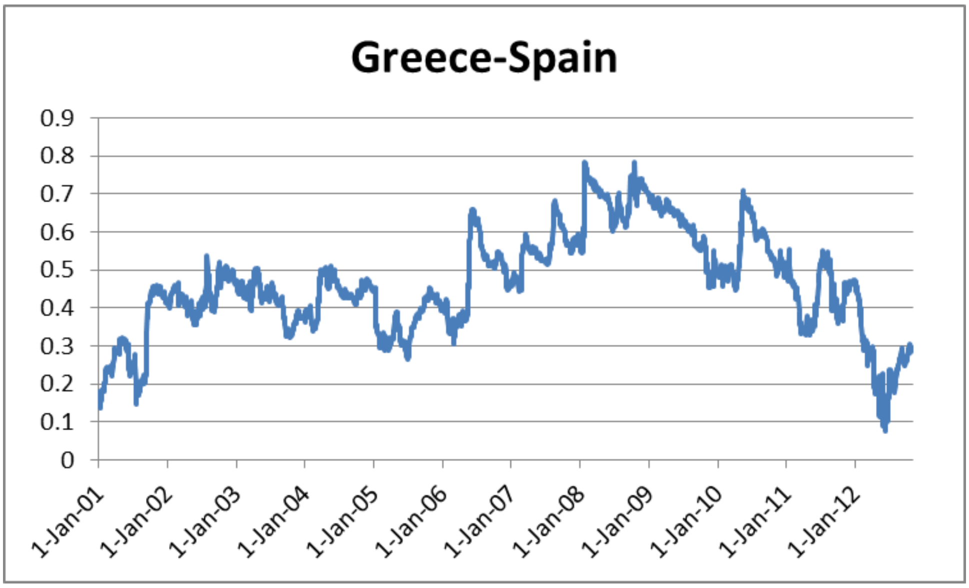


Figure6: Dynamic conditional correlation coefficients of Greece and Ireland (01/01/2001-10/31/2012)

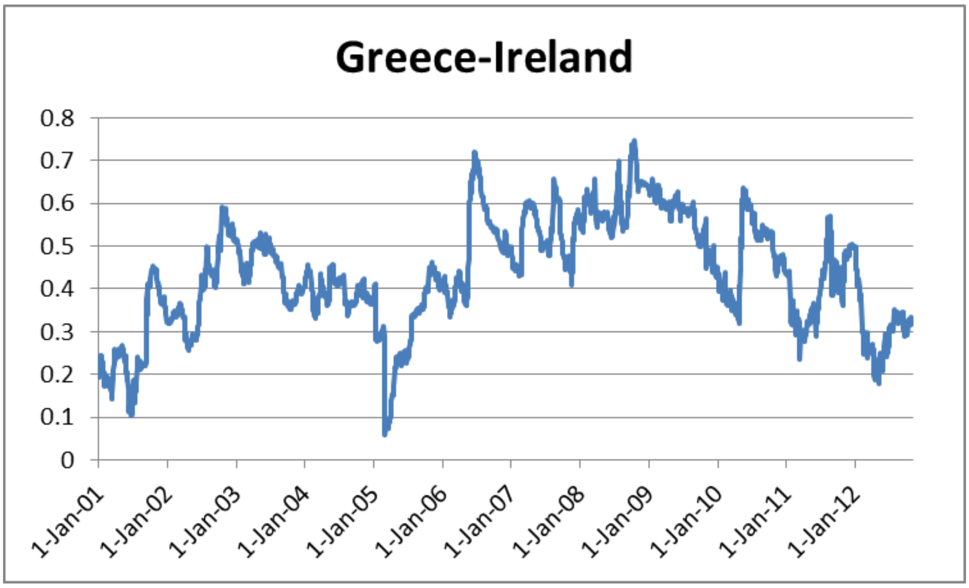


Figure7: Dynamic conditional correlation coefficients of Greece and France (01/01/2001-10/31/2012)

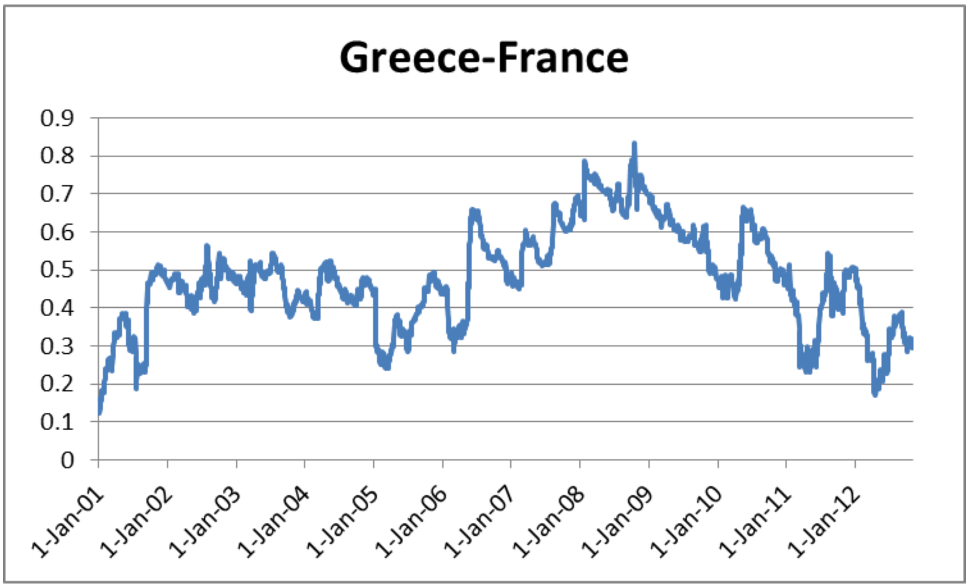
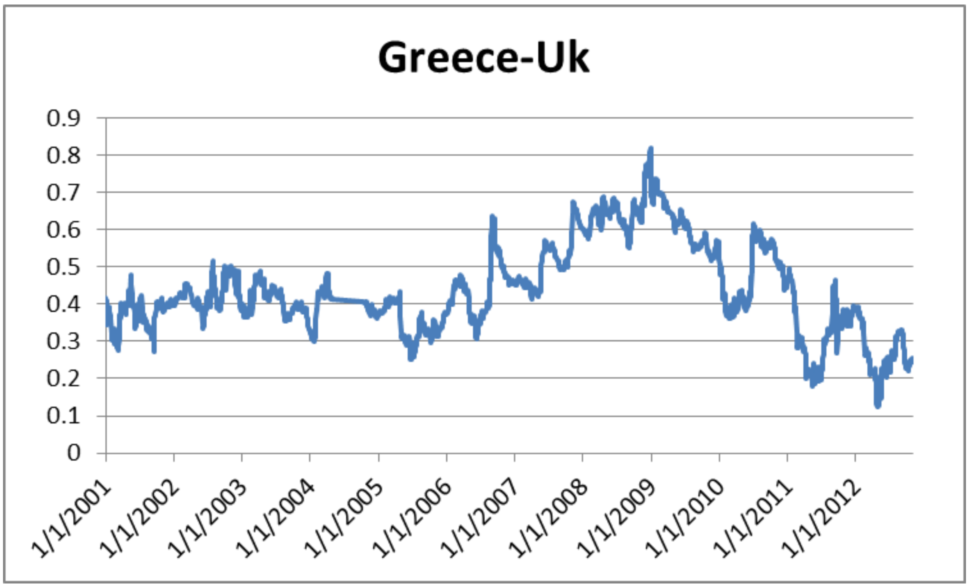


Figure8: Dynamic conditional correlation coefficients of Greece and UK (01/01/2001-10/31/2012)



These results can be explained by Chiang et al.'s (2007) interpretation of the East Asian crisis. The results indicate evidence of financial contagion in the early stage of the U.S. subprime crisis and then a transition to herding behavior in latter stages. In the early stages, investors did not recognize the financial crisis or view its source as a local country problem. Conditional correlations decreased during the early stages of the turmoil period, because investors rebalanced their portfolio from risky assets directly related to the source of the crisis to other risky assets, instead of from risky assets to risk-free assets. This investor behavior can result in sudden increase in correlations between stock market returns. As the crisis was recognized by most market participants, investor decisions converged because the cost of collecting credible information was relatively high during the crisis. Investors tend to follow major investors in making decisions bout investments, interpreting news about one country as news about a whole region. This investor behavior leads to the persistence of high correlations after their sudden change.

B. The effect of European debt crisis on correlation coefficients

The analysis in this paper aims at investigating if refinancing problems of some European countries are due to contagion effects. If that was the case, some countries would suffer unjustified financial problems which are solely driven form deteriorated investor sentiment stemming from independent and bad news of other countries. As the sovereign debt crisis initially hit Greece, we take Greece as the origin of the crisis and study if the fact that Greece was in financial stress has direct impact on other countries, even though they might actually be unrelated to thee refinancing problems and are in fact financially sound.

Based on contagion literature, to identify contagion effect a strong increase in conditional correlation coefficients needs to be observed. We investigate the effects of the debt crisis on the dynamics of conditional correlations by creating two crisis dummies to test the changes in dynamic correlations of stock returns during different financial crisis. DM_{1t} is a dummy variable for the subprime crisis during 08/01/2007 to 12/07/2009, and DM_{2t} is a dummy variable for sovereign debt crisis during 12/08/2009 to 10/31/2012. The model used is given as:

$$\rho_{ij,t} = \varphi_0 + d_{1,ij} DM_{1t} + d_{2,ij} DM_{2t} + e_{ij,t}, \tag{12}$$

where $\rho_{ij,t}$ is the conditional correlation between Greece and other 8 countries.

Table 6 presents the results of financial crisis on correlation coefficients. From Table 6, we find that the coefficients of subprime financial crisis dummies are highly significantly positive for all the eight pair-wise stock return correlations. The results show that the U.S. subprime financial crisis increased the correlation coefficients, indicating the existence of financial contagion incurred by subprime financial crisis. The coefficients of sovereign debt crisis dummies are significantly positive for 6 countries, expect UK and Netherlands. And the magnitude of the coefficients of sovereign debt crisis dummies is in general smaller than that of the coefficients of subprime crisis dummies. In summary, we observe the existence of contagion effects triggered by both subprime crisis and sovereign debt crisis although the contagion effects triggered by sovereign debt crisis are smaller than the contagion effects triggered by subprime crisis.

Table 6: Crisis effects on stock return correlations

	ϕ_0	d_1	d_2
France	0.3947	0.2614	0.0265
t-statistics	48.4000	25.1600	1.9700
p-value	0.0000	0.0000	0.0480
Austria	0.3675	0.2961	0.0869
t-statistics	37.6100	26.4600	6.5200
p-value	0.0000	0.0000	0.0000
Belgium	0.3786	0.2535	0.0445
t-statistics	38.8800	19.5200	3.2700
p-value	0.0000	0.0000	0.0010
Netherlands	0.3963	0.2562	0.0109
t-statistics	54.8800	27.8700	0.9200
p-value	0.0000	0.0000	0.3580
Spain	0.3722	0.2717	0.0529
t-statistics	46.5100	26.2100	3.5800
p-value	0.0000	0.0000	0.0000
Germany	0.3703	0.2685	0.0262
t-statistics	47.9500	25.0300	2.2700
p-value	0.0000	0.0000	0.0230
Ireland	0.3757	0.2049	0.0236
t-statistics	44.7300	19.6900	1.8800
p-value	0.0000	0.0000	0.0610
uk	0.4074	0.2106	-0.0424
t-statistics	103.6400	28.1200	-3.6500
p-value	0.0000	0.0000	0.0000

Note: $\rho_{ij,t} = \varphi_0 + d_{1,ij} DM_{1t} + d_{2,ij} DM_{2t} + e_{ij,t}$, where $\rho_{ij,t}$ is the conditional correlation between Greece and other seven countries obtained from DCC-GJR-GARCH model. DM_{1t} is a dummy variable for the subprime crisis during 08/01/2007 to 12/07/2009, and DM_{2t} is a dummy variable for sovereign debt crisis during 12/08/2009 to 10/31/2012. The regressions are conducted with Newey-West standard errors.

