Investor Induced Contagion during the Banking and European Sovereign Debt Crisis of 2007-2012: Wealth Effect or Portfolio Rebalancing?

Dimitris Petmezas and Daniel Santamaria*

Abstract

This study investigates the way a crisis spreads within a country and across borders by testing the investor induced contagion hypothesis through the liquidity channel on stock-bond relationships of the US and five European countries before and during the global banking and European sovereign debt crisis of 2007-2012. We provide evidence consistent with the wealth effect as a source of contagion for the majority of countries. Nevertheless, we uncover evidence of investor induced contagion sourced by the portfolio rebalancing effect for correlations involving Spanish and Italian bonds during the debt crisis. Further, we find that tight (narrow) credit spreads reduce (magnify) the wealth and portfolio rebalancing effects, which are offset by the opposite effects of risk aversion amongst investors, a dynamic that is not restricted to crisis periods.

*Dimitris Petmezas is from Surrey Business School, University of Surrey, GU2 7XH, UK, Tel: +44 1483 686 376, Fax: +44 1483 686 301, E-mail: d.petmezas@surrey.ac.uk. Daniel Santamaria is from Canterbury Business School, Canterbury Christ Church University, Canterbury, Kent CT1 1QU, UK, E-mail: daniel.santamaria@canterbury.ac.uk. We would like to thank an anonymous referee and participants at the 2013 International Conference on the Global Financial Crisis: European Financial Markets and Institutions for helpful comments and suggestions.

1. INTRODUCTION

One of the most prominent characteristics in the recent financial crisis is the global loss of confidence in the financial system with unprecedented levels of risk aversion amongst investors, the lack of liquidity and freezing of the credit markets. The European sovereign debt crisis that followed was not entirely unexpected (Reinhart and Rogoff, 2009). In fact, the contagion effect of past crises, which is defined as the transmission mechanism that occurs during a financial crisis, continues to dominate the views of economists, academics and policy makers (Caporale et al., 2006 on the Asian financial crisis; Yang et al., 2006 on the Russian crisis; and Ravichandran and Maloain, 2010 on the recent financial crisis).

The objective of this study is to investigate what causes a crisis to spread by testing the investor induced contagion hypothesis on the relationship between stock and bond markets. In a recent paper, Boyer et al. (2006) suggested that investor induced contagion stems from either the wealth effect or the portfolio rebalancing hypothesis. Therefore, motivated by Boyer et al. (2006), we investigate whether investor induced contagion between stock and bond markets sources from the wealth effect or portfolio rebalancing hypothesis before and during the banking and European sovereign debt crisis over the period 2007-2012. Moreover, given that a prominent characteristic of the recent financial crisis was the collapse in confidence in the financial system, the third aim is to uncover cross regional evidence on the effect of credit market liquidity and level of risk aversion on the transmission channel of the stock-bond relationship. Both sources of risk provide a barometer on the liquidity in the financial system and the degree of investor uncertainty associated with taking on high risk assets. A crucial feature of the wealth effect and portfolio rebalancing hypothesis, especially in light of credit market liquidity and investor risk aversion, is the underlying assumption that a crisis spreads through the liquidity channel. This envisages a scenario where a shock causes liquidity in the financial system to decline. Hence, the wealth effect in a stock-bond relationship stipulates that during a crisis, a shock to the funding constraints of investors causes risk aversion, a liquidation of positions, and an increase in volatility in both markets (Brunnermeier and Pedersen, 2009); similarly, under the portfolio rebalancing hypothesis, risk aversion and the associated decline in liquidity in the stock market from a shock encourages investors to sell high risk assets in search for quality (Chordia et al., 2005; and Baur and Lucey, 2009).

To test for investor induced contagion, we use the Dynamic Conditional Correlation (DCC) EGARCH to test the wealth effect versus portfolio rebalancing hypothesis on stock index and benchmark bond yield data at different times to maturity for the UK, US, France, Germany, Spain and Italy. A key feature of this approach is that proxies of credit market liquidity conditions and investor risk aversion are modelled within the conditional mean as the means of investigating the transmitting effects of both risk barometers on the transmission channel of the stock-bond relationship. The appealing feature of this framework is that we propose an asymmetric DCC estimator along the lines of Cappiello et al. (2006) that allows for conditional asymmetries to govern the dynamics of the stock-bond relationship. Additionally, we introduce a DCC(Z)-EGARCH risk factor model using interactive dummy variables on DCC estimates to identify whether the wealth effect and portfolio rebalancing hypothesis is sensitive to credit market stress and risk aversion under different market conditions. As a result, this allows us to draw fruitful conclusions on the drivers that cause a crisis to spread within a country and across borders.

In brief, we report that stock-bond correlations strengthened considerably during the banking crisis for all countries. The increase in correlation is consistent with the investor induced contagion hypothesis caused by the wealth effect. However, for stock-bond correlations involving Spanish and Italian bonds, we report a dramatic decline in correlation and diminishing investor induced contagion immediately after the banking crisis up to 2009.

However, for both countries' stock-bond relationships, we report investor induced contagion sourced by the portfolio rebalancing effect throughout the sovereign debt crisis from 2010-2012. The inclusion of proxies for credit market liquidity conditions and investor risk aversion reveals further interesting results. We find that high levels of risk aversion magnify investor induced contagion sourced by the wealth effect during the banking crisis and by portfolio rebalancing effects during the debt crisis for correlations involving Spanish and Italian bonds. Despite this, the manifestation of investor induced contagion due to risk aversion is countered by the opposite effects of changes in credit market conditions, a finding that is not necessarily limited to crisis periods.

This paper makes a number of contributions to the literature. Firstly, this study is the first to our knowledge to formally test the wealth effect versus portfolio rebalancing hypothesis on stock-bond relationships as a transmission mechanism that could explain how the banking crisis and sovereign debt crisis spread within a country and across borders. Therefore, our study deviates from the prior literature that focuses on contagion as a by-product of the arrival of negative innovations (Billio and Pelizzon, 2003; Kim and Moshirian, 2004; and Baele, 2005). Secondly, we differentiate the banking and sovereign debt crisis as separate stages of the financial crisis and in doing so, we are able to extract information and draw fruitful conclusions on how stock-bond relationships not only change during a crisis but also in the dynamics that cause a crisis to spread. Finally, we investigate the feed through effects of key financial market indicators of credit market stress and investor risk aversion in the markets on the transmission mechanism before the crisis and during the banking and sovereign debt crisis. This is particularly important when investigating how a crisis spreads given that these variables contain useful information on credit market liquidity in the real economy and investor confidence (Brunnermeier, 2009; Melvin and Taylor, 2009; and Andersson et al., 2007). Therefore, this paper has important implications in terms of how monetary authorities should respond in maintaining liquidity levels in the financial system especially during a crisis.

The rest of the paper is structured as follows; section 2 reviews the related literature. Section 3 introduces the DCC-EGARCH model and the transmission channel of credit market stress and risk aversion. Section 4 discusses the data and provides descriptive statistics. Section 5 presents the empirical results. Finally, a discussion of the results is presented in section 6, and section 7 concludes the paper.

2. RELATED LITERATURE AND HYPOTHESES DEVELOPMENT

2.1. *The Stock-Bond Relationship*

In early studies, Shiller and Beltratti (1992) and Campbell and Ammer (1993) hypothesized that the stock-bond relationship is constant over a period of time. However, the former study reported a strong negative relationship between stock prices and long maturity bond yields, which was inconsistent with the findings of Campbell and Ammer (1993). Although later studies have documented a time varying stock-bond relationship (Gulko, 2002; Connolly et al., 2005; and Jones and Wilson, 2004), they did not test for investor induced contagion between the stock and bond markets during normal market conditions and crisis periods. As a result, first and foremost, this paper tests the existence of investor induced contagion by identifying the time varying nature of correlation before and during the banking and debt crisis.

Furthermore, little attention has been paid about the factors that drive this relationship. One factor that has been suggested by previous studies is the expected rate of inflation in the long run (Li, 2004). The intuition behind the use of this macroeconomic variable is that uncertainty surrounding an increase in forecasted inflation causes an increase in discount rates, thus leading to a fall in bond prices. Indeed, according to Li (2004), a stronger correlation between stock and bond yields is observed following an increase in expected inflation. In a departure from prior literature, this paper introduces proxies for credit market liquidity and investor risk appetite as two potential drivers that represent barometers of liquidity in the interbank market and confidence in the financial markets.

Given the role of credit market liquidity and the level of risk aversion as potential drivers of the stock-bond relationship, we depart from previous studies that find the source of contagion as a by-product of innovations (King and Wadhwani, 1990; Koutmos, 1996; and Wongswan, 2006) and risk premium (Acharya and Pedersen, 2005). Instead, this study postulates that the stock-bond relationship is governed by the amount of liquidity in the financial system in which a shock leads to an overall decline in liquidity in the asset markets. One of the leading proponents of the liquidity channel in the stock-bond relationship is the study by Chordia et al. (2005). They hypothesized a relationship between liquidity induced by the microstructure of the market and macro induced liquidity as a means of providing important inferences on the main drivers of liquidity in both markets and hence, the stock-bond correlation. They reported a significantly positive relationship between stock and bond market volatility caused by shocks, with volatility being a major driver of liquidity.

2.2. *Wealth Effect versus Portfolio Rebalancing*

Investor induced contagion and the liquidity channel that causes a crisis to spread, in view of credit market liquidity and investor risk aversion, nest neatly with two competing theorems by which this study tests the stock-bond relationship. The first one is the wealth effect developed by Kyle and Xiong (2001) and later tested by Boyer et al. (2006). In their paper, Kyle and Xiong developed a contagion model based on changes in risk appetite that is determined by the wealth effect of convergence traders. The wealth effect arises when convergence traders incur losses due to negative shocks, thereby causing high levels of risk aversion and a liquidation of positions in the financial markets. According to the liquidity channel, this causes liquidity levels to decline and magnify the impact of the initial shock which inevitably transmits from one asset to the next. Therefore, under the wealth effect, the correlation between assets increases during a crisis and, thus, is consistent with investor induced contagion.

However, the Kyle and Xiong's model assumed the existence of two risky assets, which at a time of falling (rising) stock prices, leads to a decline (increase) in liquidity, an increase (decrease) in volatility and, hence, increased correlation between assets. One implication of their model is that, when faced with high and low risk assets, investors at a time of falling stock prices will substitute growth for income. However, as income falls with declines in yields due to rising bond prices, convergence traders will be inclined to liquidate their positions in the bond market, thus causing a decline in liquidity. The Brunnermeier and Pedersen's (2009) liquidity-funding model suggests that such a scenario is likely given that shocks to investors' funding constraints encourage a liquidation of positions causing a "liquidity spiral" between the markets due to the fact that the risk of hitting capital limits increase. The funding illiquidity causes a decline in liquidity in both markets leading to an increase in volatility in both asset classes and, hence, an increase in the stock-bond correlation during a financial crisis.

The alternative hypothesis tested is the portfolio rebalancing effect. This postulates a scenario where investors faced with falling (rising) stock prices, embark on a "flight *to* (*from*) quality" from (to) stocks. In such a scenario, investor induced contagion sourced by the portfolio rebalancing hypothesis is characterized by a decline in the correlation estimate in the event of a financial crisis. Like the wealth effect, proxies for credit market liquidity and investor risk aversion complement the portfolio rebalancing hypothesis through the liquidity channel. In times of a crisis, a lack of liquidity in the transmission mechanism coupled with a high level of uncertainty will cause investors to look for low risk assets during major falls in stock prices. The prior literature in support of the portfolio rebalancing hypothesis within the context of a financial crisis is limited at best. Hartmann et al. (2004) report some evidence in favor of the portfolio rebalancing hypothesis when analyzing the stock-bond relationship amongst the G-5 countries; however, this is countered by contagion effects between both asset classes at different periods of time. On the other hand, Connolly et al. (2005) find evidence that negative relationships between stock and bond markets coincide with major stock market falls as investors rebalance their portfolios from high risk to low risk assets. However, focusing on the stock-bond relationships for eight major countries, Baur and Lucey (2009) report more conclusive evidence that "flight *to* quality" is not only frequent during crisis periods, but it crosses borders, thus indicating the existence of "cross-country contagion".