The findings are consistent with the results presented by Hwang el al. (2010), in which the U.S. subprime financial crisis is found to have significant and strong influence on major international stock markets. The results reinforce the significance and the global effects of the subprime crisis originated in the U.S. Chiang et al. (2007) also found a significant increase in stock return correlations between Thailand and other major Asian markets during the Asian financial crisis period, implying the existence of contagion effect of Asian crisis. These findings are in agreement with the discussion in Forbes and Regobon (2002), in which the authors argue that based on the globalization theory and wake-up call hypothesis, financial crisis may spread from one country to another country through economic linkages and asset re-assessments, and thus leads to a significant increase in the correlations of asset returns. Hwang, In and Kim (2010) also examines the contagion effect of the U.S. sub-prime crisis on International stock markets using 38 country data. They find evidence of financial contagion not only in emerging markets but also in developed markets during the U.S. subprime crisis. They find evidence of spillover effects of news concerning sovereign credit rating during subprime crisis. The conditional correlations significantly increase during the U.S. subprime crisis and these higher levels persist for the remaining period of the subprime crisis.

C. The effect of sovereign credit-rating changes on correlation coefficients

So far we have shown that there seem to be contagious effects during the European sovereign debt crisis in general. We now study if single rating agency announcements can by themselves trigger contagious effects. If a negative rating announcement in one country significantly increases cross-country correlations, this rating cut also influences the investors' sentiment about other countries in which there was no rating downgrade at all. In this section we investigate if negative rating announcements for Greece significantly changed the correlation dynamics and consequently altered the financial situation of the other countries analyzed.

The news that received substantial attention from policy makers and investors during the debt crisis included the announcements of changes in sovereign credit ratings for a particular country. In order to analyze the contagious effect of announcements, univariate time series models for the dynamic conditional correlations are estimated and enhanced by rating announcement dummies. We define the following regression:

$$\rho_{ij,t} = \varphi_0 + \varphi_1 \rho_{ij,t-1} + d_{1,ij} DM_{i,t} + d_{2,ij} DM_{j,t} + e_{ij,t}\,, \tag{13}$$

where $\rho_{ij,t}$ is the conditional correlation between Greece and other countries. $DM_{i,t}$ equals 1 if sovereign credit rating announcements of Greece occurs. $DM_{j,t}$ equals 1 if sovereign credit rating announcement of its own country occurs.

In order to examine the impact of sovereign credit rating changes more deeply, we also have,

$$\rho_{ij,t} = \varphi_0 + \varphi_1 \rho_{ij,t-1} + w_1 I_{i,t} + w_2 I_{j,t} + e_{ij,t}\,, \text{ and } I_{i(j),t} = \Delta v\,. \tag{14}$$

$I_{i(j),t}$ is used to capture the effect of sovereign credit-rating changes in Greece i and its own country j. Δv is changes in the sovereign credit ratings. Following Chiang et al. (2007), we set $I_{i(j),t}$ =1 for an upgrade of one notch, and, we set $I_{i(j),t}$ = - 2 for a downgrade of two. If there is an outlook changes from stable to negative, rating is changed by -1/3. If an outlook changes from positive to negative, then the rating is changed by -2/3. I focus on the three major credit rating agencies, i.e. Fitch, Moody's and Standard and Poor's (S&P). If a rating cut for Greece significantly increases the stock index return correlation between Greece and another country, one might conclude for contagious effects. In the regression, we also add a dummy of rating downgrade announcement of own country.

Table 7: Effects of sovereign credit rating downgrade announcements on stock return correlations

	ϕ_0	ϕ_1	d_1	d_2
Spain	0.0015	0.9965	0.0073	-0.0032
t-statistics	2.1100	649.0300	2.3500	-0.8600
P-value	0.0350	0.0000	0.0190	0.3920
France	0.0015	0.9967	0.0066	-0.0026
t-statistics	2.0300	644.8300	2.1700	-0.2000
P-value	0.0420	0.0000	0.0300	0.8380
Austria	0.0012	0.9973	0.0018	-0.0002
t-statistics	1.7300	704.5100	0.6000	-0.0200
P-value	0.0830	0.0000	0.5510	0.9880
Belgium	0.0013	0.9970	0.0043	0.0004
t-statistics	1.8800	676.7300	1.4100	0.0600
P-value	0.0600	0.0000	0.1600	0.9520
Ireland	0.0018	0.9954	0.0078	0.0016
t-statistics	2.1800	536.5500	2.3500	0.2600
P-value	0.0290	0.0000	0.0190	0.7930
Netherlands	0.0015	0.9966	0.0060	0.0200
t-statistics	1.9800	620.9100	2.0300	2.3200
P-value	0.0480	0.0000	0.0420	0.0200
Germany	0.0017	0.9961	0.0053	0.0242
t-statistics	2.3100	615.2100	1.7000	2.6700
P-value	0.0210	0.0000	0.0900	0.0080
UK	0.0016	0.9962	-0.0034	-0.0047
t-statistics	2.0900	579.2200	-1.2500	-0.6000
P-value	0.0360	0.0000	0.2110	0.5500

Note: $\rho_{ij,t} = \varphi_0 + \varphi_1 \rho_{ij,t-1} + d_{1,ij} DM_{i,t} + d_{2,ij} DM_{j,t} + e_{ij,t}$,

where $\rho_{ij,t}$ is the conditional correlation between Greece and other countries obtained from DCC-GJR-GARCH model. $DM_{i,t}$ equals 1 if sovereign credit rating announcements of Greece occurs. $DM_{j,t}$ equals 1 if sovereign credit rating announcement of its own country occurs. The regressions are conducted with Newey-West standard errors.

Table 7 reports the results of tests of the influence of news about credit rating changes on across-market correlation between stock index returns. We find significant influence of Greek news about credit rating changes given significant coefficients of d_1 for four countries. The correlations between stock index returns of Greece and Spain, France, Ireland, Netherlands are significantly positively influenced by Greek sovereign credit rating downgrade announcements. That is, the announcement of Greek sovereign credit rating downgrade increased the cross-market correlations. We also find that stock return correlation between Greece and Germany is weakly and positively affected by Greek rating downgrade at 10% significance level. Since the correlation of Greek and these countries' stock index return correlation increases on Greek announcement days, the bad information about Greece spreads over to these countries and negative rating news on Greece seem to badly influence investors' perception of the financial stance of other countries. Therefore, contagion can be identified. The coefficients of the credit rating announcement of its own countries are significantly positive for only two countries, Netherlands and Germany.

Table 8 repots the results of tests of the influence of news about changes in credit rating notches on across-market correlation between stock index returns. Consistent with Table 7, the correlations between stock index returns of Greece and Spain, France, Ireland, Netherlands are significantly positively influenced by Greek sovereign credit rating downgrades. And Germany is also weakly affected. However, none of the coefficients of the credit rating downgrades of own countries are significant in Table 8.

Table8: Effects of sovereign credit rating notch changes on stock return correlations

	ϕ_0	ϕ_1	w_1	w_2
Spain	0.0015	0.9965	-0.0032	0.0025
t-statistics	2.1400	649.0300	-2.5200	1.2400
P-value	0.0320	0.0000	0.0120	0.2140
France	0.0015	0.9967	-0.0031	0.0026
t-statistics	2.0200	645.0300	-2.5000	0.2000
P-value	0.0430	0.0000	0.0120	0.8380
Austria	0.0012	0.9973	-0.0012	0.0002
t-statistics	1.7200	704.5600	-0.9500	0.0100
P-value	0.0860	0.0000	0.3410	0.9880
Belgium	0.0013	0.9970	-0.0023	-0.0001
t-statistics	1.8700	676.9200	-1.8600	-0.0200
P-value	0.0610	0.0000	0.0620	0.9830
Ireland	0.0018	0.9954	-0.0030	0.0002
t-statistics	2.2000	536.5800	-2.2800	0.0800
P-value	0.0280	0.0000	0.0230	0.9330
Netherlands	0.0015	0.9966	-0.0029	-0.0082
t-statistics	2.0000	620.5800	-2.4200	-0.7000
P-value	0.0460	0.0000	0.0160	0.4810
Germany	0.0017	0.9960	-0.0024	-0.0098
t-statistics	2.3300	614.5500	-1.8800	-0.8000
P-value	0.0200	0.0000	0.0600	0.4240
UK	0.0017	0.9961	0.0017	0.0157
t-statistics	2.1300	578.8600	1.5600	0.6000
P-value	0.0330	0.0000	0.1190	0.5490

Note: $\rho_{ij,t} = \varphi_0 + \varphi_1 \rho_{ij,t-1} + w_1 I_{i,t} + w_2 I_{j,t} + e_{ij,t}$, and $I_{i(j),t} = \Delta v \,.\, I_{i(j),t}$ is used to capture the effect of sovereign credit-rating changes in Greece i and its own country j. Δv is changes in the sovereign credit ratings. The regressions are conducted with Newey-West standard errors.

One possible reason for the sign of sovereign credit rating changes on correlation coefficients is due to the different speeds in reacting to the announcements. For example, if the stock return in both Greece and Spain react instantaneously to Greek rating changes, and with same speed, the pair-wise correlation coefficient is likely to increase. Thus, a Greek downgrade announcement is seen to be positively related to correlation coefficients. If stock returns in Greece and Spain react to Spanish rating changes, with different speed, the pair-wise correlation coefficient is likely to decline or remain unchanged. This may be why we find that only the effect of Greek sovereign credit rating changes on correlation coefficients is significant. Since we assume that Greece is the origin of the sovereign debt crisis, stock returns in other countries react to the Greek rating changes fast. Thus the correlations of stock returns tend to increase in response to Greek sovereign rating downgrades.

The findings are consistent with the previous studies on the impact of sovereign credit risk. Aizenman, Hutchison and Jinjarak (2011) estimate the pricing of sovereign risk for fifty countries based on fiscal space (debt/tax; deficits/tax) and other economic fundamentals over 2005–10. They focus in particular on five countries in the South-West Eurozone Periphery, Greece, Ireland, Italy, Portugal and Spain. Dynamic panel estimates show that fiscal space and other macroeconomic factors are statistically and economically important determinants of sovereign risk. However, risk-pricing of the Eurozone Periphery countries is not predicted accurately either in-sample or out-of-sample: unpredicted high spreads are evident during global crisis period, especially in 2010 when the sovereign debt crisis swept over the periphery area. They match the periphery group with five middle income countries outside Europe that were closest in terms of fiscal space during the European fiscal crisis. Eurozone Periphery default risk is priced much higher than the matched countries in 2010, even allowing for differences in fundamentals. One interpretation is that these economies switched to a “pessimistic” self-fulfilling expectational equilibrium. An alternative interpretation is that the market prices not on current but future fundamentals, expecting adjustment challenges in the Eurozone periphery to be more difficult for than the matched group of middle-income countries because of exchange rate and monetary constraints. Chiang et al (2007) also find that the correlation of stock return between Thailand and other four Asian countries (Indonesia, Malaysia, Philippines and Korea) are all significant and positively affected by sovereign credit-rating downgrades in Thailand.

Summarizing the analysis of Greek announcements we conclude that bad rating news show at least some tendency towards a generation of contagious effects for some countries. The identification of contagious effects generated by raging announcements is important for several reasons. First, the rating development of different related countries needs to be kept in mind when it comes to interpreting stock index return movements or implementing measures aiming at influencing the stock markets. For instance, countries which are badly affected by other countries' ratings should try to avoid the emission of new stocks soon after downgrades of related countries as such news will put upward pressure on the required return on their own new issue. Second, announcements effects are important from an investors' point of view as argued by Chritiansen (2000). The behavior of co-movements of different assets is important when it comes to risk management, asset allocation and asset pricing.