3. METHODOLOGY

The Exponential-GARCH (EGARCH) model, first introduced by Nelson (1991), has been amongst the most commonly used GARCH specifications that capture asymmetries in asset returns.[1] For the purpose of this study, the EGARCH model is used to derive the standardized residual returns for stocks and bonds as inputs for the dynamic correlation model. We start with the EGARCH (p,q) specification for the conditional mean and variance:

$$\boldsymbol{R_t = \gamma_1 + \varepsilon_t}$$

[1] Early advocates of the EGARCH model point out the studies of French et al. (1987) and Schwert (1990) as uncovering an asymmetric effect in the data in addition to other stylized features such as volatility clustering, serial dependencies and long memory (Hentschel, 1995; and Andersen et al., 2001). Later studies continue to highlight the usefulness of EGARCH models in generating reliable volatility forecasts that is attributable to a well-specified model (Brandt and Jones, 2006). According to Alberg et al. (2008), the forecasting performance of the EGARCH model outperforms other asymmetric GARCH model specifications when applied to Tel Aviv stock market.

$$\varepsilon_t \mid (\varepsilon_{t-1}, \varepsilon_{t-2}.......) \sim N(0, \sigma_t^2)$$

$$\sigma_t^2 = \omega_0 + \left\{ \sum_{k=1}^{q} \alpha_1 \ln(\sigma_{t-1}^2) + \alpha_2 \sum_{k=1}^{p} \forall_{t-1} \right\} \quad (1)$$

where σ_t^2 denotes the conditional variance stock market returns and bond yields, and $\forall_{t-1}$ is the innovation term that comprises the theta θ_1 coefficient that captures the asymmetric component.[2]

Using the standardised residual returns $s_t = \forall_t / \sigma_t^2$ generated by equation (1) as inputs, we propose the dynamic correlation coefficient (DCC) structure, first introduced by Engle (2002) to test the wealth effect versus the portfolio rebalancing hypothesis. The DCC model has the appealing structure that allows conditional correlation estimates to be time varying, a notion that requires decomposing into the following:

$$H_t = D_t R_t D_t \quad (2)$$

where $D_t = diag\left\{\sqrt{\sigma_t^2}\right\}$ and R_t is the correlation matrix of time varying standardized residual returns that leads the structure of the DCC model for assets *i* and *j*

$$q_{i,j,t} = (1 - \partial_1 - \partial_2)\bar{q} + \partial_1 (s_{i,t-1} s_{j,t-1}) + \partial_2 q_{i,j,t-1} \quad (3)$$

where the term $\bar{q}$ denotes the matrix of unconditional covariance of the standardised errors from equation (1) that leads to the DCC matrix $R_t = q^{*-1} q_{i,j,t} q_{i,j,t}^{*-1}$ from which the components of R_t are computed using

$$\rho_{i,j,t} = \frac{q_{i,j,t}}{\sqrt{q_{i,t} q_{j,t}}} \quad (4)$$

where $\rho_{i,j,t}$ represents the DCC estimates for assets *i* and *j* respectively. An increase in $\rho_{i,j,t}$ during a crisis period is consistent with investor induced contagion, sourced by the wealth effect. Conversely, a decline in $\rho_{i,j,t}$ suggests support for investor induced contagion sourced by the portfolio rebalancing hypothesis. Combined with the EGARCH model, the

---

[2] To maximise the log likelihood function, the Berndt, Hall, Hall & Hausman (1974) (BHHH) algorithm is proposed in this paper. Given that ARCH processes are highly nonlinear, maximising the log likelihood function on the assumption that the conditional density is normal renders the optimisation process invalid. Hence, the BHHH algorithm relaxes this restriction to obtain the log likelihood function by utilizing the covariance of the analytic gradients for each observation to form the conditional covariance matrix.

DCC structure of equations (3) and (4) is reminiscent of the asymmetric DCC estimator of Cappiello et al. (2006) in that it allows for conditional asymmetries to govern the dynamics of the stock-bond relationship. Furthermore, the DCC model proposed can be adapted to capture the transmission effects of credit market liquidity and investor risk aversion from the univariate EGARCH model by expanding the conditional mean of equation (1) so that the following transmission channel $\boldsymbol{\varepsilon_t \rightarrow s_t \rightarrow q_t^* \rightarrow R_t \rightarrow \rho_{i,j,t}}$ is envisaged.

A major implication of the DCC-EGARCH model is that the maximum likelihood function needs to be modified to take into account the DCC estimator so that the following quasi-maximum likelihood estimates (QMLE) is maximised:

$$\begin{aligned}\ln_2(\vartheta \mid \varphi) &= -\left(\frac{T}{2}\right)\sum_{t=1}^{T}\left\{n\ln(2\pi) + \ln\left(\left|D_t R_t D_t\right|\right) + \varepsilon_t^T D_t^{-1} R_t^{-1} I_k D_t^{-1} \varepsilon_t\right\} \\ &= -\left(\frac{T}{2}\right)\sum_{t=1}^{T}\left\{n\ln(2\pi) + 2\ln\left(\left|R_t\right|\right) + \forall_t^T R_t^{-1} \forall_t\right\} \\ &= \Omega_0 - \left(\frac{T}{2}\right)\sum_{t=1}^{T}\left\{\ln\left(\left|R_t\right|\right) + \forall_t^T R_t^{-1} \forall_t\right\}\end{aligned} \quad (5)$$

where $\boldsymbol{\Omega}$ represents the constant and $\vartheta \mid \varphi$ denotes the sum of the univariate variance generated by the EGARCH model conditional of the correlation parameters. Next, we proceed to describe the data used in this study followed by a preliminary empirical analysis.

4. DATA

4.1. *The Data*

The database comprises of daily index returns on the FTSE-100, Russell 3000, CAC-40, DAX-30, IBEX-35 and the FTSE MIB Index from January 1, 2004 to September 6, 2012 (*n* = 2,266 observations). The choice of stock markets was determined by the degree of coverage and of diversification in each index. For instance, the FTSE-100 Index lists the 100 largest blue chip companies that make up 84% of the total market capitalization in the UK. Given that the US is the origin country of the banking crisis, the US market is represented by the Russell 3000, which covers the 3000 largest public limited companies and, as such, represents 98% of the total market capitalization of US stocks. The CAC-40 lists the performance of the top 40 largest stocks on Paris Euronext based on market capitalization. In turn, the DAX-30 represents the Frankfurt Stock Exchange listing of the top 30 blue chip companies that represent 80% of the total market capitalization. To proxy southern European countries, the IBEX-35 consists of 35 of the most liquid stocks listed on the Madrid Stock Exchange General Index and the FTSE MIB Index represents 40 of the largest and most liquid stocks by capitalization that are traded on the Borsa Italiana.

For short and long term interest rates, our database includes the FTSE Global 1-3 year and 10+ year government benchmark bond yields for the UK, US, France and Germany. The 1-3 year index is defined as the aggregate of benchmark indices of bond yields from one to three years to maturity for each country. Similarly, the 10+ year index represents the aggregate of the indices for ten years and longer to maturity. Due to data limitations, we collected interest rate data on three year bond yields for Spain and Italy as well as ten year benchmark bond yields for both countries.[3]

To generate proxies for credit market liquidity conditions and investor risk aversion, we have also collected daily three month LIBOR rates, three month interest rate data and implied volatility index values (VIX) for the same countries from Datastream. However, in relation to the implied volatility index, the absence of data for both Spain and Italy means that VIX index for the Euro-zone (EU) was used to proxy investor confidence.

4.2. *The T-bill Euro Dollar (TED) Spread*

To proxy for credit market liquidity conditions in the real economy, we computed the three month TED spread based on the London Interbank Offering Rate (LIBOR) and three month

[3] For the remainder of the paper, 1-3 year and 10+ year benchmark yields will be referred to as short dated and long dated bond yields respectively.

interest rates. The LIBOR, which is the expected average rate of interest over the life time of interbank loans, reflects default risk levels and wholesale market liquidity. Indeed, Taylor and Williams (2009) argue that increases in LIBOR are attributable to higher interest rates demanded by lenders for taking higher default risk in times of market stress. This is reflected by the spike in the TED spread shown in Figure 1 for the UK, US, France, Germany, Spain and Italy as the average rate of interest charged by banks increased as liquidity dried up during the height of the banking crisis. [4,5]

[Please Insert Figure 1 About Here]

Other measures of credit market liquidity risk, such as Credit Default Swap (CDS) spreads, are not considered in this study given recent evidence that they are not fully attributable to credit market liquidity risk factors (Collin-Dufresne et al. 2001, Blanco et al. 2005). Additionally, the behavior of CDS spreads during the recent financial crisis has raised more questions regarding the usefulness of this measure of credit market liquidity risk as a leader of other markets. For instance, Forte and Peña (2009) and Norden and Weber (2009) both find that global stock markets tend to lead the CDS and bond markets more frequently than the opposite. By contrast, the TED spread, as a barometer of credit market liquidity, has received attention in a growing body of literature. For instance, Lashgari (2000) uses the TED spread as an independent variable on the S&P 500 index returns and reports a negative and significant coefficient. The intuition is that a widening TED spread signifies deteriorating liquidity conditions thus leading to a liquidation of positions and net portfolio outflows. In later studies, Brunnermeier (2009) and Melvin and Taylor (2009)

[4] The appealing feature of the TED spread is that it comprises the three month interest rate OIS-LIBOR spread. This represents the cost of three month liquidity from the perception of banks that is defined in terms of the risk attached to undertaking unsecured lending over the three months versus unsecured lending for one day. Further, the TED spread also incorporates the three month interest rate OIS spread, which contains a demand driven component that in a crisis causes portfolio managers to reallocate their portfolios away from high risk to low risk assets. The implication is a fall in yields and a widening of the TED spread.

[5] The negative TED spread for Spain is attributable to a spike in three month interest rates that coincided with Moody's downgrade of Spanish sovereign debt in October 2011. The short term interest rate, which peaked at 5.06% in November 2011, represents investors' expectations that the country will default on its debt obligations.

demonstrate the usefulness of the TED spread as a measure of liquidity in the wholesale market. For instance, the former study postulates that banks borrowing in the interbank market during a crisis tend to be charged a higher LIBOR and, thus, regard short term bonds a more attractive proposition given that they are considered as risk free; this leads to a spike in the TED spread as shown in Figure 1.

4.3. *Implied Volatility (VIX) Index*

The implied volatility index (VIX) first introduced by the Chicago Board Options Exchange (CBOE) in 1993 and revised in 2003 is regarded by markets as a measure of investor fear. For the purpose of this study, we used daily VIX index values based on the revised 2003 methodology. In short, this incorporates the S&P 500 index and averages the weighted prices of out-of-the-money puts and calls over a range of strike prices to estimate the implied volatility of stock index options. As a result, the high index readings between late October 2008 and March 2009 observed in Figure 2 are representative of high volatility associated with large stock market downturns.

[Please Insert Figure 2 About Here]

Realizing the information content of the VIX index, an increasing number of studies have used the implied volatility index as an independent variable within the GARCH framework (Blair et al., 2001; and Koopman et al., 2005). Both studies reported a major improvement in the performance of daily GARCH models after adding realized volatility and the VIX implied volatility index as explanatory variables into the variance equation. However, this paper makes an important departure from previous studies in the use of the VIX index. In particular, we use the information uncovered in the VIX index to establish whether investor risk aversion magnifies investor induced contagion sourced by the wealth effect or portfolio rebalancing hypothesis in the stock-bond relationship before and during crisis periods. For instance, unlike previous studies, to capture the impact of pre-crisis, banking crisis and debt crisis periods, we include the implied volatility measure into the conditional mean as interaction dummy variables for each of the three sub-periods. Low (2004) provides intuition behind this, postulating that the VIX index contains useful information on option trader's perception of risk, and demonstrates how risk perceptions and price are related. As a result, in this paper, the VIX index proxies for investor confidence as a potential driving force behind the stock-bond relationship.

4.2.3. *Preliminary Analysis and Descriptive Statistics*

As a starting point, Table 1 provides descriptive statistics and unconditional correlation analysis on stock and bond market returns. We show that average stock returns are generally positive for the entire sample period with the exception of the IBEX-35 and FTSE MIB indexes. The positive stock index returns coincide with negative bond yields at long and short maturities where the UK short dated bond yields reported the largest loss of 15.92%. This contrasts Spanish bond yields at long and short maturities which recorded an increase of 1.3% and 1.6% respectively over the same period.

[Please Insert Table 1 About Here]

Focusing on the unconditional correlation matrix, the stock-bond relationship varies considerably from relatively strong and positive readings involving UK and US bond yields to weak and negative for Spanish and Italian bonds. By discovering a relatively strong positive stock-bond correlation points to a generalized wealth effect whereas evidence of a weak and negative relationship introduces the possibility of a portfolio rebalancing effect. These findings will be of particular interest when we estimate the DCC model later in the paper.

5. EMPIRICAL FINDINGS

5.1. *DCC-EGARCH Model Estimations*

A major characteristic of the recent banking crisis and European sovereign debt crisis is the unconventional tools employed by central banks across the globe through the implementation of various quantitative easing (QE) programmes. For instance, both the US Federal Reserve and Bank of England embarked on large scale asset purchasing programs that involved long term government bonds (Gagnon et al., 2011 for the US; Joyce et al., 2011 for the UK; and Neely, 2011 for the international bond market). On the other hand, the European Central Bank (ECB) embarked on a covered bond purchasing programme as a means of reviving the long term debt market used by banks to refine loans to the public and private sectors.

The scale of central bank intervention means that we have to adjust for the effects of QE in the EGARCH model and standardized residual returns as inputs into the DCC structure of equation (3). Hence, we begin with the conditional mean equation:

$$R_{i,j,t} = \gamma_1 + \alpha_1 \sum_{j=1,2} D_{j,t} + \varepsilon_t \qquad (6)$$

where $D_{j,t}$ are dummy variables designed to capture the effects of QE on stock returns and bond yields. The term j = 1,2 provides flexibility in the specified model by isolating the effects of different stages in the asset purchasing programmes on the stock and bond markets.[6] However equation (6) is restrictive in that it does not model the transmitting

[6] For instance, for the UK market, we use two dummy variables; QE1 and QE2 (k=1,2) to represent two major policy advances from the Bank of England. For QE1, $\boldsymbol{D_{j,t}}$ **= 1** between 5th March 2009 to 30th November 2009, and zero otherwise. This covers the initial asset purchase programme of £200bn in long term conventional gilts. The QE2 dummy variable is designed to capture the effects of three further rounds of QE from October 2011 to 6th September 2012. As such, $\boldsymbol{D_{j,t}}$ **= 1** from the 10th October 2011 onwards, and zero otherwise. Similarly, for the Federal Reserve, we employ two dummy variables to control for the impact of QE1 and QE2. For QE1, $\boldsymbol{D_{j,t}}$ **= 1** represents the period November 2008 to March 2010, and zero otherwise. This coincides with the acquisition of $1.25trillon in Mortgage Backed Securities (MBS), $200bn in Federal Agency debt followed by $300bn in long term government bonds. On the other hand, with QE2, $\boldsymbol{D_{j,t}}$ **= 1** covers the time period from November 2010 until end of June 2011, when a second wave of asset purchasing was announced which involved buying up to $600bn in long term government bonds. In relation to the ECB, we earmarked two major policy decisions to define our dummy variables. The first dummy variable $\boldsymbol{D_{j,t}}$ **= 1** covers a twelve month

effects of changes in liquidity conditions and the level of risk aversion under different market conditions. As a result, we expand equation (6) to enable feed through effects into the DCC model so that:

$$R_{i,j,t} = \gamma_1 + \alpha_1 \sum_{j=1,2} D_{j,t} + \phi_{1,k} \sum_{k=1,2,3} D_k \Delta TED_{t-1} + \phi_{2,k} \sum_{k=1,2,3} D_k \Delta VIX_{t-1} + \varepsilon_t \quad (7)$$

where k =1,2,3 represents interactive dummies that denote the pre-crisis period, the banking crisis and sovereign debt crisis, respectively. The coefficients $\boldsymbol{\phi_{1,1}}$ to $\boldsymbol{\phi_{2,3}}$ measure the impact of the TED spread and VIX index before and during the banking crisis followed by the debt crisis. The pre-crisis represents the period 1st January 2004 to 27th November 2006; the banking crisis from 28th November 2006 to 15th October 2009; and finally, the European debt crisis from 16th October 2009 to 6th September 2012.[7] Hence, to generate the standardized residual returns $\left(\boldsymbol{\varepsilon_t} / \sqrt{\boldsymbol{h_t}}\right)$ for the DCC model, adjusted for the effects of QE, credit market liquidity and investor risk aversion, involves estimating the following EGARCH (1,1) model on stock index returns and bond yields denoted as assets i and j respectively:

$$\boldsymbol{h_{i,j,t} = \exp\{a_0 + a_1 \log(h_{i,j,t-1}) + a_2 \xi_{i,j,t-1}\}} \quad (8)$$

where $\boldsymbol{h_{i,j,t}}$ is the conditional variance at time t and $\boldsymbol{\xi_{i,j,t-1}}$ is the information component that contains the asymmetric term $\boldsymbol{\theta_1}$. Table 2 provides estimations from the DCC-EGARCH (1,1) model on all return series for the whole sample. Given the volume of

---

period between June 2009 and June 2010, to coincide with the covered bond purchasing programme. The second dummy variable $\boldsymbol{D_{j,t} = 1}$ is defined as the period 10th May 2010 until 6th September 2012 that coincides with the setting up of the Securities Market Programme (SMP) and the re-introduction of the Long Term Refinancing Operation (LTRO).

[7] The three sub-periods used are derived from the definition of the banking crisis period provided by the Bank of International Settlements (2009) Annual Report. The sovereign debt crisis period coincides with the downgrade of Greece in December 2009 and the start of the next stage of the global financial crisis as stipulated by Reinhart and Rogoff (2009).

results, only coefficients that are statistically significant at least at the 10% level are reported in the conditional mean equation.

A number of important observations can be made from these findings. After adjusting for the effects of QE, we find that stock market returns appear to be relatively insensitive to changes in the TED spread and VIX index. By contrast, both short and long dated bond yields are sensitive to the TED spread and VIX index, with the exception of German and to a lesser extent French and Italian benchmark bonds. The negative statistical significance of the TED spread and VIX index provide preliminary indications of a flight *to* (*from*) quality as a potential source of contagion due to tighter (relaxed) credit liquidity conditions and increased (falling) risk aversion (Chordia et al., 2005; and Baur and Lucey, 2009). Although this finding is generally robust to bonds of different times to maturity regardless of market conditions, evidence in favor of the portfolio rebalancing hypothesis is counterbalanced by the insensitivity of stock index returns to changes in credit market liquidity and investor risk aversion.

[Please Insert Table 2 About Here]

Focusing on the conditional variance equation, the parameters $(\boldsymbol{a}_1, \boldsymbol{a}_2, \boldsymbol{\theta}_1)$ are statistically different from zero, thus indicating the presence of EGARCH effects regardless of asset class and time to maturity. Closer inspection of the results reveals that volatility is persistent across all asset returns with the exception of UK long dated bond yields, a finding that coincides with the news innovation coefficient $\boldsymbol{a}_2$, which is dominated by the asymmetric component $\boldsymbol{\theta}_1$. In contrast, the estimated theta $\boldsymbol{\theta}_1$ is positive and statistically significant for long dated Spanish bond yields, as well as short and long dated Italian bonds, which coincides with high innovation coefficient $\boldsymbol{a}_2$ estimates. Nevertheless, all other model estimates show that asset returns (both stock and bond index returns) exhibit asymmetries, a finding that differs from the results reported by Cappiello et al. (2006), who find little evidence of an asymmetric effect in the conditional volatility of bond index yields.

5.2. *Dynamic Conditional Correlation (DCC) Analysis*

Using the standardized residual returns generated by the EGARCH model of Table 2, we estimate DCC coefficients using equation (4) to test if the investor induced contagion hypothesis holds and whether this is caused by the wealth effect or portfolio rebalancing effect during crisis and non-crisis periods. As implied by Boyer et al. (2006), for investor induced contagion sourced by the wealth effect to hold, stock-bond correlation $\rho_{i,j,t}$ must increase in times of crisis. Conversely, for investor induced contagion to hold through the portfolio rebalancing hypothesis, the stock-bond correlation $\rho_{i,j,t}$ must decline during a crisis period.

To take into consideration that the transmission channel linking stock and bond markets may vary over time, Figure 3 plots the time varying correlation estimations $\rho_{i,j,t}$ on stock-bond relationships for the entire sample period. The stock-bond correlation estimates exhibit a number of interesting features; for instance, the correlation estimates vary quite considerably over time, with a decline in $\rho_{i,j,t}$ observed before the banking crisis especially for stock-bond relationships involving long dated bonds. For correlations involving bond yields of the UK, US, France and Germany, $\rho_{i,j,t}$ increased during the banking crisis and sovereign debt crisis, thus indicating investor induced contagion is caused by a wealth effect. In all cases $\rho_{i,j,t}$ increased sharply in the aftermath of the collapse of Lehman Brothers and US House of Representatives rejection of the $700bn financial bailout in 2008, thus suggesting widespread systemic risk on the financial system (Acharya et al., 2009). However, for Spain and Italy, $\rho_{i,j,t}$ declined dramatically immediately after the banking crisis indicating that investor induced contagion diminished until 2009. However, from 2010, we report investor induced contagion sourced by the portfolio rebalancing hypothesis as $\rho_{i,j,t}$ became negative during the debt crisis. Additionally, the sharp decline in stock-bond correlations that involve French bonds appears to coincide with France's AAA downgrade in early 2012. The volatile nature of DCC estimates especially during the sovereign debt crisis, suggests that the spread of the crisis is the result of a portfolio rebalancing effect caused by a "flight *to* quality", which has a destabilizing effect across asset classes at a time of falling stock prices in the smaller markets.[8] This is consistent with the findings of previous studies that have documented a negative impact of ratings downgrades on the stock markets (Behr and Güttler, 2008; and Bannier and Hirsch, 2010). A notable feature is the robustness of these results in all maturities that is not only country-specific but crosses borders.[9]

An issue of particular interest raised by the results is the trend in correlation estimates involving UK, US, French and German bonds and how this contrasts with stock-bond relations involving Spanish and Italian bonds in the aftermath of the banking crisis. This indicates that there are different forces at work in the transmission channels of the stock-bond relationship. For instance, the increase in $\rho_{i,j,t}$ involving bond yields irrespective of time to maturity for the UK, US, France and Germany during the sovereign debt crisis, at a time of rising stock prices in the major markets, uncovers investor induced contagion that coincides with the purchase of long term government debt under the QE programmes. An

[8] For instance, whilst the FTSE 100, Russell 3000 and DAX30 all increased by 11.31%, 32.70% and 24.79%, respectively during the debt crisis period, this contrasts with the performance of stock markets in the epicentre of the crisis, such as the CAC40, IBEX35 and FTSEMIB indexes, which all declined by 11.18%, 29.04% and 34.66%, respectively.