D. Robustness Check

In the last section, I conduct the analysis using the conditional correlations obtained from asymmetric DCC model, which allows asymmetries in both conditional variance and conditional correlations. The asymmetric DCC model is specified as follows:

Return equation: $r_t = \mu + \varepsilon_t$ (15)

Variance equation: Glosen-Jagannathan-Runkle Garch (GJR-GARCH)

$$h_{ii,t} = c + (\alpha + \theta I_t[\varepsilon_{t-1} < 0])\varepsilon_{ii,t-1}^2 + \beta h_{ii,t-1} \quad (16)$$

The evolution of the correlation in the DCC model is given by:

$$Q_t = \overline{Q}(1 - a - b) - g\overline{m} + a\varepsilon_{t-1}\varepsilon_{t-1}^{'} + bQ_{t-1} + gm_{t-1}m_{t-1}^{'} \quad (17)$$

Table 9 reports the estimation results of asymmetric DCC model. In Panel A, the μ term in the mean equation is negative for three countries, France, Netherlands, UK and positive for the other 6 countries.

In Panel B, the parameter theta are significant and positive for all the 9 countries, implying that the conditional variance of stock returns is affected more significantly by negative shocks than by positive shock. The results indicate that the volatility of the European stock markets increase more by bad news than by good news, e.g., showing the leverage effects. The finding is consistent with the existing literature such as the evidence presented by Cappiello et al. (2006).

Panel C of Table 9 reports the estimation results for the evolution equation of the correlation in asymmetric DCC model. Both a and b coefficients are significant at one percent level indicating strong time-varying conditional correlations of the returns of these stock markets. We obtain negative g, implying that the correlation evolution is influenced less by bad news in the market. However, Cappiello et. al (2006) and Yiu et. al (2010) find that the coefficient g is insignificant, and that the negative innovations to return do not play a different role than positive innovations in determining the dynamic conditional correlations of stock returns.

Table 9: Estimation results of asymmetric DCC model

PanelA: Mean Equation			
	mean	t-statistics	P-value
Greece	0.0209	0.8532	0.3936
France	-0.0168	-0.8320	0.4054
Austria	0.0713	3.6573	0.0003
Belgium	0.0288	1.6439	0.1002
Netherlands	-0.0125	-0.6459	0.5184
Spain	0.0121	0.5956	0.5515
Germany	0.0088	0.4077	0.6835
Ireland	0.0402	2.0259	0.0428
UK	-0.0076	-0.4457	0.6558
PanelB: Variance Equation			
	constant	t-statistics	P-value
Greece	0.0180	3.1798	0.0015
France	0.0252	5.1022	0.0000
Austria	0.0326	4.9138	0.0000
Belgium	0.0245	6.2829	0.0000
Netherlands	0.0191	5.9738	0.0000
Spain	0.0193	5.1068	0.0000
Germany	0.0251	5.4101	0.0000
Ireland	0.0306	5.1213	0.0000
UK	0.0173	5.1065	0.0000
	alpha	t-statistics	P-value
Greece	0.0388	4.3686	0.0000
France	-0.0225	-3.0587	0.0022
Austria	0.0259	2.2917	0.0219
Belgium	0.0143	1.5680	0.1169
Netherlands	-0.0245	-3.0464	0.0023
Spain	-0.0054	-0.7596	0.4475
Germany	-0.0239	-3.4439	0.0006
Ireland	0.0470	3.9444	0.0001
UK	-0.0143	-1.4405	0.1497
	beta	t-statistics	P-value
Greece	0.9308	101.7512	0.0000
France	0.9201	93.7427	0.0000
Austria	0.8926	65.8083	0.0000
Belgium	0.8848	80.0956	0.0000
Netherlands	0.9257	107.5383	0.0000
Spain	0.9234	102.9514	0.0000
Germany	0.9276	101.2154	0.0000
Ireland	0.8851	67.8499	0.0000
UK	0.9116	88.3680	0.0000

Table 9: continued

	theta	t-statistics	P-value
Greece	0.0543	4.5618	0.0000
France	0.1876	9.4736	0.0000
Austria	0.1242	6.3697	0.0000
Belgium	0.1716	11.2355	0.0000
Netherlands	0.1793	10.9005	0.0000
Spain	0.1458	9.0734	0.0000
Germany	0.1690	10.2415	0.0000
Ireland	0.1035	5.5870	0.0000
UK	0.1800	9.3774	0.0000
PanelC: ADCC Equation			
	Coefficient	t-statistics	p-value
a	0.1201	23.7456	0.0000
b	0.9824	750.3204	0.0000
g	-0.1167	-12.5456	0.0000

Notes: Return equation: $r_t = \mu + \varepsilon_t$

Variance equation: Glosen-Jagannathan-Runkle Garch (GJR-GARCH)

$$h_{ii,t} = c + (\alpha + \theta I_t [\varepsilon_{t-1} < 0])\varepsilon_{ii,t-1}^2 + \beta h_{ii,t-1}$$

The evolution of the correlation in the ADCC model is given by:

$$Q_t = \overline{Q}(1-a-b) - g\overline{m} + a\varepsilon_{t-1}\varepsilon_{t-1}' + bQ_{t-1} + gm_{t-1}m_{t-1}'$$

Table 10 and Table 11 reports the effects of sovereign credit rating changes on the conditional correlations obtained from asymmetric DCC model. From Table 10 and Table 11, we can see that the results are consistent with previous results. The correlations between stock index returns of Greece and Spain, France, Ireland, Netherlands are significantly positively influenced by Greek sovereign credit rating downgrade announcements. However the effects of Greek sovereign credit rating downgrade announcements are significant for Netherlands and France at 10%, instead of 5%.

Table 10: Effects of sovereign credit rating downgrade announcements on stock return correlations

	ϕ_0	ϕ_1	d_1	d_2
Spain	0.0022	0.9951	0.0073	-0.0033
t-statistics	2.5500	541.1600	2.1600	-0.8400
P-value	0.0110	0.0000	0.0310	0.4030
France	0.0024	0.9948	0.0064	-0.0026
t-statistics	2.5600	516.4900	1.8700	-0.1900
P-value	0.0100	0.0000	0.0610	0.8520
Austria	0.0018	0.9961	0.0018	-0.0002
t-statistics	2.1500	581.6900	0.5300	-0.0100
P-value	0.0320	0.0000	0.5960	0.9880
Belgium	0.0022	0.9951	0.0042	0.0004
t-statistics	2.4500	529.6000	1.2100	0.0500
P-value	0.0140	0.0000	0.2280	0.9590
Ireland	0.0021	0.9948	0.0077	0.0016
t-statistics	2.3600	503.2900	2.2200	0.2500
P-value	0.0190	0.0000	0.0260	0.8000
Netherlands	0.0022	0.9951	0.0059	0.0198
t-statistics	2.4100	518.7800	1.7900	2.0900
P-value	0.0160	0.0000	0.0730	0.0370
Germany	0.0028	0.9939	0.0050	0.0240
t-statistics	2.9000	489.0900	1.4500	2.3800
P-value	0.0040	0.0000	0.1460	0.0170
UK	0.0018	0.9959	-0.0034	-0.0047
t-statistics	2.1800	560.0800	-1.2200	-0.5800
P-value	0.0290	0.0000	0.2230	0.5600

Note:

$$\rho_{ij,t} = \varphi_0 + \varphi_1 \rho_{ij,t-1} + d_{1,ij} DM_{i,t} + d_{2,ij} DM_{j,t} + e_{ij,t} ,$$

where $\rho_{ij,t}$ is the conditional correlation between Greece and other countries obtained from Asymmetric DCC- GARCH model. $DM_{i,t}$ equals 1 if sovereign credit rating announcements of Greece occurs. $DM_{j,t}$ equals 1 if sovereign credit rating announcement of its own country occurs. The regressions are conducted with Newey-West standard errors.

Table 11: Effects of sovereign credit rating notch changes on stock return correlations

	ϕ_0	ϕ_1	w_1	w_2
Spain	0.0023	0.9950	-0.0032	0.0026
t-statistics	2.5800	541.0900	-2.3300	1.2000
P-value	0.0100	0.0000	0.0200	0.2310
France	0.0024	0.9949	-0.0030	0.0026
t-statistics	2.5500	516.6400	-2.1700	0.1900
P-value	0.0110	0.0000	0.0300	0.8520
Austria	0.0018	0.9961	-0.0012	0.0002
t-statistics	2.1300	581.7000	-0.8600	0.0100
P-value	0.0330	0.0000	0.3920	0.9880
Belgium	0.0022	0.9952	-0.0023	-0.0001
t-statistics	2.4400	529.7300	-1.6100	-0.0200
P-value	0.0150	0.0000	0.1070	0.9850
Ireland	0.0021	0.9948	-0.0030	0.0002
t-statistics	2.3700	503.3300	-2.1600	0.0800
P-value	0.0180	0.0000	0.0310	0.9380
Netherlands	0.0023	0.9951	-0.0028	-0.0081
t-statistics	2.4300	518.5700	-2.1400	-0.6300
P-value	0.0150	0.0000	0.0320	0.5300
Germany	0.0028	0.9938	-0.0023	-0.0096
t-statistics	2.9200	488.6800	-1.6200	-0.7100
P-value	0.0040	0.0000	0.1040	0.4790
UK	0.0018	0.9958	0.0017	0.0159
t-statistics	2.2100	559.7200	1.5200	0.5800
P-value	0.0270	0.0000	0.1290	0.5590

Note:

$\rho_{ij,t} = \varphi_0 + \varphi_1 \rho_{ij,t-1} + w_1 I_{i,t} + w_2 I_{j,t} + e_{ij,t}$, and $I_{i(j),t} = \Delta v \, . \, I_{i(j),t}$ is used to capture the effect of sovereign credit-rating changes in Greece i and its own country j. Δv is changes in the sovereign credit ratings. The regressions are conducted with Newey-West standard errors.

VI. Summary and Future Research

In this chapter, we estimate the time-varying conditional correlations of stock returns between Greece and other 8 European countries over 2001 to 2012, and analyze how the sovereign rates announcements and the U.S. subprime crisis have effects on these correlations. We find that the correlations vary over time between these countries and tend to reach the peaks in the late 2008 during the U.S. subprime crisis, and in the beginning of 2010 of the height of European debt crisis. The correlations between stock index returns of Greece and Spain, France, Ireland, Netherlands are significantly increased by Greek sovereign credit rating downgrade announcements. One possible reason is that the stock returns in these four countries and Greece reacts instantaneously to Greek sovereign rating changes, and a Greek rating downgrade announcement is positively related to correlation coefficients. In the future research, we plan to explore the factors that contribute to the changes on the correlation coefficients, and study on the different speeds of stock returns in reacting to rating announcements.

The spreading refinancing problems of some European countries are to some extent caused by contagion. This conclusion is important for the choice of political intervention. As argued by Forbs and Rigobon (2002), an identified contagion infecting countries with no economically justified financing problems would calm down investors and would possibly reduce the refinancing costs to normal or fundamental values. This would allow the normal economic development of the country to continue without any detrimental effects from the contagion. If however, no contagion is identified, then the financing problems are entirely due to fundamental economic and fiscal problems of the relevant country. For the current European situation it means that rescue strategies should adjusted to these insights. In May 2010, the European Financial Stability Facility was implemented and a 110 billion Euro loan to Greece was provide by the countries of the Eurozone and IMF. This was at the time when the DCC-GJR-GARCH model identifies contagious effects and thus this decision seems very reasonable. Further rescue strategies should be evaluated with respect to the similar quantitative analysis.

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Chapter3

The Effects of Macroeconomic Announcements on the Correlations of Gold, Dollar and Stock Returns

I. Introduction

Financial markets and the variety of financial instruments have grown steadily in both volume and value in recent decades. This growth has raised the risks of the financial system and potentially established the need for a hedge or safe haven asset for investors. Gold is considered to serve as a hedge against a falling dollar and a safe haven for stock, especially during financial crisis period. During the subprime crisis, the S&P stock index dropped by 13.54% and the trade weighted value of dollar dropped by 7.19% over 08/01/2007 to 07/30/2008. But during the same period, the spot gold price increased by 38.45%. Since the beginning of subprime crisis in August 2007, the nominal gold price has risen by 145.78%, from $660/oz on 08/01/2007 to $1622/oz on 07/31/2012. The performance of gold is very impressive given the losses suffered in other asset classes. The recent financial crisis and the strength of gold price present a strong motivation to test the ability of gold as a hedge or safe haven for losses in financial markets. Previous literature shows the hedging, diversifying and safe haven properties of gold. Based on Baur and Lucey (2010), the following concepts distinguish a safe haven from a hedge and a diversifier:

A hedge is an asset that is uncorrelated or negatively correlated with another asset or portfolio on average. A hedge does not have the property of reducing losses in times of market stress or financial crisis period since the asset could exhibit a positive correlation in such periods and a negative correlation in normal times with a negative correlation on average. Researchers found that there exists an inverse correlation based relationship between fluctuations in gold prices and the U.S. dollar (Capie, Mills and Wood, 2005). A safe haven is an asset that is uncorrelated or negatively correlated with another asset or portfolio in times of market stress or financial crisis. The property of a safe haven is the nonpositive correlation with a portfolio in extreme market conditions. This property does not force the correlation t be positive or negative on average but only to be zero or negative in specific periods. Some researchers find evidence that gold is used as a safe haven for stock (Baur and McDemott, 2010, Baur and Lucey, 2010). A diversifier is an asset that is positively (but not perfectly correlated) with another asset on average. Some researchers suggest diversification benefits of gold in portfolio settings (Jaffe, 1989, Hillier, Draper & Faff , 2006).

Previous studies also show that the asset returns and volatilities are affected by the macroeconomic announcements (Flannery and Protopapadakis, 2002, Roache and Rossi, 2009, Almeida, Goodhart and Payne, 1998). Some papers also suggest that asset returns and volatilities respond differently to news announcements in recessions and expansions (Boyd et al., 2005, Andersen et al., 2004). But the research on how macroeconomic announcements affect the correlations of asset returns is scarce. So the research questions in this paper are as follows: how do markets adjust to important news arrivals? Do macroeconomic announcement affect the correlations of gold, dollar and stock returns? Does the current economic business cycle characterize the markets' price reactions to macroeconomic news? In this paper, I attempt to shed new lights on these important issues.

This paper has three objectives. First, I'll study if gold is a hedge against change in the value of dollar and if gold is a safe haven or just a diversifier for stock. Second, I'll examine the effect of macroeconomic announcements on the correlations of gold-stock and gold-dollar returns. Third, I'll test if the correlations of the asset returns respond differently to news announcements under different economic conditions.

The study of co-movement across asset classes is important for several reasons. First, asset correlation is a key issue in asset allocation decisions. Portfolio rebalancing and optimization hinge on the concept of correlation. Second, correlation is a central issue in risk management and hedging. Third, correlation patterns across business cycles and in response to major macroeconomic announcements provide important information to investors.

This paper contributes the existing literature in three ways. First, the previous studies have largely focused only on the first moment of the stock returns, foreign exchange rates and gold returns using either regression or cointegration methods. In this paper, we use ADCC-GARCH model to obtain the dynamic conditional correlation. And I'll study how the subprime financial crisis affects the correlations of gold, stock and dollar returns. Second, the previous literature focuses only on the impact of news announcement on asset returns and volatilities, but I investigate the news effect on the correlation between these three asset returns. Third, I'll also examine how the response of the correlations of asset returns to the news announcements varies over recessions and expansions.

II. Literature Review

In this section, I discuss the related literature. First, I discuss the literature on correlations of gold, dollar and stock returns. Second, I discuss the literature on macroeconomic announcement effects.

Researchers found that there exists an inverse correlation based relationship between fluctuations in gold prices and the U.S. dollar. For example, Capie, Mills and Wood (2005) suggest that gold has served as a hedge against fluctuations in the foreign exchange value of the dollar. A negative, typically inelastic, relationship is found between gold and yen-dollar (sterling-dollar), but the strength of this relationship has shifted over time. Some researchers suggest diversification benefits of gold in portfolio settings (Jaffe, 1989,). The author found low correlations between gold-stock returns and argue that gold can be used to decrease the total risk of a well-diversified common stock portfolio without diminishing its average return. Hillier, Draper & Faff (2006) examine whether gold, platinum and silver provide valuable diversifying qualities for a sample period from 1976-2004. They found that portfolios containing a moderate weighting of gold perform better. And they suggest that precious metals have the potential to play a diversifying role in broad based investment portfolios. Many researchers also find evidence that gold is used as a hedge against and safe haven for stock. For example, Baur and Lucey (2010) study constant and time-varying relations between U.S., U.K. and German stock and bond returns and gold returns. They find that gold is a hedge against stocks on average. Baur and McDemott (2010) examine the role of gold in the global financial system. They test the hypothesis that gold represents a safe haven against stocks of major emerging and developing countries. A descriptive and econometric analysis for a sample spanning a 30 year period from 1979 to 2009 shows that gold is both a hedge and a safe haven for major European stock markets and the US but not for Australia, Canada, Japan and large emerging markets such as the BRIC countries. Looking at specific crisis periods, they find that gold was a strong safe haven for most developed markets during the peak of the recent financial crisis. Moore (1990) tests the relationship between the leading signals of inflation and the gold prices of the New York market since 1970. The author found that from 1970 to 1988, gold prices and stock and bond returns are negatively correlated. When gold prices rose, the stock and bond returns declined.

The study of asset return correlations has important implications for investors' portfolio rebalancing. For example, Hau and Rey (2006) explore whether the pattern of international equity returns, equity portfolio flows, and exchange rate returns are consistent with the hypothesis that (unhedged) global investors rebalance their portfolio in order to limit their exchange rate exposure when there are relative equity return and exchange rate shocks. They also explore whether equity flow shocks influence the exchange rates and relative equity prices. In the estimation of the VAR system they do not impose any causal ordering upon the primitive shocks, but instead identify the system based on theoretical priors about the contemporaneous conditional correlations between the three variables. International data for the five largest equity markets are consistent with a theory in which equity returns and portfolio rebalancing are an important source of exchange rate dynamics. Buraschi, Porchia and Trojani (2010) develop a new framework for multivariate intertemporal portfolio choice to derive optimal portfolio implications for economies in which the degree of correlation across industries, countries, or asset classes is stochastic. Optimal portfolios include distinct hedging components against both stochastic volatility and correlation risk. They find that the hedging demand is typically larger than in univariate models, and it includes an economically significant covariance hedging component, which tends to increase with the persistence of variance–covariance shocks, the strength of leverage effects, the dimension of the investment opportunity set, and the presence of portfolio constraints.

Some researchers have examined the effects of macroeconomic announcements on the returns of gold, dollar and stock. But so far, there are no studies that examine the effects of macroeconomic announcement on the correlations of gold, dollar and stock returns. Overall, the previous research shows that macroeconomic announcements effects are significant for asset returns. Flannery and Protopapadakis (2002) find that stock market returns are significantly affected by the macroeconomic announcements. Faust et al. (2003) show that macroeconomic announcements affect the returns of dollar in a window around the announcements. Roache and Rossi (2009) show that gold is unique among commodities, with prices reacting to specific scheduled announcements in the United States and the Euro area (such as indicators of activity or interest rate decisions) in a manner consistent with gold's traditional role as a safe-haven and store of value. Using intraday data, Christie and Chaudhry (2000) document the responses of gold and silver future prices to monthly macroeconomic news releases. Both metals respond strongly to the release of Capacity Utilization. Gold also responds strongly to the release of the CPI. They also find that the release of the Unemployment Rate affects both gold and silver, whereas the Gross Domestic Product and PPI have significant effects on gold. Almeida, Goodhart and Payne (1998) study the high frequency reaction of the DEM/USD exchange rate to publicly announced macroeconomic information emanating from Germany and the U.S. By using data sampled at a five-minute frequency, they are able to identify significant impacts of most announcements on the exchange rate change in the 15 minutes post-announcement. Truck and Liang (2012) investigate the volatility dynamics of gold markets. While there are a number of recent studies examining volatility and Value-at-Risk (VaR) measures in financial and commodity markets, none of them focuses on the gold market. They use a large number of statistical models to model and then forecast daily volatility and VaR. Both insample and out-of-sample forecasts are evaluated using appropriate evaluation measures. For in-sample forecasting, the class of TARCH models provide the best results. For out-of-sample forecasting, the results were not that clear-cut and the order and specification of the models were found to be an important factor in determining model's performance. VaR for traders with long and short positions were evaluated by comparing failure rates and a simple AR as well as a TARCH model perform best for the considered back-testing period. Overall, most models outperform a benchmark random walk model, while none of the considered models performed significantly better than the rest with respect to all adopted criteria. Ratner and Klein (2008) investigate the use of gold as an investment asset. The data consist of U.S. and foreign equity returns from 1975 to 2005. The results indicate that investment in gold is inferior to a simple buy-and-hold strategy of U.S. equities over the long term. Gold is often believed to provide potential as a defensive asset, given its low correlation with U.S. equities. However, a portfolio optimization technique using actual and simulated data indicates that the long-term portfolio benefits of holding gold are marginal at best. Demidova and Heidorn (2007) examine the key drivers of gold investment. Since 2000 the gold price has risen drastically, making gold an interesting add-on to a portfolio. The authors suggest that in the portfolio context gold has had a positive impact on Euro and USD portfolios between 2000 and 2006 due to considerable returns and low correlation to other assets. However, this has not been true for almost all other periods, the correlation was always low but the returns of gold were almost zero, overriding the positive diversification effect.

Some researchers have studied the effect of macroeconomic announcements on the volatility of asset returns, typically using the GARCH-volatility relying on daily data and indicator variables as explanatory variables. Flannery and Protopapadakis (2002) find that the GARCH variance of stock returns is affected by macroeconomic announcements. They estimate a GARCH model of daily equity returns, where realized returns and their conditional volatility depend on 17 macro series' announcements. They find six candidates for priced factors: three nominal (CPI, PPI, and a Monetary Aggregate) and three real (Balance of Trade, Employment Report, and Housing Starts). Rangel (2011) examine the effect of macroeconomic releases on stock market volatility through a Poisson–Gaussian-GARCH process with time-varying jump intensity, which is allowed to respond to such information. The day of the announcement, *per se*, is found to have little impact on jump intensities. Employment releases are an exception. However, when macroeconomic surprises are considered, inflation shocks show persistent effects while monetary policy and employment shocks reveal only short-lived effects. Also, the jump intensity responds asymmetrically to macroeconomic shocks. Evidence on macroeconomic variables relevance in explaining jump dynamics and improving volatility forecasts on event days is provided. Hautsch Hess and Veredas (2011) study the impact of the arrival of macroeconomic news on the informational and noise-driven components in high-frequency quote processes and their conditional variances. They decompose bid and ask returns into a common (“efficient return”) factor and two market-side-specific components capturing market microstructure effects. The corresponding variance components reflect information-driven and noise-induced volatilities. They find that all volatility components reveal distinct dynamics and are positively influenced by news. The proportion of noise-induced variances is highest before announcements and significantly declines thereafter. Moreover, news-affected responses in all volatility components are influenced by order flow imbalances. Macro news can affect currency prices directly and indirectly via order flow. Past research shows that the direct effects of scheduled macro news account for less than 10% of daily price variance. Evans and Lyons (2008) show that the arrival of macro news can account for more than 30% of daily price variance. Two features of their analysis account for this finding. They consider the broad spectrum of macro news items that market participants observe, not just scheduled announcements. And they allow the arrival of news to affect prices indirectly via its impact on the volatility of order flow. Their analysis shows that order flow variations contribute more to currency price dynamics following the arrival of public macro news than at other times. Roughly two-thirds of the total effect of macro news on the DM/$ exchange rate is transmitted via order flow.