[9] Further support for the portfolio rebalancing hypothesis is reported for correlations involving Spanish and Italian bonds during the debt crisis by re-estimating the DCC model on bond yields for all countries. Additional robustness tests were carried out by estimating the DCC model on stock-bond relationships involving Euro-zone short and long dated bond yields. We find investor induced contagion caused by the wealth effect is evident during the banking crisis, whereas for the debt crisis, the portfolio rebalancing effect is the dominant source of contagion especially for EU short dated bonds. Although the results are not presented in the paper, they are available upon request.

implication of the contagion model of Kyle and Xiong (2001) and a persistently high stock-bond correlation suggests an increase in the amount of liquidity in both the stock and bond markets due to global central bank intervention. This finding is in marked contrast to the decline in $\rho_{i,j,t}$ involving Spanish and Italian bonds regardless of maturity, which is suggestive of portfolio rebalancing by investors. However, it is also worth noting that this may have been triggered by ratings downgrades of Spanish and Italian sovereign debt and the subsequent ECB intervention in the international bond markets.[10]

[Please Insert Figure 3 About Here]

The remainder of this paper empirically investigates the feed through effects of a change in credit market liquidity conditions using the TED spread and investor confidence based on implied volatility estimates on the transmission channel of the stock-bond relationship.

5.3. *DCC(Z)-EGARCH Risk Factor Model Analysis*

To begin with, we re-estimated the EGARCH model using the conditional mean model of equation (6) that excludes the TED spread and VIX index to generate the standardized residual returns as inputs into the DCC model. Following this, we formulated the DCC(*Z*)-EGARCH risk factor model derived from equation (4):

$$\boldsymbol{h_{i,j,t} = \rho(Z_t)\sqrt{h_{i,t}h_{j,t}}} \qquad (9)$$

in which $-\mathbf{1} \leq \rho(\boldsymbol{Z}_t) \leq +\mathbf{1}$ is an increasing function of $\boldsymbol{Z}_t$, which in turn denotes a $\boldsymbol{K} \times \mathbf{1}$ vector of proxies for credit market stress and investor confidence that are used as determinants of the correlation coefficient. As a result, equation (9) represents a useful way of identifying the transmitting effects of both factors that cause an increase (decrease) in the wealth effect or portfolio rebalancing process during crisis and non-crisis periods. To

[10] Spain's credit rating was downgraded by S&P from AA+ to AA in April 2010, Moodys also downgraded Spanish debt from Aa2 to A1 in October 2011. Italian sovereign debt was downgraded from A+ to A by S&P in September 2011.

identify different market conditions, interactive dummy variables were introduced into the following risk factor model specification of the DCC function:

$$\rho(Z_t) = 2\left[\frac{\exp(\Gamma_{1k,a,b}' Z_{t-1})}{1+\exp(\Gamma_{1k,a,b}' Z_{t-1})}\right] - 1 \qquad (10)$$

where $\Gamma_{1k,ij} = [\Gamma_{11},.., \Gamma_{12},....., \Gamma_{1k}]$ and $Z_t = [z_0,.., z_2,....., z_k]$ in the home country a and foreign country b.[11] We define Γ_{1k} as the coefficients to be estimated for interactive dummy variables that are designed to capture the impact of both confidence indicators from countries a and b before and during the banking and debt crises. Therefore, the exogenous variables used are the TED spread and implied volatility index (VIX) of Figures 1 and 2 for each country of origin.[12]

The interactive dummy parameters for the TED spread are denoted as $\Gamma_{11},.....,\Gamma_{13}$ and $\Gamma_{14},.....,\Gamma_{16}$ for the VIX index where coefficient numbers [11]-[14], [12]-[15], and [13]-[16] capture the periods before the crisis, the banking crisis, and sovereign debt crisis, respectively.[13] Tables 3 and 4 present the estimation results from the DCC(Z)-EGARCH risk factor model of equation (9) for stock-bond correlations involving short and long dated bond yields. Given the volume of results, the most significant findings are reported. Therefore, Table 3 reports stock-bond correlations that include the stock markets of the US, France, Spain and Italy for short dated bonds. For Table 4, stock-bond relationships involving long

[11] Γ_{10} represents constants and k = 0,........,6 represents the number of parameters used to estimate the lagged correlation coefficient estimates and proxies for credit market liquidity and investor risk appetite during the pre-crisis, banking crisis and sovereign debt crisis periods, respectively.

[12] The usefulness of the TED spread as a measure for credit market liquidity is well known, whereas for the VIX index, the information contained has been found to cause a decoupling between bond and stock prices, especially during bouts of risk aversion (Andersson et al., 2007).

[13] The interactive dummies for the TED spread and VIX index are defined as $\Gamma_{11,a,b},........, \Gamma_{13,a,b} = 1 \times \Delta TED$ and $\Gamma_{14,a,b},........, \Gamma_{16,a,b} = 1 \times \Delta VIX$, and zero otherwise. To maintain consistency within the analysis, the sample periods used to define all interactive dummies are the same as before.

dated bond yields present results for France.[14] Furthermore, only statistically significant coefficients are reported up to the 5% level.

Turning to our findings, there are some notable features identified in the results; firstly, there is limited evidence that the TED spread and VIX index are the driving forces behind the stock-bond relationships before the banking crisis, in spite of earlier findings presented in Table 2 on short and long dated bond yields. Focusing on the banking crisis, we report some evidence that a widening of TED spreads reduces stock-bond correlations that include the Russell 3000 and DAX-30 indexes for long dated bond yields. This suggests that it reduces investor induced contagion sourced by the wealth effect, thus indicating evidence that funding illiquidity that leads to deteriorating liquidity conditions (Brunnermeier and Pedersen, 2009) caused some rebalancing of portfolios away from high risk assets towards quality (Chordia, et al., 2005; and Baur and Lucey, 2009). Nevertheless, risk aversion measured by the VIX index is a relatively more dominant driver behind the increase in stock-bond correlations involving the Russell 3000, IBEX-35 and FTSE MIB indexes, a finding that is consistent with the wealth effect.[15] Interestingly, we uncover a spillover effect of risk aversion originating from foreign country *b*, which explains the increase in stock-bond correlations involving the CAC-40 for short dated bond yields. Spillover effects involving the TED spread and VIX index are also reported for correlations that incorporate the IBEX-35 index. Both results suggest that risk aversion levels and credit market liquidity conditions are not necessarily country-specific drivers of the asset markets, which implies that both factors may be determinants of cross-asset market volatility that crosses borders (Bianconi et al., 2013). Results on the debt crisis reveal that both the TED spread and the

[14] In relation to stock-bond relationships that involve the FTSE-100, we find that stock-bond correlations are relatively insensitive to credit market illiquidity and high levels of risk aversion. However, for correlations involving the DAX Index with short dated bonds, we find some evidence that risk aversion explains the wealth effect. Although these findings are not presented here, the results are available upon request.

[15] According to the modified contagion model, this implies that risk aversion may arise from shocks to the funding constraints of investors resulting in a liquidation of positions in the asset markets (Brunnermeier and Pedersen, 2009), which, in turn, lead to higher volatility and an increase in stock-bond correlations.

level of risk aversion are the main drivers behind the wealth effect and portfolio rebalancing hypotheses. On the one hand, finding a negative relationship between the TED spread and stock-bond correlations involving the Russell 3000 once again suggests that a narrowing of spreads observed in Figure 2 magnifies the wealth effect with the exception of correlations involving Spanish and Italian bonds.[16] On the other hand, the positive association between risk aversion and stock-bond correlations for the Russell 3000 and to a lesser extent, the CAC-40, IBEX-35 and FTSE MIB indexes involving short dated bonds implies that it contributes to the increase in the wealth effect. For correlations involving particularly Italian bonds, risk aversion contributes significantly to the increase in contagion sourced by the portfolio rebalancing effect.

[Please Insert Table 3 About Here]

[Please Insert Table 4 About Here]

5.4. *Credit Liquidity Conditions, Risk Aversion and the DCC Estimates*

So far, the results suggest that in general, the dominant force behind investor induced contagion during the crisis is the wealth effect for correlations involving the stock markets of the UK, US, France and Germany. For Spain and Italy, investor induced contagion is caused by the portfolio rebalancing hypothesis, which seems to be the main driver during the debt crisis. However, the statistical significance of the TED spread and VIX index reported in Table 2 poses a question on the impact of credit market liquidity and risk aversion on the transmission channel that governs the stock-bond relationship. Figure 4 plots the difference between the DCC estimates using the standardized residual returns from the EGARCH model with and without the TED spread and VIX index in the conditional mean. A manifestation of the wealth effect due to credit market liquidity conditions, risk aversion or

[16] This implies that a relaxation of credit market liquidity conditions encourages investors to participate in the stock markets at a time of more relaxed funding constraints (Brunnermeier and Pedersen, 2009) and high bond market liquidity due to the large asset purchasing programmes (Gagnon et al., 2011; Joyce et al., 2011; and Neely, 2011).

both during the banking and sovereign debt crises is represented by readings greater than zero. Conversely, the inducement of the portfolio rebalancing effect is identified by readings less than zero.

Noticeably, the impact of credit market illiquidity and the level of risk aversion are generally more persistent on stock-bond correlations that incorporate short dated bonds than relationships with longer dated bonds especially during the banking crisis. For instance, a manifestation of the wealth effect is reported for correlations involving the Russell 3000 index and, in particular, stock-bond relationships that include UK short dated bonds. Based on the Brunnermeier and Pedersen (2009) model, this suggests that a lack of liquidity and increased funding constraints imposed on investors following the arrival of shocks cause an increase in risk aversion and a further decline in liquidity in both markets. Yet despite this, the inclusion of both risk barometers has tended to reduce investor induced contagion sourced by the wealth effect for correlations involving Spanish short dated bonds. The above results are repeated for the period of the debt crisis at a time of narrow TED spreads (see Figure 1) indicating relaxed credit liquidity conditions and low VIX index readings with the exception of two periods of risk aversion in 2010 and 2012 (see Figure 2). However, the most notable exception here is the stock-bond relationships involving Spanish short dated bonds and the IBEX-35 with Italian bonds where a manifestation of the portfolio rebalancing effect is reported. Finally, a striking feature for stock-bond relationships involving long dated bond yields is the sensitivity of DCC estimates to the inclusion of the TED spread and VIX index, especially for correlations that include UK bonds, which is not necessarily restricted to crisis periods. This is hardly surprising in light of the EGARCH results of Table 2 where UK bond yields appear to be very sensitive to credit market liquidity and the level of risk aversion before the banking crisis.

6. DISCUSSION OF THE RESULTS

The results presented in this paper offer important insights into how a crisis spreads. Finding evidence that stock-bond correlations are volatile from pre-crisis to the banking and European sovereign debt crisis indicates that the transmission mechanism that defines the correlation of assets does vary in different market conditions (Forbes and Rigobon, 2000, 2002), a finding that is also consistent with the results of Gulko (2002) and Fleming et al. (1998, 2003). Most importantly, it provides support to the investor induced contagion hypothesis.

We have also established an increase in stock-bond correlations during the banking crisis that is indicative of a wealth effect and, as such, is consistent with the implications derived from the contagion model postulated by Kyle and Xiong (2001), after relaxing the assumption of a two high risk asset markets. However, this differs from the key findings of Baur and Lucey (2009) who reported evidence of flight *to* quality regularly occurring during crisis periods; nevertheless, their time frame considered the pre-2007 banking crisis period. Intuitively, the increase in correlation observed during the banking crisis appears to be caused by a volatile "liquidity spiral" between both markets (Brunnermeier and Pedersen, 2009). In the modified contagion model, investors tend to substitute growth for income in a crisis; yet at the same time, shocks increase the risk that investors will hit their funding limits, which, as yields decline, leads to a liquidation of positions in bonds as lower income streams are associated with an increased risk of capital constraints (Brunnermeier and Pedersen, 2009). As a consequence, an unstable "liquidity spiral" between the two markets is the result, causing both asset classes to become more volatile and an increase in stock-bond correlations.

The increase in stock-bond correlations reported is robust during the debt crisis for stock-bond relationships involving all stock indexes and bond yields of the UK, US and

Germany at a time when stock markets of those countries are rising. However, according to the Brunnermeier and Pedersen (2009) model, such a scenario would coincide with relaxed funding constraints on investors to undertake activities that generate greater liquidity and a decline in volatility in the asset markets.[17] As a consequence, the increase in stock-bond correlations observed during the debt crisis for the major countries contradict the findings implied by Baur and Lucey (2009) who postulate that a "flight *from* quality" and a decline in liquidity in the bond market would arise at a time of rising stock prices. Finding an increase in stock-bond correlations suggests that contagion is not necessarily restricted to negative events and falling stock prices as also implied by previous studies (King and Wadhwani, 1990; Koutmos, 1996). On the other hand, for correlations involving Spanish and Italian bonds, our results also indicate that investor induced contagion does diminish after the banking crisis until the end of 2009. Negative DCC estimates from 2010 onwards suggest further evidence of investor induced contagion, but this time, caused by the portfolio rebalancing effect during the sovereign debt crisis. Whilst this is consistent with the findings of previous studies (Hartmann et al., 2004; Connolly et al., 2005; and Baur and Lucey, 2009), this is indicative of a change in the transmission mechanism in different market conditions.

An added dimension of this paper is that we consider the transmitting effects of a change in financial market confidence indicators on the transmission channel of the stock-bond relationship. The inclusion of two barometers of risk is motivated by the findings of previous studies that view the TED spread (Brunnermeier, 2009; and Melvin and Taylor, 2009) and VIX index (Low, 2004) as containing useful information on the state of the credit market and investor confidence; this, in turn, has a causal impact on the behavior of different asset classes (Lashgari, 2000 and Andersson et al., 2007). Our findings suggest that a major

[17] This period also coincides with the large scale QE programmes investigated by Gagnon et al. (2011), Joyce et al. (2011) and Neely (2011) outlined in footnote 6 that have caused bond prices (yields) to remain high (low) in a highly liquid market at a time of rising stock prices.

driving force of investor induced contagion is risk aversion during the banking and debt crises. Interestingly, this is counter balanced by evidence of an inverse relationship between credit market liquidity and stock-bond correlations. As a result, a widening of TED spreads, i.e., funding illiquidity conditions, observed in Figure 1 appears to reduce investor induced contagion caused by the wealth effect during the banking crisis. This implies that some investors engage in portfolio rebalancing and a "flight *to* quality", a dynamic that is consistent with the results of Baur and Lucey (2009). A narrowing of TED spreads during the debt crisis contributed to the wealth effect for the majority of stock-bond relationships as well as the portfolio rebalancing effect for correlations involving Spanish and Italian bonds.

The intuition behind these results can generally be found in the liquidity channel postulated by Chordia et al. (2005) where the banking crisis characterized by a lack of liquidity and a high degree of uncertainty causes investors to liquidate their positions in high risk assets in exchange for low risk assets. Ultimately, this causes a shift in liquidity away from the stock market to the bond market. Conversely, the debt crisis characterized by narrow TED spreads and rising stock prices in the major markets will encourage investors to buy high risk assets, making the bond markets less liquid. When added together, this leads to a negative stock-bond relationship, which nests neatly with the correlation estimates reported for Spanish and Italian bonds.

Exploring the difference in DCC estimates with and without the TED spread and VIX index in the EGARCH model provides greater insight into the role of both risk barometers on the source of investor induced contagion over a period of time. The key finding reported is the manifestation of the wealth effect arising from credit market liquidity and the level of risk aversion in the pre-crisis period of 2007 and especially during the banking crisis. The results are repeated for the majority of stock-bond relationships during the debt crisis with the exception of correlations involving Spanish and Italian bonds where a manifestation of the portfolio rebalancing effect is reported. This is consistent with previous studies that find contagion only arises in times of a crisis (Kaminsky and Schmukler, 1999; and Chiang et al., 2007).

7. CONCLUSION

We provide evidence in support of the investor induced contagion hypothesis during the banking crisis and European sovereign debt crisis for stock-bond relationships. We find that the source of contagion during the banking crisis is the wealth effect that spreads across borders due to the drying up of liquidity from the stock and bond markets. However, a mixed picture is reported for the debt crisis where we report some evidence in favor of the portfolio rebalancing hypothesis as the reason behind the spread of the crisis for correlations involving Spanish and Italian bonds. Our results also indicate that risk aversion during the banking crisis contributes to the wealth effect in all instances. However, for stock-bond correlations involving Spanish and Italian bonds, we have also established that increased risk appetite magnified the portfolio rebalancing effect during the debt crisis.

Taken together, our findings imply that transmission mechanisms that define the relationship between asset markets within a country and beyond change as a result of a financial crisis. Additionally, our results offer important insights to policy makers. The evidence which supports the existence of a liquidity channel in explaining how a crisis spreads, in light of credit market liquidity conditions and levels of risk aversion, implies that policy makers should consider whether liquidity levels in the financial markets are maintained through interventionist policies, particularly in periods of market stress. Finally, our results also pose questions on the unintentional consequences of central bank intervention in undertaking QE programmes on the way a crisis spreads. Such an assertion is borne out by overwhelming support for investor induced contagion sourced by the portfolio rebalancing hypothesis for stock-bond correlations involving Spanish and Italian bonds from 2010 onwards. Overall, our findings provide striking evidence on the time varying nature of stock–bond relationships over different market conditions suggesting that investor induced contagion explains how a crisis spreads within a country and beyond its borders.

REFERENCES

Acharya, V., & Pedersen, L. (2005). Asset pricing with liquidity risk, *Journal of Financial Economics*, 77, 375–410.

Acharya, V., Philippon, T., Richardson, M., & Roubini, N. (2009) The financial crisis of 2007-2009: causes and remedies. in Acharya, V., and Richardson, M. (Eds.), Restoring financial stability: how to repair a failed system, John Wiley and Son Ltd.

Alberg, D., Shalit, H., & Yosel, R. (2008). Estimating stock market volatility using Asymmetric GARCH Models, *Applied Financial Economics*, 18, 1201–1208.

Andersen, T. G., Bollerslev, T., Diebold, F.X., & Ebens, H. (2001). The distribution of realized stock return volatility, *Journal of Financial Economics*, 61, 43–76.

Andersson, M., Krylova, E., & Vahamaa, S. (2007). Why does the correlation between stock and bond yields vary over time?, *Applied Financial Economics*, 18, 139–151.

Baele, L. (2005). Volatility spillover effects in european equity markets, *Journal of Financial and Quantitative Analysis*, 40, 373 – 401.

Bank of International Settlements (2009). 79th Annual Report.

Bannier, C.E., & Hirsch, C.W. (2010). The economic function of credit rating agencies - what does the watchlist tell us?, *Journal of Banking and Finance*, 34, 3037-3049.

Baur, D.G., & Lucey, B.M. (2009). Flights and contagion-an empirical analysis of stock-bond correlations, *Journal of Financial Stability*, 5 (4), 339-352.

Behr, P., & Güttler, A. (2008). The informational content of unsolicited ratings, *Journal of Banking and Finance*, 32, 587-599.

Berndt, E.K., Hall, B., Hall, R., & Hausman, J.A. (1974). Estimation and inference in nonlinear structural models, *Annals of Economic and Social Measurement*, 3(4), 653 – 665.

Bianconi, M., Yoshino, J. A., & Machado De Sousa, M.O. (2013). BRIC and the US financial crisis: an empirical investigation of stock and bond markets, *Emerging Markets Review*, 14, 76-109.

Billio, M., & Pelizzon, L. (2003). Volatility and shocks spillover before and after emu in European stock markets, *Journal of Multinational Financial Management*, 13, 323 – 340.

Blair, B.J., Poon, S.H., & Taylor, S.J. (2001). Forecasting S&P 100 volatility: the incremental information content of implied volatilities and high frequency returns, *Journal of Econometrics*, 105, 5 – 26.

Blanco, R., Brennan, S., & Marsh, I. W. (2005). An empirical analysis of the dynamic relation between investment-grade bonds and credit default swaps, *Journal of Finance*, 60, 2255–2281.

Boyer, B.H., Kumagai, T., & Yuan, K. (2006). How do crises spread? Evidence from accessible and inaccessible stock indices, *Journal of Finance*, 61, 957 – 1003.

Brandt, M.W., & Jones, C.S. (2006). Volatility forecasting with range-based EGARCH models, *Journal of Business and Economic Statistics*, 24, 470 – 486.
Brunnermeier, M.K. (2009). Deciphering the liquidity and credit crunch 2007–2008, *Journal of Economic Perspectives,* 23, 77 – 100.
Brunnermeier, M.K., & Pedersen, L.H. (2009). Market liquidity and funding liquidity, *Review of Financial Studies,* 22 (6), 2201-2238.
Campbell, J., & Ammer, J. (1993). What moves the stock and bond markets? A variance decomposition for long-term asset returns, *Journal of Finance*, 48, 3-37.
Caporale, G.M., Pittis, N., & Spagnolo, N. (2006). Volatility transmission and financial crisis, *Journal of Econometrics*, 30, 376 – 390.
Cappiello, L., Engle, R.F., & Sheppard, K. (2006). Asymmetric dynamics in the correlations of global equity and bond yields, *Journal of Financial Econometrics*, 4, 537 – 572.
Chiang, T. C., Jeon, B.N., & Li, H. (2007). Dynamic correlation analysis of financial contagion: Evidence from Asian markets, *Journal of International Money and Finance*, 26, 1206 – 1228.
Chordia, T., Sarkar, A., & Subrahmanyam, A. (2005). An empirical analysis of stock and bond market liquidity, *Review of Financial Studies,* 18, 85-129.
Collin-Dufresne, P., Goldstein, R. S., & Martin, J. S. (2001). The determinants of credit spread changes, *Journal of Finance*, 56, 2177–2207.
Connolly, R., & Wang, F. (2003). International equity market co-movements: economic fundamentals or contagion?, *Pacific-Basin Financial Journal*, 11, 23 – 43.
Connolly, R., Stivers, C., & Sun, L. (2005). Stock market uncertainty and the stock–bond yield relation. *Journal of Financial and Quantitative Analysis*, 40, 161-193.
Engle, R. (2002). Dynamic Conditional Correlation: A simple class of multivariate Generalized Autoregressive Conditional Heteroskedasticity Models, *Journal of Business & Economic Statistics*, 20, 339 - 350.
Fleming, J., Kirby, C., & Ostdiek, B. (1998). Information and volatility linkages in the stock, bond, and money markets, *Journal of Financial Economics*, 49, 111 - 137.
Fleming, J., Kirby, C., & Ostdiek, B. (2003). The economic value of volatility timing using "realized" volatility, *Journal of Financial Economics*, 67, 473 - 509.
Forbes, K., & Rigobon, R. (2000). Contagion in Latin America: Definitions, measurement, and policy implications, *Economia*, 1, 1 – 46.
Forbes, K., & Rigobon, R. (2002). No Contagion, only interdependence: measuring stock market co-movements, *Journal of Finance*, 5, 2223 – 2261.
Forte, S., & Peña, J. I. (2009). Credit spreads: An empirical analysis on the informational content of stocks, bonds, and CDS, *Journal of Banking & Finance*, 33, 2013–2025.
French, K.R., Schwert, G.W., & Stambaugh, R.F. (1987). Expected stock returns and volatility, *Journal of Financial Economics*, 19, 3 – 30.
Gagnon, J., Raskin, M., Remache, J., & Sack, B. (2011). The financial market effects of the Federal Reserve's large-scale asset purchases, *International Journal of Central Banking*, 7 (1), 3 - 43.
Gulko, L. (2002). Decoupling, *Journal of Portfolio Management*, 28, 59-67.
Hartmann, P. Straetmans, S., & de Vries, C.G. (2004). Asset market linkages in crisis periods, *Review of Economics and Statistics*, 86, 313 – 326.
Hentschel, L. (1995). All in the family: nesting symmetric and asymmetric GARCH models, *Journal of Financial Economics,* 39, 71 – 104.
Jones, C., & Wilson, J. (2004). The changing nature of stock and bond volatility. *Financial Analysts Journal*, 60, 100-113.