Many studies show that asset prices have different news reactions in expansions and recessions. For example, Boyd et al. (2005) find that stock price rises as a reaction to bad labor market news during expansions but fall during recessions. The authors find that on average, an announcement of rising unemployment is good news for stocks during economic expansions and bad news during economic contractions. Boyd (2005) argues that unemployment news must convey more information about the real interest rates in expansions, and more information about risk premia and dividends in recessions. Andersen et al. (2004) find that good news releases in retail sales, GDP, employment have a positive impact on stock prices in recessions and a negative impact in expansions. So the interpretation of macroeconomic news items depends on the economic situation. The influence of these factors on gold-stock and dollar-stock co-movements varies over economic conditions. Yang Zhou and Wang (2009) documents time-varying stock–bond correlation over macroeconomic conditions (the business cycle, the inflation environment and monetary policy stance) using monthly stock and bond return data in the past 150 years (1855–2001) for both the US and the UK,. They find different patterns of time variation in stock–bond correlations over the business cycle between US and UK, which implies that bonds may be a better hedge against stock market risk and offer more diversification benefits to stock investors in the US than in the UK. Further, there is a general pattern across both the US and the UK during the post-1923 subperiod and during the whole sample period: higher stock–bond correlations tend to follow higher short rates and (to a lesser extent) higher inflation rates. Helmersson Kang and Skold (2008) study the historical price development of gold during recessions in order to find out whether an inclusion of gold can improve a portfolio held in today’s recession. They find that the gold price is strongly influenced by uncertainty, and even though an optimal allocation of gold in each recession could be found, no general optimal allocation applicable in today’s recession could be found.

III. Methodology

ADCC-GARCH model is a developed model based on DCC-GARCH model proposed by Engle (2002). First, univariate GARCH models are estimated for each single asset and the standardized residual from the models for the conditional variance are used to calculate the conditional correlations.

The return equation is specified as

$$r_{gold,t} = \mu_{gold} + \varepsilon_t$$

$$r_{dollar,t} = \mu_{dollar} + \varepsilon_t \tag{1}$$

$$r_{stock,t} = \mu_{stock} + \varepsilon_t$$

$$\varepsilon_t / \xi_{t-1} \sim N(0, H_t) \tag{2}$$

Where r_t is an n*1 vector of asset returns, and ξ_{t-1} is the information set at time t-1. The AR(1) term is used to take into account the autocorrelation of asset returns.

All DCC-GARCH models use the fact that H_t can be decomposed as

$$H_t \equiv D_t R_t D_t \tag{3}$$

Where $D_t = diag\{\sqrt{h_{it}}\}$ is the n*n diagonal matrix of time-varying standard deviations from the univariate GARCH models, and R_t is the n*n time-varying correlation matrix. The DCC-GARCH model is designed to allow for a two-stage estimation of the conditional covariance matrix H_t. In the first stage, univariate volatility models are fitted to each of the asset return residuals and estimates of $\sqrt{h_{it}}$ are obtained. In the second stage, asset returns are transformed by their estimated standard deviations as $u_{it} = \varepsilon_{it} / \sqrt{h_{ii,t}}$. $u_{i,t}$ is used to estimate the correlation parameters. The evolution of the correlation in the standard DCC-GARCH model is given by

$$Q_t = (1-a-b)\overline{Q} + a u_{t-1} u_{t-1}^{'} + b Q_{t-1} \quad (4)$$

$$R_t = Q_t^{*-1} Q_t Q_t^{*-1} \quad (5)$$

Where $Q_t = \lfloor q_{ij,t} \rfloor$ is the n*n time-varying covariance matrix of u_t, $\overline{Q} = E\lfloor u_t u_t^{'} \rfloor$ is the n*n unconditional variance matrix of u_t, and a and b are scalars such as that a+b<1. $Q_t^* = \lfloor q_{ii,t}^* \rfloor = \lfloor \sqrt{q_{ii,t}} \rfloor$ is a diagonal matrix with the square root of the ith diagonal element of Q_t on its ith diagonal position. As long as Q_t is positive definite, Q_t^* guarantees that R_t is a correlation matrix with ones on the diagonal and the absolute values of all the other elements less than 1.

Following Engle (2002), the DCC-GARCH model can be estimated by a two-stage approach to maximize the log-likelihood function. Let the parameters D be denoted by θ and the additional parameters in R be denoted by φ. The log likelihood function can be written as the sum of a volatility part and a correlation part:

$$\begin{aligned} L(\theta,\varphi) &= L_V(\theta) + L_C(\theta,\varphi) \\ &= \left[-\frac{1}{2} \sum_t (n \log(2\pi) + \log|D_t|^2 + \varepsilon_t^{'} D_t^{-2} \varepsilon_t) \right] \\ &+ \left[-\frac{1}{2} \sum_t (\log|R_t| + u_t^{'} R_t^{-1} u_t - u_t^{'} u_t) \right] \end{aligned} \quad (6)$$

The volatility part of the likelihood is the sum of individual GARCH likelihoods. In the first stage, the volatility part of the likelihood is maximized to find,

$$\hat{\theta} = \arg\max \left[L_V(\theta) \right] \quad (7)$$

And the correlation part is then maximized in the second stage,

$$\max_{\varphi} \left\lfloor L_C(\hat{\theta},\varphi) \right\rfloor \quad (8).$$

To incorporate the asymmetries in volatilities:

The variance equation is the asymmetric GJR (1,1):

$$h_{ii,t} = c + (\alpha + \theta I_t[\varepsilon_{t-1} < 0])\varepsilon_{ii,t-1}^2 + \beta h_{ii,t-1} \tag{9}$$

Where $I_t = 1$, if $\varepsilon_{t-1} < 0$; $I_t = 0$, if $\varepsilon_{t-1} \geq 0$

$$R_t = diag[Q_t]^{-1} Q_t diag[Q_t]^{-1} \tag{10}$$

$$Q_t = \overline{Q}(1 - a - b) - g\overline{m} + a\varepsilon_{t-1}\varepsilon_{t-1}^{'} + bQ_{t-1} + gm_{t-1}m_{t-1}^{'} \tag{11}$$

Where a,b and g are scalar parameters. The vector $m_t = I[\varepsilon_t < 0] \circ \varepsilon_t$, where $\circ$ is the Hadamard product) isolates observations where standardized residuals are negative.

The ADCC process extends previous specifications by permitting conditional asymmetries in volatilities and conditional correlations. The ADCC specification is well suited to examine correlation dynamics among different assets and investigate the presence of asymmetric responses in conditional variance and correlations to negative returns. We use ADCC model because that correlation may be higher after a negative innovation than after a positive innovation of the same magnitude.

IV. Data

The data employed in this paper are daily observations on U.S. stock prices, gold price and dollar values over the Jan 1st 2001 – July 31st 2012 period. The stock return data is obtained from CRSP, the value-weighted return on all NYSE, AMEX, and NASDAQ stocks. I obtain the daily gold price data from the website of St. Louis Federal Reserve Database, the gold price is the gold fixing price at 10:30am (London time) in London Bullion Market, based in U.S. dollars. I get the daily U.S. dollar value also from the St. Louis Fed eral Reserve Database. It's the trade-weighted U.S. dollar index against major currencies

(DTWEXM, March 1973=100). I construct a recession indicator variable in this paper that is equal to one when the economy is in recession as defined by NBER (National Bureau of Economic Research, Cambridge, MA) business cycle data.

In this paper, I'll examine the announcement effects of the following 3 macroeconomic variables: (a) gross domestic product (GDP); (b) unemployment rate (UE); (c) consumer price index (CPI). The gross domestic product (GDP) estimates are released by the U.S. Department of Commerce, Bureau of Economic Analysis. Announcements relating to the whole economy unemployment rate (UE) are released by the Bureau of Labor Statistics. The national consumer price index (CPI) is released monthly by the Bureau of Labor Statistics.

I use the data obtained from "Econoday" on the expectations and realizations of 3 U.S. macroeconomic announcements. "Econoday" is a professional website which provides information of daily important economic events in U.S. and all over the world. Actually, the 'news' component or the "surprise" component of an announcement is important. The extent of any "surprise" contained in a given announcement is reflected by the deviation of the observed value of the macroeconomic statistic from its counterpart market expectation value. Balduzzi, Elton and Green (2001) proposed a measure of the "surprise" component,

$$E_{it} = A_{it} - F_{it}$$

where A_{it} is the actual released value for news i on day t, F_{it} is the forecast value for the announcement, E_{it} is the news surprise. In this paper, the forecast values for the announcements are constructed by Market News International and Thomson Financial from surveys held amongst professional analysts who give their expectations on approaching announcements. The median of the forecasts is then used as the expected market consensus for the macroeconomic announcements. The measure translates announcements into surprises, that is, the measure of this news component is the deviation of released (actual) figures from a market expectation estimate. Each of the news items maybe classified as either a positive-sign or negative-sign news announcement. For example, a negative GDP news event occurs where actual GDP<expected GDP and vice versa. In this paper, an announcement with positive surprise is defined as a positive news announcement (PNEWS), and an announcement with negative surprise is defined a negative news announcement (NNEWS).

Table 1: Summary Statistics of US Macroeconomic Announcements

	GDP	CPI	Unemployment rate
Unit of measurement	$billion	M/M % Change	Unemployment rate %
Total number of Announcements	139	139	139
Number of Positive News obs.	63(45%)	52(37%)	68(49%)
Number of Negative News obs.	51(37%)	41(30%)	36(26%)
Number of No Surprise News obs.	25(18%)	46(33%)	35(25%)

Note: Sample period : 01/01/2001-07/31/2012.

Table 1 shows the summary statistics of U.S. macroeconomic announcement data and the associated surprise component. I classified positive and negative announcements based on news surprise. For example, during 01-01-2001 to 07-31-2012, there are 139 CPI announcements in total and 52 out of 139 announcements are positive announcements, 41 out of 139 announcements are negative announcements. During sample periods, there are 139 unemployment announcements and 68 out of 139 announcements are positive announcements, 36 out of 139 are negative announcements. During sample periods, there are 139 GDP announcements and 63 out of 139 announcements are positive announcements, 51 out of 139 announcements are negative announcements.

Table 2: Summary statistics of asset returns

Panel A: Before the crisis (01/01/2001-07/31/2007)			
	DOLLAR	GOLD	STOCK
Mean	-0.011	0.051	0.028
Variance	0.064	1.051	1.066
Skewness	0.212	-0.178	0.155
Kurtosis	3.724	5.705	5.892
Panel B: During the subprime crisis (08/01/2007-12/07/2009)			
	DOLLAR	GOLD	STOCK
Mean	-0.002	0.109	-0.019
Variance	0.204	2.812	4.447
Skewness	-0.362	-0.092	-0.010
Kurtosis	6.339	7.053	7.207
Panel C: During the sovereign debt crisis (12/08/2009-07/31/2012)			
	DOLLAR	GOLD	STOCK
Mean	0.002	0.034	0.052
Variance	0.120	1.501	1.587
Skewness	0.340	-0.629	-0.332
Kurtosis	4.519	7.505	6.242

Table 2 reports the summary statistics of gold, dollar and stock returns during the sample period. Compared to the pre-crisis period, the average dollar returns increases during both crisis periods. However, the average stock returns declines during subprime crisis then rise during the debt crisis period. The average gold returns rise during subprime crisis period but decline during the debt crisis period. We see an increase in the variance of the three asset returns during both crisis periods. The results are consistent with previous studies on the effects of financial crisis on asset returns. Financial crisis, such as subprime crisis and sovereign debt crisis are negative shocks to stock markets. Thus value weighted stock returns exhibit significant decrease during U.S. subprime crisis. Subprime crisis also lead to significant increase in volatilities of U.S. stock market, since the variance of stock returns increase to 4.447 from 1.066 during subprime crisis. However, I didn't observe a substantial increase in volatility of stock return during European sovereign debt crisis. And during European sovereign debt crisis, mean stock return is even higher than the mean return before U.S. subprime crisis. It implies that after U.S. subprime crisis, U.S. stock market is recovering and is not seriously affected by the European sovereign debt crisis. An interesting result is that the mean trade weighted value of U.S. is increasing over time. Based on previous studies, gold may be used by investors as a hedge against stock especially during economic recessions or financial crisis. From Table 1, we can observe a substantial increase in mean gold returns during U.S. subprime crisis, from 0.051 to 0.109, and a substantial increase in variance of gold returns, from 1.051 to 2.812. This result provides us some evidence of the role of gold as a hedge against stock during financial crisis period and it motivates us to examine the correlation structure between gold returns and stock returns over time. However we don't observe such a pattern for European sovereign debt crisis.

V. Empirical results

A. Estimation of ADCC-GARCH model and conditional correlations

First, I report the unconditional correlations of gold-stock returns and gold-dollar returns during different sub-sample periods in Table3. Before we examine the dynamic conditional correlation of asset returns, I calculated the unconditional correlations and conduct a z-test to examine if there exist significant changes in unconditional correlations during subprime crisis and European sovereign debt crisis.

Table 3: Test in changes in unconditional correlations

	Gold-Dollar	Gold-Stock	Dollar-Stock
Correlation before the crisis	-0.2170	-0.0489	0.0046
Correlation during the subprime crisis	-0.2932	0.1743	-0.2865
Z-statistics	1.6801	-4.6342	6.4348
Correlation during the sovereign debt crisis	-0.2741	0.0210	-0.5682
Z-statistics	1.3548	-1.5595	2.6177

Note: I test the changes in unconditional correlations during period before crisis (1/1/2001-07/31/2007), during subprime crisis (08/01/2007-12/07/2009) and during sovereign debt crisis (12/08/2009-7/31/2012).

From Table 3, we can see that the unconditional correlations of gold-dollar returns are negative during all the three sub-sample periods and significantly increase in magnitude during both subprime crisis and sovereign debt crisis. The mean correlation of gold-stock returns is negative before the crisis, but become positive during the subprime crisis and remains positive during sovereign debt crisis. If gold is used as a hedge against U.S. stock, we expect to observe a significant decrease in gold-stock correlation. That is when stock returns substantially decrease during recession periods or financial crisis periods, investors would be more willing to hold gold to hedge investment risks. And thus when stock returns decrease, gold returns would increase. We would observe a significant decrease in gold-stock correlations. From Table 3, we can see that during U.S. subpirme mean gold-stock correlations significantly increase to 0.1743 from -0.0489 and during European sovereign debt crisis, the gold-stock correlation decreases to 0.0210 from 0.1743. The results based on unconditional correlations imply that gold returns are weakly and positively correlated with stock returns during crisis periods, implying that gold may be just used as a diversifier by investors, not a strong hedge against stock. In the next section, I'll obtain dynamic conditional gold-stock correlations and conduct regressions with financial crisis dummies to examine how the correlation structure of asset returns changes over time.

On the other hand, if gold is used by investors as a hedge against dollar, then during U.S. subprime crisis and European sovereign debt crisis, we would observe significant decrease in gold-dollar correlations. That is when dollar value substantially decreases during recession periods or financial crisis periods, investors would be more willing to hold gold to hedge currency risks. And thus when dollar value decrease gold returns would increase. We would observe a significant decrease in gold-dollar correlations. From Table 3, we can see that during U.S. subpirme crisis gold-dollar correlations significantly decrease to -0.2932 from -0.2171 and during European sovereign debt crisis, the gold-dollar correlation is -0.2741, still lower than the correlation before U.S. subprime crisis. This finding suggests that gold is always used as a hedge against dollar over time and this role is stronger during financial crisis periods.

Table4: Results of ADCC model estimation

Panel A: Return Equation			
	Gold	Dollar	Stock
μ	0.0794	-0.0106	0.0178
T-statistics	4.3679	-2.0657	1.1020
P-value	0.0000	0.0389	0.2705
Panel B: Variance Equation			
	Gold	Dollar	Stock
C	0.0116	0.0007	0.0145
T-statistics	4.0148	2.9648	4.7704
P-value	0.0001	0.0030	0.0000
alpha	0.0893	0.0601	-0.0191
T-statistics	9.5077	6.9930	-2.7390
P-vlaue	0.0000	0.0000	0.0062
Beta	0.9372	0.9436	0.9342
T-statistics	130.9590	131.3846	101.0479
P-value	0.0000	0.0000	0.0000
Theta	-0.0627	0.0215	0.1446
T-statistics	-6.6466	2.1836	9.5382
P-value	0.0000	0.0290	0.0000
Panel C: Conditional Correlation equation			
Variable	Coefficient	T-statistics	P-value
a	0.0982	10.3757	0.0000
b	0.9944	843.8056	0.0000
g	0.0319	0.7712	0.4406

Note: Return equation:

$$r_{gold,t} = \mu_{gold} + \varepsilon_t$$

$$r_{dollar,t} = \mu_{dollar} + \varepsilon_t$$

$$r_{stock,t} = \mu_{stock} + \varepsilon_t$$

Variance equation: Glosen-Jagannathan-Runkle Garch (GJR-GARCH)

$$h_{ii,t} = c + (\alpha + \theta I_t[\varepsilon_{t-1} < 0])\varepsilon_{ii,t-1}^2 + \beta h_{ii,t-1}$$

The evolution of the correlation in the ADCC model is given by:

$$Q_t = \overline{Q}(1 - a - b) - g\overline{m} + a\varepsilon_{t-1}\varepsilon_{t-1}^{'} + bQ_{t-1} + gm_{t-1}m_{t-1}^{'}$$

Table 4 reports the estimation results for the Asymmetric DCC-GJR-GARCH model. The Asymmetric DCC-GJR-GARCH model consists of three equations, the return equation, the variance equation and the equation of the evolution of the conditional correlation. The variance equation we use is the GJR-GARCH model which allows us to examine the asymmetric effects of response of variance to negative news. First, the coefficients for the lagged variance and shock-squared terms in the variance equation are highly significant, which is consistent with time-varying volatility and justifies the appropriateness of the GARCH(1,1) specification. It reveals the presence of conditional heteroskedasticity in the time series. As we expect, the theta coefficient in the stock variance equation is significantly positive, which suggests the asymmetric effect of the response of stock variance to negative news. That is stock variance respond more to negative news than to positive news. However, we found significantly negative theta coefficients in gold variance equation. Our results suggest that gold returns also exhibit asymmetric response to negative news and positive news. However positive shocks increase the volatility by more than negative shocks. This effect is related to the safe haven and hedge property of gold. Investors interpret positive gold price changes as a signal for future adverse conditions and uncertainty in other asset markets. It introduces uncertainty in the gold market and thus higher volatility (Baur 2011). Second, Panel C of Table2 reports the estimation results for the evolution equation of the correlation in ADCC model. The a and b coefficients are highly significant. So we can conclude that conditional correlations of three financial asset returns are highly dynamic and time-varying. The g coefficient in the equation of evolution of conditional correlation is positive, but not significant.

Figure1: Dynamic Conditional Correlations of Gold and Dollar Returns (01/01/2001-07/31/2012)

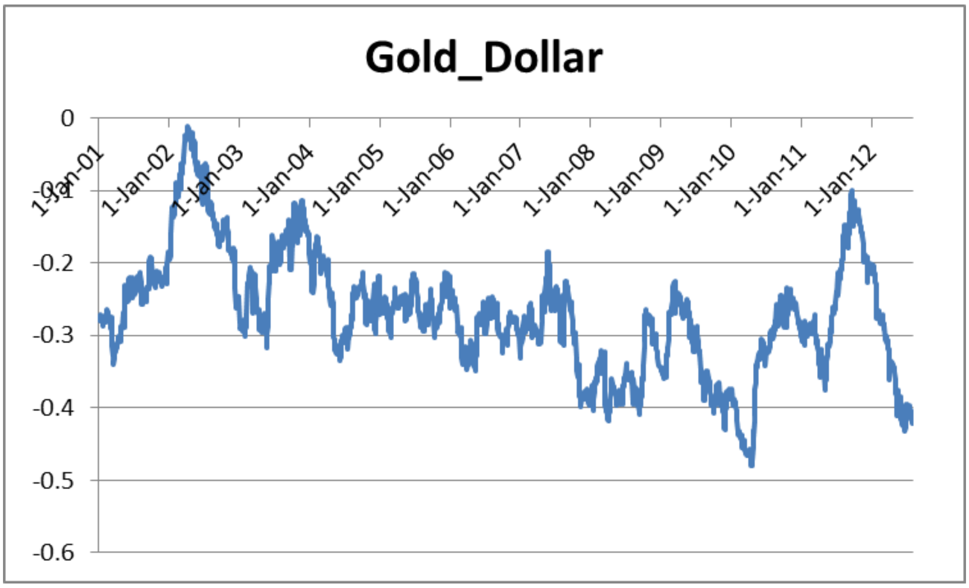

Figure2: Dynamic Conditional Correlations of Gold and Stock Returns (01/01/2001-07/31/2012)

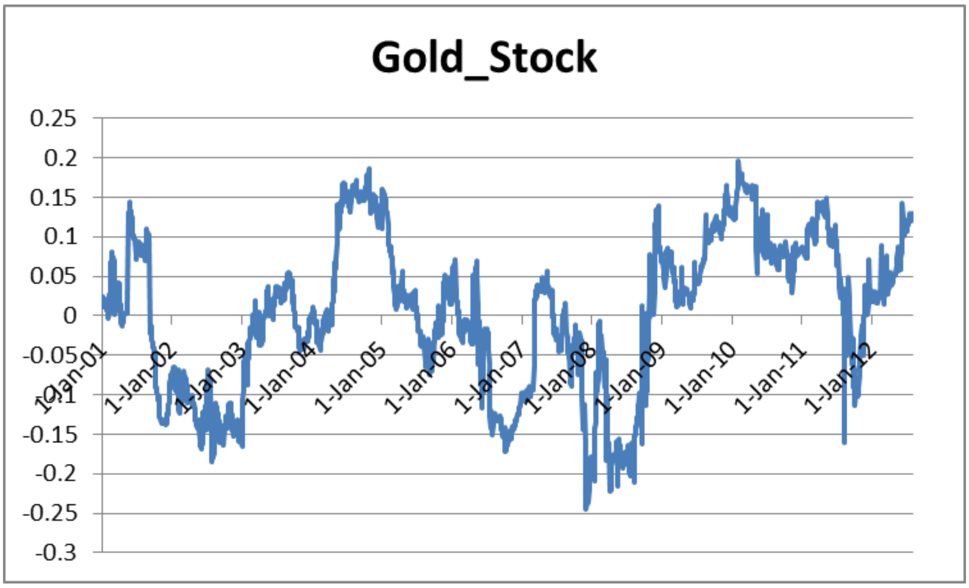

Figure3: Dynamic Conditional Correlations of Dollar and Stock Returns (01/01/2001-07/31/2012)