Joyce, M., Lasaosa, A., Stevens, I., & Tong, M. (2011). The financial market impact of quantitative easing in the United Kingdom', *International Journal of Central Banking*, 7, 113 – 161.
Kaminsky, G.L., & Schmukler, S.L. (1999). What triggers market jitters? A chronicle of the Asian Crisis, *Journal of International Money and Finance*, 18, 537 – 560.
Kim, S.J., & Moshirian, F. (2004). Dynamic stock market integration driven by the European Monetary Union: An empirical analysis, *Journal of Banking and Finance*, 29, 2475 – 2502.
King, M., & Wadhwani, S. (1990). Transmission of volatility between stock markets, *Review of Financial studies*, 3, 5 – 33.
Koopman, S.J., Jungbacker, B., & Hol, E. (2005). Forecasting daily variability of the S&P 100 stock index using historical, realized and implied volatility measurements, *Journal of Empirical Finance*, 12, 445 – 475.
Koutmos, G. (1996). Modelling the dynamic interdependence of major European stock markets, *Journal of Business, Finance and Accounting*, 23, 975 – 988.
Kyle, A.S., & Xiong, W. (2001). Contagion as a Wealth Effect, *Journal of Finance,* 56, 1401 – 1440.
Lashgari, M. (2000).The role of TED spread and confidence index in explaining the behaviour of stock prices, *American Business Review*, 1, 1 – 3.
Li, L. (2004). Macroeconomic factors and the correlation of stock and bond yields, *Proceeding of the 2004 American Finance Association Meeting*.
Low, C. (2004). The fear and exuberance from implied volatility of S&P 100 index options, *Journal of Business*, 77, 527 - 546.
Melvin, M., & Taylor, M.P. (2009). The crisis in the foreign exchange market, *Journal of International Money and Finance,* 28, 1317-1330.
Neely, C.J., (2011). The large-scale asset purchases had large international effects, *St. Louis Working Paper 2010-018C.*
Nelson, D. (1991). Conditional Heteroscedasticity in asset returns: A New Approach, *Econometrica*, 59, 347 - 370.
Norden, L., & Weber, M. (2009). The Co-movement of Credit Default Swap, Bond and Stock Markets: An Empirical Analysis, *European Financial Management*, 15, 529-562.
Ravichandran K., & Maloain, A.M. (2010). The global financial crisis and stock market linkages: Further evidence on GCC Market. *Journal of Money, Investment and Banking*, 16, 46 - 56.
Reinhart, C.M., & Rogoff, K.S. (2009). The aftermath of Financial Crisis, A*merican Economic Review,* 9, 466-472.
Schwert, G.W. (1990). Stock Volatility and the Crash of '87, *Review of Financial Studies,* 3, 77 - 102.
Shiller, R., & Beltratti, A. (1992). Stock prices and bond yields: Can their comovements be explained in terms of present value models?, *Journal of Monetary Economics*, 30, 25-46.
Taylor, J.B., & Williams, J.C. (2009). A black swan in the money market, *American Economic Journal: Macroeconomics*, 1, 58 - 83.
Wongswan, J. (2006). Transmission of information across international equity markets, *Review of Financial Studies*, 19, 1157–1189.
Yang, J., Hsiao, C., & Wang, Z. (2006). The emerging market linkages: Further evidence, *Journal of Applied Econometrics*, 21, 727-744.

Table 1: Descriptive Statistics and Unconditional Correlations Between Stock and Bond Markets

		FTSE	Russell	CAC	DAX	IBEX	FTSE	UK		US		FRANCE		GERMANY		SPAIN		ITALY	
		100	3000	40	30	35	MIB	1-3	10+	1-3	10+	1-3	10+	1-3	10+	3	10	1	10
Mean		0.011	0.012	-0.002	0.026	-0.001	-0.024	-0.159	-0.018	-0.081	-0.030	-0.113	0.020	-0.072	-0.035	0.013	0.016	-0.052	0.009
St.dev		1.249	1.362	1.467	1.428	1.489	1.559	4.960	0.626	4.637	1.406	4.367	1.092	16.51	1.334	4.052	1.303	4.460	1.251
Skewness		0.145**	-0.357**	0.068	0.046	0.075	-0.046	0.753**	0.523**	-0.734**	-0.452**	1.391**	-0.059**	3.485**	-0.017	0.433**	-1.126**	0.158**	-0.895*
Kurtosis		8.479**	9.765**	7.294**	6.890**	6.686**	6.132**	43.90**	230.21**	14.05**	5.038**	64.76**	3.506**	142.24**	-4.744**	25.92**	13.92**	12.18**	13.56*
Q(12)		56.41**	47.67**	43.14**	22.47*	27.25**	38.81**	239.98**	19.10*	66.22**	151.51**	196.43**	44.37**	230.98**	29.92**	142.74**	130.11**	587.31**	79.08*
FTSE100		1	0.570	0.902	0.842	0.819	0.828	0.213	0.261	0.360	0.368	0.168	0.259	0.095	0.324	0.017	0.107	0.065	0.073
Russell			1	0.603	0.627	0.558	0.569	0.157	0.191	0.259	0.233	0.130	0.192	0.050	0.245	0.011	0.075	0.030	0.039
CAC40				1	0.914	.896	0.908	0.239	0.292	0.379	0.401	0.177	0.292	0.095	0.396	0.008	0.079	0.090	0.026
DAX30					1	0.825	0.841	0.219	0.280	0.356	0.378	0.165	0.274	0.091	0.359	0.010	0.105	0.067	0.053
IBEX35						1	0.893	0.244	0.274	0.356	0.378	0.168	0.261	0.118	0.398	0.063	0.018	0.086	0.061
FTSE MIB							1	0.258	0.296	0.373	0.391	0.161	0.281	0.105	0.423	-0.047	-0.024	0.076	-0.087
UK	1-3							1	0.308	0.398	0.353	0.193	0.265	0.077	0.450	0.019	0.014	0.060	0.031
	10+								1	0.337	0.378	0.201	0.379	0.060	0.438	0.039	0.225	0.070	0.191
US	1-3									1	0.548	0.323	0.404	0.073	0.449	0.063	0.219	0.096	0.182
	10+										1	0.267	0.525	0.100	0.642	0.063	0.231	0.099	0.202
FRANCE	1-3											1	0.531	0.065	0.371	0.132	0.225	0.122	0.216
	10+												1	0.098	0.775	0.100	0.433	0.144	0.429
GERMANY	1-3													1	0.125	0.019	-0.028	0.027	0.023
	10+														1	0.022	0.190	0.127	0.153
SPAIN	3															1	0.383	0.025	0.293
	10																1	0.022	0.824
ITALY	1																	1	0.035
	10																		1

Notes: The asterisks ** and * represent significance at the 1% and 5% levels respectively. The grey shaded area is the unconditional stock-bond correlation for the whole sample.

Table 2: DCC-EGARCH (1,1) Estimations – Country Stock and Bond Market Returns

Index		QE Adjustment			Market Risk Factors						Conditional Variance				Model Diagnostics	
		γ_1	α_1	α_2	$\emptyset_{1,1}$	$\emptyset_{1,2}$	$\emptyset_{1,3}$	$\emptyset_{2,1}$	$\emptyset_{2,2}$	$\emptyset_{2,3}$	a_0	a_1	a_2	θ_1	LB(6)	LB(12)
FTSE100			0.0736**			-0.0258[a]		0.0007[a]			-0.0682**	0.9847**	0.0862**	-0.1396**	4.9636	7.2810
			(0.025)			(0.013)		(0.004)			(0.012)	(0.002)	(0.015)	(0.010)	[0.55]	[0.84]
Russell 3000			0.1280**	0.0793**					0.0007*	0.0004*	-0.0652**	0.9832**	0.0845**	-0.1351**	5.0176	7.6638
			(0.034)	(0.023)					(0.0003)	(0.0002)	(0.013)	(0.002)	(0.015)	(0.011)	[0.54]	[0.81]
CAC40			0.0910*								-0.0799**	0.9775**	0.1107**	-0.1570**	9.7300	10.837
			(0.046)								(0.012)	(0.003)	(0.016)	(0.011)	[0.14]	[0.54]
DAX30											-0.0886**	0.9748**	0.1261**	-0.1369**	5.7245	7.8531
											(0.013)	(0.003)	(0.017)	(0.009)	[0.46]	[0.80]
IBEX35							0.0048[a]		0.0005[a]		-0.1055**	0.9776**	0.1470**	-0.1294**	7.8395	13.196
							(0.003)		(0.0003)		(0.012)	(0.003)2	(0.016)1	(0.009)	[0.25]	[0.36]
FTSE MIB											-0.0874**	0.9853**	0.1187**	-0.1130**	3.7516	6.6119
											(0.011)	(0.002)	(0.014)	(0.008)	[0.71]	[0.88]
Maturity																
UK	1-3		-0.1697[a]			-0.0499**					-0.0597**	0.9995**	0.0823**	-0.0483**	0.5450	2.1775
			(0.099)			(0.017)					(0.007)	(0.006)	(0.009)	(0.006)	[0.99]	[0.99]
	10+			-0.0585**	0.1572**	-0.0392**	-0.1297**	-0.0165**			-0.1250**	0.9265**	0.0825**	-0.2696**	0.1871	0.2624
				(0.015)	(0.012)	(0.002)	(0.030)	(0.002)			(0.006)	(0.005)	(0.008)	(0.011)	[0.99]	[1.00]
US	1-3				-0.0339*	-0.0180**	-0.0332*	-0.0094*	-0.0180**		-0.0334**	0.9987**	0.0468**	-0.0615**	8.9988	11.749
					(0.010)	(0.006)	(0.014)	(0.005)	(0.006)		(0.005)	(0.006)	(0.006)	(0.004)	[0.17]	[0.47]
	10+			0.1444**	-0.0219*			-0.0106[a]	-0.0161**	-0.0191**	-0.0761**	0.9922**	0.1045**	-0.0498**	5.2068	14.358
				(0.041)	(0.009)			(0.006)	(0.006)	(0.005)	(0.009)	(0.002)	(0.011)	(0.007)	[0.52]	[0.28]
FRANCE	1-3	0.0487[a]									-0.0851**	0.9995**	0.1144**	-0.0552**	5.9047	17.121
		(0.027)									(0.008)	(0.001)	(0.010)	(0.006)	[0.43]	[0.15]
	10+									0.0004**	-0.0847**	0.9916**	0.1099**	-0.0367**	13.398	17.206
										(0.0002)	(0.010)	(0.002)	(0.013)	(0.007)	[0.04]	[0.14]
GERMANY	1-3	0.0567*	-0.2529[a]								-0.0974**	0.9989**	0.1315**	-0.0529**	7.2210	10.453
		(0.026)	(0.140)								(0.008)	(0.001)	(0.011)	(0.007)	[0.30]	[0.58]
	10+										-0.0924**	0.9950**	0.1216**	-0.0350**	9.3980	11.977
											(0.010)	(0.002)	(0.012)	(0.009)	[0.15]	[0.45]
SPAIN	3	0.1179**			-0.0103*	-0.0123**	-0.0304**		-0.0014**		-0.09437**	0.9961**	0.1444**	-0.0046	9.776	11.380
		(0.035)			(0.0039)	(0.002)	(0.006)		(0.0002)		(0.005)	(0.001)	(0.008)	(0.007)	[0.13]	[0.50]
	10	0.0471*	-0.0909[a]		-0.0062*		-0.0109**		0.0003*		-0.1051**	0.9941**	0.1417**	0.0491**	7.0067	14.367
		(0.023)	(0.051)		(0.003)		(0.003)		(0.0002)		(0.010)	(0.002)	(0.013)	(0.008)	[0.32]	[0.28]
ITALY	3	0.0854**								0.0006[a]	-0.1341**	0.9977**	0.1902**	0.0237**	1.9373	5.6783
		(0.030)								(0.0003)	(0.008)	(0.002)	(0.010)	(0.006)	[0.93]	[0.93]
	10		-0.0761[a]						0.0004*		-0.1157**	0.9914**	0.1555**	0.0557**	16.709	23.049
			(0.0451)						(0.0002)		(0.011)	(0.002)	(0.014)	(0.008)	[0.01]	[0.03]

Table 3: DCC(*Z*)-EGARCH Risk Factor Model: Stock-Bond Correlations (Short Dated Bond Yields)

	Russell 3000						CAC40					
	UK	US	FRANCE	GERMANY	SPAIN	ITALY	UK	US	FRANCE	GERMANY	SPAIN	ITALY
Γ_{10}			0.2684**				0.4337**	0.3998**	0.3917**	0.1004**		
			(0.075)				(0.105)	(0.114)	(0.110)	(0.019)		
ρ	0.998**	0.9990**	0.9834**	0.9988**	0.9988**	0.9982**	0.9833**	0.9875**	0.9844**	0.9693**	0.9988**	0.9977**
	(0.001)	(0.001)	(0.004)	(0.001)	(0.001)	(0.002)	(0.004)	(0.003)	(0.004)	(0.005)	(0.001)	(0.002)
Transmission effects – country *a*												
$\Gamma_{11,i}$							0.0707*					
							(0.034)					
$\Gamma_{12,i}$												
$\Gamma_{13,i}$	-0.0448**	-0.048**	-0.1393*	-0.0842**	-0.0370**							
	(0.017)	(0.017)	(0.060)	(0.025)	(0.001)							
$\Gamma_{14,i}$												0.0020*
												(0.001)
$\Gamma_{15,i}$	0.0003**	0.0005**	0.0010**	0.0005**		0.0005**		0.0011**				0.0005**
	(8.42E-5)	(8.47E-5)	(0.0003)	(0.0001)		(0.0001)		(0.0004)				(0.0001)
$\Gamma_{16,i}$	0.0004**	0.0012**	0.0007**	0.0005**	0.0011**	0.0004**						0.0011**
	(0.0001)	(0.0004)	(0.0002)	(7.76E-5)	(0.0003)	(0.0001)						(0.0003)
Transmission effects – country *b*												
$\Gamma_{11,j}$		-					-		-			
		-					-		-			
$\Gamma_{12,j}$		-			0.0013*		-		-			
		-			(0.0006)		-		-			
$\Gamma_{13,j}$		-					-	-0.1055*	-			
		-					-	(0.054)	-			
$\Gamma_{14,j}$		-					-		-			
		-					-		-			
$\Gamma_{15,j}$		-						0.0010*-	0.0008**	-	0.0029**	0.0005**
		-						(0.0004)	(0.0003)	-	(0.0008)	(0.0002)
$\Gamma_{16,j}$		-			-0.0002*	-0.0006*	-	0.0008*	-	0.0032*		
		-			(7.62E-5)	(0.0003)	-	(0.0004)	-	(0.002)		
$\chi^2(6)$	3.6122	5.3993	3.5376	6.0984	0.5163	0.1305	2.3983	1.9739	3.5946	2.5295	0.4219	0.1305
	[0.73]	[0.49]	[0.74]	[0.41]	[0.99]	[1.00]	[0.88]	[0.92]	[0.73]	[0.87]	[0.99]	[1.00]
LB(6)	6.5759	4.8388	7.7137	56.167	2.7931	6.7748	2.9683	4.7866	2.1919	5.3473	5.1576	6.7748
	[0.36]	[0.57]	[0.26]	[0.00]	[0.83]	[0.34]	[0.81]	[0.57]	[0.90]	[0.50]	[0.52]	[0.34]
LogL	-1786.44	-2035.8	-4734.30	-2745.59	-668.67	-3438.10	-4689.34	-4499.03	-5401.72	-6199.26	-2844.26	-3438.10

Table 3: *continued*

	IBEX35						FTSE MIB					
	UK	US	FRANCE	GERMANY	SPAIN	ITALY	UK	US	FRANCE	GERMANY	SPAIN	ITALY
Γ_{10}	0.3350**	0.3048**	0.5982**	1.0852**			0.3313**	0.2889**3	0.2935**	0.1042**		
	(0.090)	(0.096)	(0.133)	(0.194)			(0.092)	(0.096)	{0.096)	(0.019)		
ρ	0.9860**	0.9895**	0.9749**	0.9665**	0.9985**	0.9978**	0.9863**	0.9905**	0.2935**	0.9678**	0.9976**	0.9983**
	(0.003)	(0.003)	(0.005)	(0.005)	(0.001)	(0.002)	(0.003)	(0.003)	(0.003)	(0.005)	(0.002)	(0.001)
Transmission effects – country *a*												
$\Gamma_{11,i}$										-0.1220*		
										(0.054)		
$\Gamma_{12,i}$												
$\Gamma_{13,i}$			-0.0130**	-0.0251**		-0.0373**						
			(0.006)	(0.007)		(0.009)						
$\Gamma_{14,i}$					0.0009**							
					(0.0003)							
$\Gamma_{15,i}$	0.0014**	0.0010**	0.0023**		0.0006**		0.0014*	0.0013**	0.0021**	0.0029*		0.0029**
	(0.0004)	(0.0003)	(0.0007)		(0.0001)		(0.0005)	(0.0003)	(0.0005)	(0.001)		(0.0007)
$\Gamma_{16,i}$			0.0035**		0.0004*				0.0022*			0.0014**
			(0.001)		(0.0002)				(0.001)			(0.0003)
Transmission effects – country *b*												
$\Gamma_{11,j}$												
$\Gamma_{12,j}$												
$\Gamma_{13,j}$							0.3287*					
							(0.139)					
$\Gamma_{14,j}$						0.0018*					0.0013**	
						(0.0007)					(0.0004)	
$\Gamma_{15,j}$						0.0007*					0.0006**	
						(0.0003)					(0.0002)	
$\Gamma_{16,j}$												
$\chi^2(6)$	5.8873	4.0207	7.7774	2.0233	0.6494	5.1899	3.0439	3.1946	3.4875	2.2674	1.0449	1.6143
	[0.44]	[0.67]	[0.25]	[0.92]	[0.99]	[0.52]	[0.80]	[0.78]	[0.75]	[0.89]	[0.98]	[0.95]
LB(6)	4.6430	4.3898	2.2651	3.5108	12.552	9.3483	3.8078	5.5880	2.7080	3.6115	3.2060	14.229
	[0.59]	[0.62]	[0.89]	[0.74]	[0.05]	[0.16]	[0.70]	[0.47]	[0.85]	[0.73]	[0.78]	[0.03]
LogL	-4508.26	-4460.17	-6029.26	-6289.30	-3261.56	-4876.79	-4777.25	-4381.12	-5337.94	-6291.19	-3706.726	-4937.35

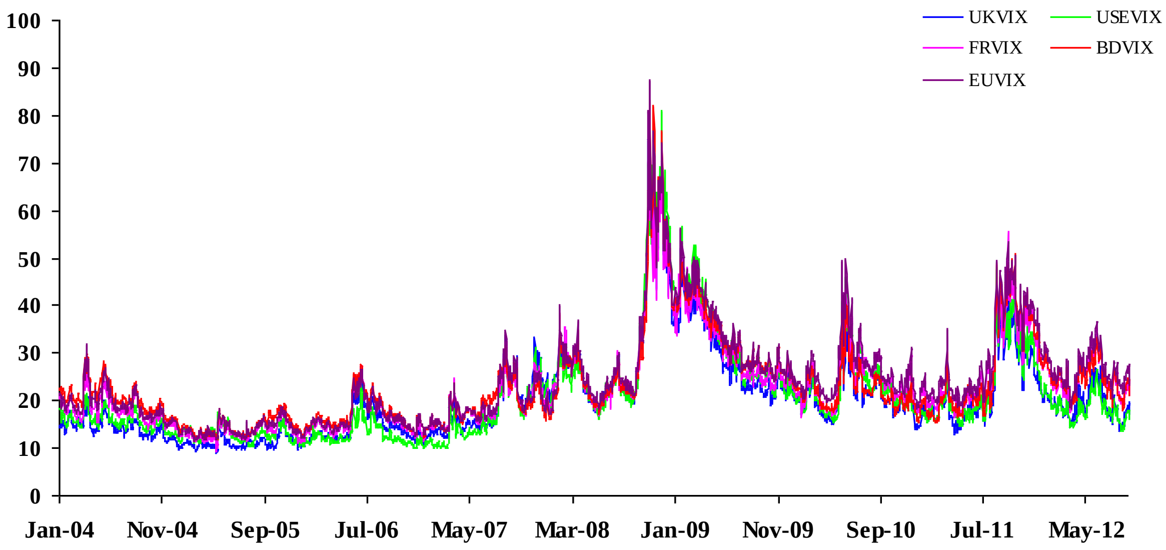
Table 4: DCC(Z)-EGARCH Risk Factor Model: Stock-Bond Correlations (Long Dated Bond Yields)