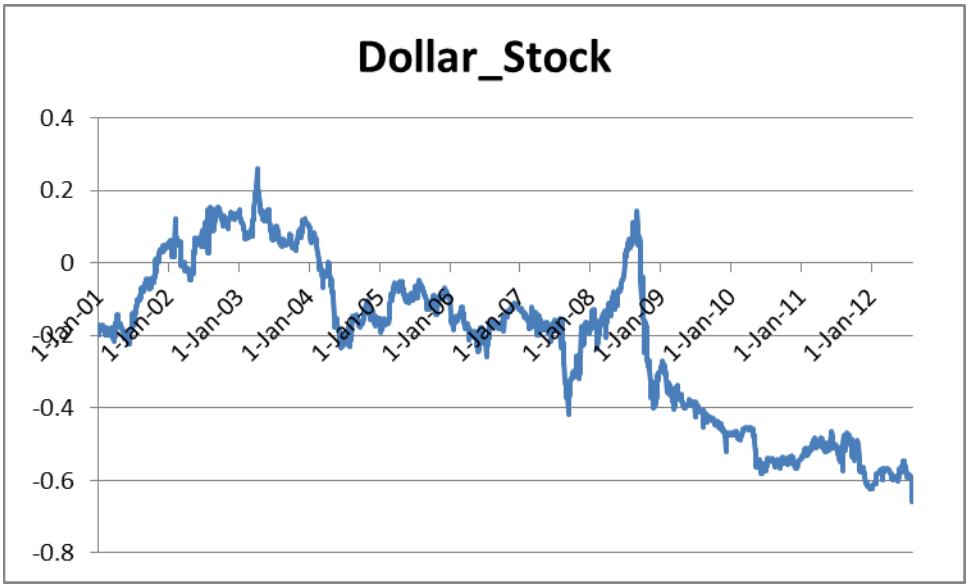

Figure1 through Figure3 present the conditional correlations of gold, dollar and stock returns during the sample period. From Figure1, we can see that gold-dollar correlations are always negative during the entire sample period and vary over time. We also observe a substantial increase in the magnitude of gold-dollar correlation at the end of 2008, during U.S. subprime crisis and at the end of 2010, during European sovereign debt crisis. This result suggests the role of gold as a hedge against dollar in general, especially during financial crisis period. Figure 2 depicts the dynamic gold-stock correlation over 01-01-2001 to 07-31-2012. Based on our analysis, gold and stock tend to commove during the entire period, since gold-stock correlation is positive during most of the sample period. However, the magnitude of the gold-stock correlation is around 0.05 to 0.1, very small. During the 2007-2009 U.S. subprime crisis and the second half of 2011, European sovereign debt crisis, we observe negative gold-stock correlation. It suggests that under extreme economic conditions, gold may be used by investors as a hedge against stock. An interesting result is that at the end of

2009, there exists a substantial increase in gold-stock correlation. Gold-stock correlation rises to almost 0.2 from around 0.05. However, the correlation reverts to lower level soon after it rocked to the peak.

Our findings are consistent with previous studies. For example, Baur and McDermott (2010) examine the role of gold in the global financial system. They find that gold is both a hedge and a safe haven for major European stock markets and the US and they also find that gold was a strong safe haven for most developed markets during the peak of the recent financial crisis.

B. The effect of financial crisis on conditional correlations

Next we are going to test the effects of financial crisis on the dynamics of conditional correlations. I create two dummies to test the changes in dynamic correlations during different crisis periods. DM_{1t} is a dummy variable for the U.S. subprime crisis during 08/01/2007 to 12/07/2009. And DM_{2t} is a dummy variable for the European debt crisis during 12/08/2009 to 07/31/2012. The equation is written as:

$$\rho_t = \varphi_0 + d_1 DM_{1t} + d_2 DM_{2t} + \varepsilon_{ij,t} \tag{12}$$

where ρ_t is the correlation of gold-dollar returns, gold-stock returns or dollar-stock returns.

Table 5 shows the results of the effect of financial crisis on conditional correlations obtained from Asymmetric DCC-GJR-GARCH model.

Table 5: Financial crisis effect on asset correlations

PanelA: Gold-stock correlation			
	Coefficient	T-statistics	P-value
d_1	-0.0159	-3.7400	0.0000
d_2	0.0881	21.4500	0.0000
ϕ_0	-0.0129	-5.8400	0.0000
PanelB: Gold-dollar correlation			
	Coefficient	T-statistics	P-value
d_1	-0.1037	-30.4900	0.0000
d_2	-0.0681	-20.8100	0.0000
ϕ_0	-0.2339	-133.3100	0.0000
PanelC: Dollar-stock correlation			
	Coefficient	T-statistics	P-value
d_1	-0.1935	-34.7200	0.0000
d_2	-0.4719	-87.9100	0.0000
ϕ_0	-0.0632	-21.9700	0.0000

Note: The equation is written as: $\rho_t = \varphi_0 \rho_{t-1} + d_1 DM_{1t} + d_2 DM_{2t} + \varepsilon_{ij,t}$

DM_{1t} is a dummy variable for the U.S. subprime crisis during 08/01/2007 to 12/07/2009. And DM_{2t} is a dummy variable for the European debt crisis during 12/08/2009 to 07/31/2012. The regressions are conducted with Newey-West standard errors.

From Table 5, we can see that the coefficients of subprime crisis dummies and European sovereign debt crisis dummies are significant for all the three pair-wise correlations. Gold-dollar correlation is always negative during the entire sample period. Based on Panel B, the coefficients of subprime crisis dummy and sovereign debt crisis dummy are significantly negative. This result suggests that negative gold-dollar correlation is strengthened by financial crisis. The role of gold as a hedge against dollar is stronger during financial crisis periods. From Panel A, we can see that the coefficient of subprime crisis dummy is significantly negative for gold-stock correlation, which implies that gold price is more likely to move against stock returns during U.S. subprime crisis period. This finding suggests that gold is more likely to be used as a hedge against stock during extreme economic conditions, such as financial crisis. But stock and gold returns tend to co-move during sovereign debt crisis, which may imply that U.S. stock market is not seriously affected by debt crisis. These results are consistent with Figure 1 through Figure 3.

C. The effect of the macroeconomic news announcements on correlation coefficients

In this paper, I investigate the impact of scheduled government announcements relating to three macroeconomic variables on the correlations of stock, gold and dollar returns.

The market announcements are considered for three US macroeconomic variables.

The 3 macroeconomic announcements are:

(a) Consumer price index (CPI);

(b) Gross domestic product (GDP);

(c) Unemployment rate (UE);

To incorporate the announcements effect into the model, we have

$$\rho_t = \alpha + \beta\rho_{t-1} + \sum_{i=PGDP}^{PCPI} \gamma_i PNEWS_{i,t} + \sum_{j=NGDP}^{NCPI} \theta_j NNEWS_{j,t} + \varepsilon_t \qquad (13)$$

Where $PNEWS_{i,t}$ is a dummy variable taking the value of 1 on the day when news announcement with positive surprise occurs and 0 otherwise. And $NNEWS_{i,t}$ is a dummy variable taking the value of 1 on the day when news announcement with negative surprise occurs and 0 otherwise.

Table6: Effects of Macroeconomic announcements on Gold-Stock correlation (2001/01/01-2012/07/31)

	Coefficient	t-statistics	P-value
α	-0.0001	-0.2000	0.8430
β	0.9912	391.6000	0.0000
γ_{PGDP}	0.0002	0.1400	0.8890
θ_{NGDP}	0.0008	0.4400	0.6600
γ_{PCPI}	-0.0064	-3.4900	0.0000
θ_{NCPI}	0.0014	0.6900	0.4910
$\gamma_{Punemployment}$	-0.0010	-0.5900	0.5520
$\theta_{Nunemployment}$	-0.0004	-0.1900	0.8490

Note: $\rho_{gold\_stock,t} = \alpha + \beta\rho_{t-1} + \sum_{i=PGDP}^{PCPI} \gamma_i PNEWS_{i,t} + \sum_{j=NGDP}^{NCPI} \theta_j NNEWS_{j,t} + \varepsilon_t$

PNEWS is a dummy variable taking the value of 1 on the day when news announcement with positive surprise occurs and 0 otherwise. And NNEWS is a dummy variable taking the value of 1 on the day when news announcement with negative surprise occurs and 0 otherwise. The regressions are conducted with Newey-West standard errors.

Table6 reports the effect of macroeconomic announcements on gold-stock correlations. From Table6, we can see that the coefficient of positive CPI news announcement dummy is significantly negative at 1%. The positive CPI announcements decrease the gold-stock correlations. The finding implies that when positive CPI announcement occurs, gold price tends to move against stock price. Based on previous research, gold is a hedge against inflation. Thus positive CPI announcements lead to an increase in gold price. When expected inflation goes up, the discount rate will rise and thus the current stock price will decline. Consequently positive CPI announcement leads to a decrease in gold-stock correlation. This finding implies that investors could reap diversification benefits via “flight-to-quality”, by moving their capital out of riskier equities and into safer gold investment. In the following section, I examine how this portfolio rebalancing strategy changes during economic recessions.

The results we obtained are consistent with previous studies. For example, Hsing (2011) examines the effects of selected macroeconomic variables on the stock market index in South Africa using the exponential GARCH model. The author finds that South Africa’s stock market index is positively influenced by the growth rate of real GDP, the ratio of the money supply to GDP and the U.S. stock market index and negatively affected by the ratio of the government deficit to GDP, the domestic real interest rate, the nominal effective exchange rate, the domestic inflation rate, and the U.S. government bond yield. Nikkinen et al (2006) investigates how global stock markets are integrated with respect to the U.S. macroeconomic news announcements. To investigate this issue they analyze the behavior of GARCH volatilities around ten important scheduled U.S. macroeconomic news announcements on 35 local stock markets that are divided in six regions. The results show that the G7 countries, the European countries other than G7 countries, developed Asian countries and emerging Asian countries are closely integrated with respect to the U.S. macroeconomic news. Jiang Konstantinidi and Skiadopoulos (2012) examine the effect of US and European news announcements on the spillover of volatility across US and European stock markets. They also find significant spillovers of implied volatility between US and European markets as well as within European markets.

Table7: Effects of Macroeconomic announcements on Gold-Dollar correlation (2001/01/01-2012/07/31)

	Coefficient	T-statistics	P-value
α	0.0000	-0.0500	0.9590
β	0.9993	1009.0400	0.0000
γ_{PGDP}	-0.0011	-0.7500	0.4520
θ_{NGDP}	-0.0071	-4.2700	0.0000
γ_{PCPI}	-0.0008	-0.5000	0.6200
θ_{NCPI}	-0.0029	-1.5800	0.1150
$\gamma_{Punemployment}$	-0.0048	-3.2300	0.0010
$\theta_{Nunemployment}$	0.0031	1.5400	0.1240

Note: $\rho_{gold\_dollar,t} = \alpha + \beta\rho_{t-1} + \sum_{i=PGDP}^{PCPI} \gamma_i PNEWS_{i,t} + \sum_{j=NGDP}^{NCPI} \theta_j NNEWS_{j,t} + \varepsilon_t$

PNEWS is a dummy variable taking the value of 1 on the day when news announcement with positive surprise occurs and 0 otherwise. And NNEWS is a dummy variable taking the value of 1 on the day when news announcement with negative surprise occurs and 0 otherwise. The regressions are conducted with Newey-West standard errors.

Table7 reports the effects of macroeconomic announcements on gold-dollar correlations. From Table7, we can see that the coefficients of negative GDP and positive unemployment announcements are significantly negative at 1% level. The negative GDP and positive unemployment decrease the gold-dollar correlations. This result implies that a negative GDP announcement or a positive unemployment announcement, as negative economic indicators, may lead to depreciation in the value of dollar. To reduce currency risk, investors may turn to investment of gold, as a hedge. Thus gold price would be driven up. Consequently we would observe a significant decrease in gold-dollar correlation.

Our findings are consistent with previous research. For example, Tkacz (2007) assess the leading indicator properties of gold at horizons ranging from 6 to 24 months using data for 14 countries over the 1994 to 2005 period. They find that gold contains significant information for future inflation for several countries, especially for those that have adopted formal inflation targets. Simpson Ramchander and Chaudhry (2005) evaluate the effects of surprises in 23 types of macroeconomic announcements on foreign exchange rates. They find that announcements that convey a decline in consumer demand increase foreign exchange rates. And exchange rates respond to announcements related to consumer demand, inflation, and interest rates, but not to the announcements directly related to the general strength of the economy. Among the news releases considered, surprises in the Treasury budget, trade balance and capacity utilization have the strongest influence in the currency market. Mun (2012) investigates the joint response of stock and foreign exchange (FX) market returns to macroeconomic surprises and finds that US stock markets are asymmetrically responsive to domestic developments in output growth. The surprise in the FX market seems to affect stock markets in the US and Japan, respectively.