	Russell 3000						DAX30					
	UK	US	FRANCE	GERMANY	SPAIN	ITALY	UK	US	FRANCE	GERMANY	SPAIN	ITALY
Γ_{10}	1.3724**		0.2411**				0.3317	0.6645**	0.3558**	0.3321**		
	(0.186)		(0.073)				(0.036)	(0.151)	(0.108)	{0.110)		
ρ	0.9338**	0.9989**	0.9848**	0.9979**	0.9984**	0.9979**	0.8887	0.9786**	0.9848**	0.9890**	0.9976**	0.9975**
	(0.008)	(0.001)	(0.004)	(0.001)	(0.001)	(0.002)	(0.010)	(0.004)	(0.004)	(0.003)	(0.022}	(0.002)
Transmission effects – country *a*												
$\Gamma_{11,i}$		0.0174*						0.0793*			0.0450*	
		(0.009)						(0.038)			(0.022)	
$\Gamma_{12,i}$								-0.0261*	-0.0248*	-0.0227*		
								(0.012)	(0.012)	(0.010)		
$\Gamma_{13,i}$					-0.1156**	-0.0955**						
					(0.032)	(0.033)						
$\Gamma_{14,i}$												
$\Gamma_{15,i}$	0.0028**	0.0003**	0.0006*		0.0004*							
	(0.0008)	(0.0001)	(0.0003)		(0.0002)							
$\Gamma_{16,i}$		0.0004*		0.0005*	0.0017**	0.0010**						
		(0.0002)		(0.0002)	(0.0003)	(0.0003)						
Transmission effects – country *b*												
$\Gamma_{11,j}$		-								-		
		-								-		
$\Gamma_{12,j}$		-	0.0267**							-		-0.0257**
		-	(0.009)							-		(0.009)
$\Gamma_{13,j}$		-								-		
		-								-		
$\Gamma_{14,j}$		-								-		
		-								-		
$\Gamma_{15,j}$		-								-		
		-								-		
$\Gamma_{16,j}$		-			-0.0007**					-		
		-			(0.0002)					-		
$\chi^2(6)$	3.6672	1.0332	6.0714	11.876	1.1692	10.60547	9.0423	6.8459	18.741	13.161	2.1132	3.1585
	[0.72]	[0.98]	[0.42]	[0.06]	[0.98]	[0.10]	[0.17]	[0.34]	[0.00]	[0.04]	[0.91]	[0.79]
LB(6)	8.7621	7.0813	2.6159	6.3597	10.424	8.5272	4.9903	7.9171	4.4232	6.4405	5.7602	5.7657
	[0.19]	[0.31]	[0.86]	[0.38]	[0.11]	[0.20]	[0.55]	[0.24]	[0.62]	[0.38]	[0.45]	[0.45]
LogL	-6756.81	-2994.36	-4859.72	-3263.93	-3328.86	-3366.98	-8498.47	-5820.50	-5716.98	-5494.54	-4635.70	-4762.95

Table 4: *continued*

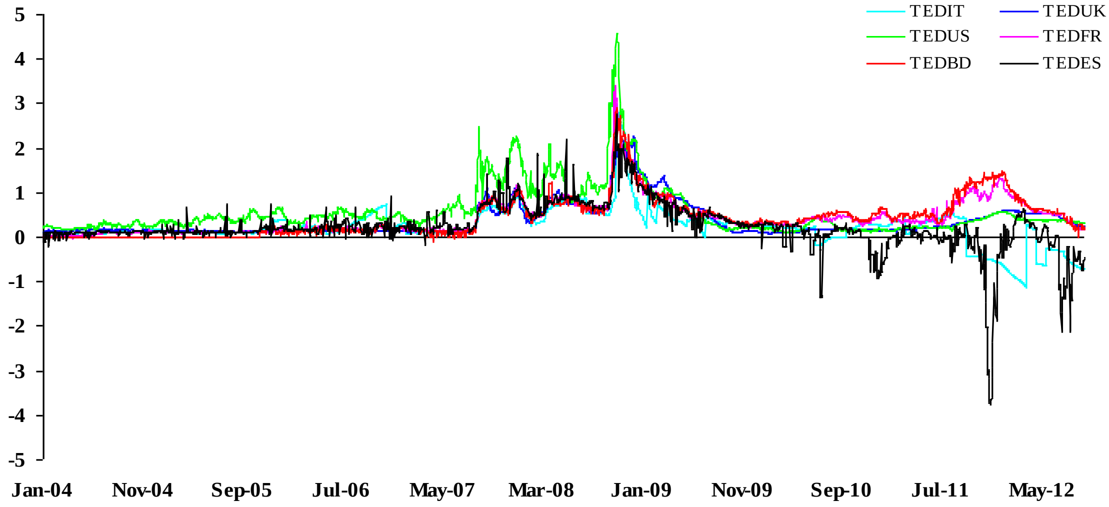
	IBEX35						FTSE MIB					
	UK	US	FRANCE	GERMANY	SPAIN	ITALY	UK	US	FRANCE	GERMANY	SPAIN	ITALY
Γ_{10}	0.1727**	0.7541**	0.3814**	0.3050**			0.3367**	0.5840**	0.3011**	0.2688*		
	(0.024)	(0.160)	(0.112)	(0.108)			(0.037)	(0.140)	(0.101)	(0.104)		
ρ	0.9379**	0.9742**	0.9829**	0.9901**	0.9845**	0.9987**	0.8862	0.9805**	0.9867**	0.9913**	0.9982**	0.9982**
	(0.007)	(0.005)	(0.004)	(0.003)	(0.004)	(0.001)	(0.010)	(0.004)	(0.003)	(0.003)	(0.001)	(0.002)
Transmission effects – country *a*												
$\Gamma_{11,i}$												
$\Gamma_{12,i}$							-0.1060**	-0.0360**	-0.0420**	-0.0402**	-0.0232**	-0.0260**
							(0.045)	(0.013)	(0.013)	(0.012)	(0.008)	(0.009)
$\Gamma_{13,i}$											0.0198*	
											(0.010)	
$\Gamma_{14,i}$												0.0020**
												(0.0007)
$\Gamma_{15,i}$												0.0007*
												(0.0003)
$\Gamma_{16,i}$												
Transmission effects – country *b*												
$\Gamma_{11,j}$	-											
	-											
$\Gamma_{12,j}$	-	-0.0252*				-0.0163*						
	-	(0.011)				(0.008)						
$\Gamma_{13,j}$	-											
	-											
$\Gamma_{14,j}$	-				0.0047**	0.0021**					0.0018**	
	-				(0.0017)	(0.0006)					(0.0006)	
$\Gamma_{15,j}$	-	0.0013*				0.0011**					0.0006*	
	-	(0.0006)				(0.0003)					(0.0002)	
$\Gamma_{16,j}$	-											
	-											
$\chi^2(6)$	4.6294	46.144	24.895	18.552	3.3865	8.6340	6.8379	4.6523	28.520	12.495	4.7612	20.912
	[0.59]	[0.00]	[0.00]	[0.01]	[0.76]	[0.20]	[0.34]	[0.59]	[0.00]	[0.05]	[0.57]	[0.00]
LB(6)	3.6761	5.2635	5.3746	4.6297	2.5697	11.780	5.2334	11.652	6.7137	6.4713	13.537	7.4972
	[0.72]	[0.51]	[0.50]	[0.59]	[0.86]	[0.07]	[0.51]	[0.07]	[0.35]	[0.37]	[0.04]	[0.28]
LogL	-7248.15	-6155.21	-5934.50	-5532.16	-6861.19	-4672.50	-8554.50	-5695.32	-5660.26	-5530.91	-4678.67	-4920.74

Figure 1: The Implied Volatility (VIX) Index of Investor Risk Appetite



Note: The country codes for the VIX index of investor confidence are: UK: UK, US: US, FR: France, BD: Germany, EU: Euro-zone.

Figure 2: The TED Spread Measure of Credit Market Liquidity

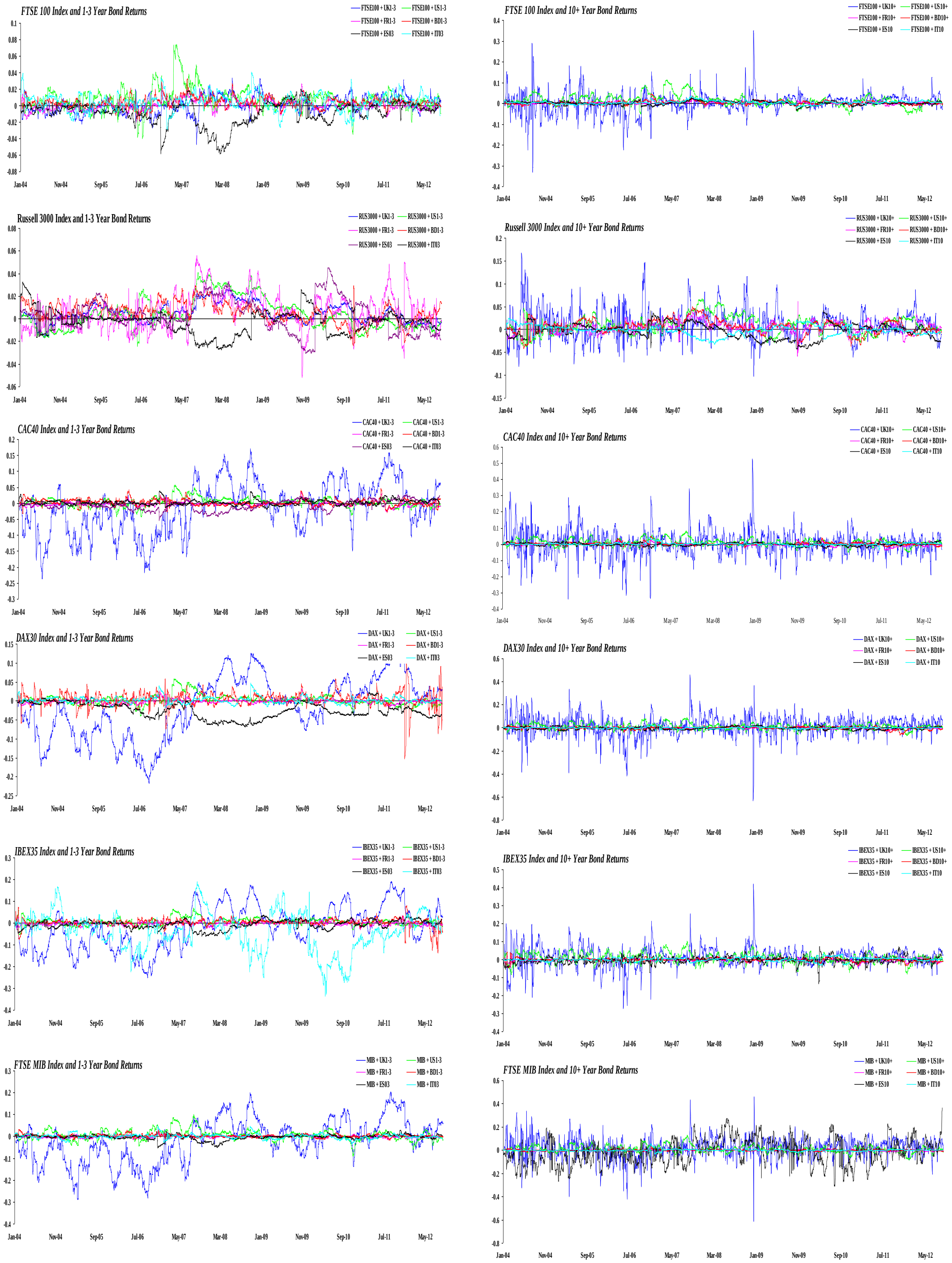


Note: The country codes for the three month TED spreads are: UK: UK, US: US, FR: France, BD: Germany, ES: Spain and IT: Italy.

Figure 3: DCC Estimates on Stock-Bond Relationships

Note: The country codes for DCC estimates involving short dated and long bond yields are: UK: UK, US: US, FR: France, BD: Germany, ES: Spain and IT: Italy.

Figure 4: The Impact of Credit Market Liquidity and Investor Confidence



Note: The country codes for DCC estimates involving short dated and long bond yields are: UK: UK, US: US, FR: France, BD: Germany, ES: Spain and IT: Italy.