D. The effect of the macroeconomic news announcements on correlation coefficients across different economic conditions

To test of the effect of macroeconomic announcements under different economic conditions, I use the following equation:

$$\rho_t = \alpha + \beta\rho_{t-1} + \sum_{i=PGDP}^{PCPI} \gamma_i PNEWS_{i,t} + \sum_{i=PGDP}^{PCPI} \gamma_i^* R_t \times PNEWS_{i,t} + \sum_{j=NGDP}^{NCPI} \theta_j NNEWS_{j,t} + \sum_{j=NGDP}^{NCPI} \theta_j^* R_t \times NNEWS + \varepsilon_t \quad (14)$$

R_t is a recession indicator variable that is equal to one when the economy is in recession as defined by the NBER.

Table8:Effects of Macroeconomic announcements on Gold-Stock correlation under different economic conditions(2001/01/01-2012/07/31)

	Coefficient	Std.Err.	P-value
α	0.0000	0.0003	0.9300
β	0.9912	0.0026	0.0000
γ_{PGDP}	-0.0002	0.0019	0.9040
θ_{NGDP}	0.0012	0.0021	0.5500
γ_{PCPI}	-0.0055	0.0021	0.0070
θ_{NCPI}	0.0002	0.0024	0.9450
$\gamma_{Punemployment}$	-0.0011	0.0017	0.5170
$\theta_{Nemployment}$	-0.0014	0.0028	0.6270
γ^*_{PGDP}	0.0025	0.0042	0.5530
θ^*_{NGDP}	0.0005	0.0044	0.9020
γ^*_{PCPI}	-0.0071	0.0046	0.1220
θ^*_{NCPI}	0.0040	0.0046	0.3890
$\gamma^*_{Punemployment}$	-0.0019	0.0049	0.6940
$\theta^*_{Nunemployment}$	0.0013	0.0046	0.7720

Table8 reports the effects of macroeconomic announcements on gold-stock correlations under recessions. From Table8, we can see that consistent with Table6, the coefficient of positive CPI dummy is still significantly negative at 1% level. And the coefficient of the interactive variables of (Recession*Positive CPI) is significantly negative at 15%. Thus we found weak evidence that the effect of macroeconomic announcements on gold-stock correlations varies under different economic conditions. During recession periods, a positive CPI announcements lead to greater decrease in gold-stock correlations. This result may imply that gold plays a stronger role of hedging against stock during recessions, such as financial crisis.

Table9 reports the effects of macroeconomic announcements on gold-dollar correlations under recessions. From Table9, we can see that consistent with Table7, the coefficients of negative GDP and positive unemployment announcements are significantly negative. And the coefficient of the interactive variable (Recession*Positive Unemployment) and (Recession*Negative GDP) are significantly negative, which suggests that the positive employment announcements and negative GDP announcements have more effects on the gold-dollar correlations during recession periods, implying that the role of gold as a hedge against dollar is stronger during recessions.

Table9:Effects of Macroeconomic announcements on Gold-Dollar correlation under different economic conditions(2001/01/01-2012/07/31)

	Coefficient	Std.Err.	P-value
α	0.0000	0.0003	0.9990
β	0.9993	0.0010	0.0000
γ_{PGDP}	-0.0013	0.0017	0.4290
θ_{NGDP}	-0.0082	0.0019	0.0000
γ_{PCPI}	-0.0001	0.0019	0.9450
θ_{NCPI}	-0.0036	0.0022	0.1000
$\gamma_{Punemployment}$	-0.0042	0.0016	0.0070
$\theta_{Nemployment}$	0.0041	0.0025	0.1050
γ^*_{PGDP}	-0.0001	0.0038	0.9760
θ^*_{NGDP}	-0.0075	0.0040	0.0610
γ^*_{PCPI}	-0.0027	0.0042	0.5160
θ^*_{NCPI}	0.0028	0.0042	0.5020
$\gamma^*_{Punemployment}$	-0.0096	0.0044	0.0300
$\theta^*_{Nunemployment}$	-0.0021	0.0041	0.6110

Our results are in agreement with the discussion in previous studies. For example, Yang Zhou and Wang (2009) documents time-varying stock–bond correlation over macroeconomic conditions using monthly stock and bond return data in the past 150 years for both the US and the UK,. They find different patterns of time variation in stock–bond correlations over the business cycle between US and UK, which implies that bonds may be a better hedge against stock market risk and offer more diversification benefits to stock investors in the US than in the UK. Helmersson Kang and Skold (2008) study the historical price development of gold during recessions in order to find out whether an inclusion of gold can improve a portfolio held in today's recession. They find that the gold price is strongly influenced by uncertainty, and even though an optimal allocation of gold in each recession could be found, no general optimal allocation applicable in today's recession could be found.

E. Block Exogeneity Test

In this section, we conduct a Block Exogeneity Test of the gold-stock, gold-dollar and dollar-stock correlations to examine the causal relationship between these asset return correlations. First, I apply a VAR model to three time series of asset correlations. Table 10 reports the results of the VAR lag selection criteria. Based on Table 10, we should select 4 lags to run the VAR model. The estimation results of VAR model is reported in Table 11.

Table 10: VAR lag order selection criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	6632.14	NA	0.00	-4.68	-4.68	-4.68
1	26209.44	39099.28	0.00	-18.50	-18.48	-18.49
2	26289.36	159.45	0.00	-18.55	-18.50	-18.54
3	26297.40	16.03	0.00	-18.55	-18.49	-18.53
4	26333.98	72.82*	1.73e-12*	-18.56*	-18.48	-18.54*
5	26339.52	11.02	0.00	-18.57	-18.47	-18.53

Table 11: Estimation results of VAR model of conditional correlations

PanelA: Dependent Variable Gold-Stock correlation			
Gold-Stock	Coefficient	T-statistics	P-Value
Lag1	0.8404	44.0400	0.0000
Lag2	0.1545	6.2400	0.0000
Lag3	-0.0541	-2.1800	0.0290
Lag4	0.0508	2.6600	0.0080
Dollar-Stock	Coefficient	T-statistics	P-Value
Lag1	0.0399	1.9000	0.0580
Lag2	0.0036	0.1300	0.8950
Lag3	-0.0614	-2.2400	0.0250
Lag4	0.0173	0.8300	0.4090
Gold-Dollar	Coefficient	T-statistics	P-Value
Lag1	0.0069	0.2600	0.7960
Lag2	-0.0212	-0.5700	0.5700
Lag3	-0.1485	-3.9800	0.0000
Lag4	0.1578	5.9100	0.0000
Constant	-0.0014	-1.6100	0.1080
PanelB: Dependent Variable Dollar-Stock correlation			
Gold-Stock	Coefficient	T-statistics	P-Value
Lag1	-0.0739	-4.2400	0.0000
Lag2	0.0464	2.0600	0.0400
Lag3	0.0439	1.9400	0.0520
Lag4	-0.0206	-1.1800	0.2370
Dollar-Stock	Coefficient	T-statistics	P-Value
Lag1	0.8348	43.5200	0.0000
Lag2	0.1330	5.3200	0.0000
Lag3	0.0553	2.2100	0.0270
Lag4	-0.0250	-1.3100	0.1920
Gold-Dollar	Coefficient	T-statistics	P-Value
Lag1	-0.0364	-1.5000	0.1350
Lag2	0.0804	2.3600	0.0180
Lag3	-0.1374	-4.0400	0.0000
Lag4	0.0961	3.9500	0.0000
Constant	0.0002	0.2600	0.7960
PanelC: Dependent Variable Gold-Dollar correlation			
Gold-Stock	Coefficient	T-statistics	P-Value
Lag1	0.0085	0.6400	0.5250
Lag2	-0.0074	-0.4300	0.6700
Lag3	-0.0016	-0.0900	0.9280
Lag4	0.0027	0.2000	0.8430

Table 11: Continued

Dollar-Stock	Coefficient	T-statistics	P-Value
Lag1	-0.0096	-0.6400	0.5200
Lag2	0.0112	0.5800	0.5630
Lag3	-0.0169	-0.8700	0.3820
Lag4	0.0171	1.1600	0.2480
Gold-Dollar	Coefficient	T-statistics	P-Value
Lag1	0.9788	52.0600	0.0000
Lag2	-0.0211	-0.8000	0.4220
Lag3	0.0386	1.4700	0.1430
Lag4	-0.0028	-0.1500	0.8820
Constant	-0.0014	-2.3800	0.0170

From Table 11, we can see that first, the gold-stock correlations are significantly affected by its lags. And gold-stock correlation is significantly positively affected by the first lag of dollar-stock correlation at 10% level. Second, dollar-stock correlation is significantly negatively affected by the first lag of gold-stock correlation. Third, gold-dollar correlation can be explained only by its lags.

Table 12: Results of Block Exogeneity Wald Tests

PanelA: Dependent variable Dollar-Stock correlation			
Excluded	Chi-sq	df	Prob.
Gold-Dollar	21.4170	4	0.0003
Gold-Stock	21.5479	4	0.0002
All	43.7694	8	0.0000
PanelB: Dependent variable Gold-Dollar correlation			
Excluded	Chi-sq	df	Prob.
Dollar-Stock	5.6278	4	0.2287
Gold-Stock	1.4328	4	0.8385
All	6.1971	8	0.6252
PanelC: Dependent variable Gold-Stock correlation			
Excluded	Chi-sq	df	Prob.
Dollar-Stock	8.3188	4	0.0806
Gold-Dollar	38.7872	4	0.0000
All	47.5403	8	0.0000

Table 12 shows the results of Block Exogeneity Tests. Panel A reports whether dollar-stock correlation can be explained by gold-dollar correlation and gold-stock correlation. The first hypothesis tested in Panel A is that change in gold-dollar correlation does not Granger cause the change in dollar-stock correlation. The P-value is 0.0003, thus we can strongly reject the hypothesis and conclude that dollar-stock correlation is significantly affected by gold-dollar correlation. The second hypothesis tested in Panel A is that change in gold-stock correlation does not Granger cause the change in dollar-stock correlation. The P-value is 0.0002, thus we can strongly reject the hypothesis and conclude that dollar-stock correlation is significantly affected by gold-stock correlation. The third hypothesis tested in Panel A is that change in gold-stock correlation and gold-dollar correlation jointly do not Granger cause the change in dollar-stock correlation. The P-value is 0.0000, thus we can strongly reject the hypothesis and conclude that dollar-stock correlation is significantly affected by gold-dollar correlation and gold-stock correlation jointly. Panel C shows the test result of gold-stock correlation. We find that change in dollar-stock and gold-dollar correlation Granger cause the change in gold-stock correlation.

VI. Summary and future research

In this paper, I examine the correlations of gold, dollar and U.S. stock returns over the Jan 1st 2001 – July 31st 2012 period using ADCC-GARCH model. I found that the conditional correlations of gold-dollar returns are negative during all sub-sample periods and significantly increase in magnitude during both subprime crisis and sovereign debt crisis. I found positive conditional correlations of gold-stock returns on average over time. However, gold-stock correlation falls below zero during subprime crisis and sovereign debt crisis, which implies that gold is used as a strong hedge against stock during financial crisis periods.

I also examine the macroeconomic announcement effects on the conditional correlations of gold, dollar and stock returns and how the effects vary over different economic conditions. The “surprise” content of these announcements cause the asset return correlations to change. And different news items have different impacts and the market response depends on the business cycle. I found that gold-stock correlation is significantly negatively affected by positive CPI announcements. And gold-dollar correlation is significantly negatively affected by negative GDP announcements and positive unemployment announcements. The effects of macroeconomic announcements are stronger during economic recessions.

Last, I study the relationship between three pair-wise correlations. The gold-stock correlation is significantly positively affected by the first lag of dollar-stock correlation. Our future research will focus on the way the market participants process the information content of news items into prices and the cross-country impact of macroeconomic announcements. For example, we’ll study the impact of U.S. macroeconomic announcements on other economies in the future.

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