Information Transmission across European Equity Markets During Crisis Periods

Jing Chen
School of Mathematics
Cardiff University

David G. McMillan
Accounting and Finance Division
Stirling Management School
University of Stirling

Mike Buckle
Management School
University of Liverpool

October 2016
Revised December 2017

Abstract

To respond to the market turmoil following the demise of Lehman Brothers in September 2008, the majority of European countries imposed short selling restrictions on their equity markets. Such a regulatory intervention is likely to have impact on the price formation process and information transmission between markets. We find that the long-run cointegrating relation between the high and low risk country groups in Europe broke down as the crisis emerged and the regulatory remedy failed to correct this. Furthermore, we find the information transmission between markets has reversed from the high risk to low risk markets in the period following the Lehman demise and imposition of the ban. Further, we notice a similar reversal in the spillover of both return and volatility processes between the different risk-level country groups. We, therefore, conclude that, overall, the 2008 short selling ban had an adverse impact on information transmission between the identified country portfolios in both the long and short run. Notably, the ban did not restore the pre-crisis transmission channels.

Key words: Short Selling, Cointegration, Spillover, Causality

JEL classification: G12, G15, G18, C32

Information Transmission across European Equity Markets During Crisis Periods

1. Introduction.

The bankruptcy of Lehman Brothers, officially announced on September 14, 2008, [1] unleashed a wave of information to the market including that on the riskiness of sub-prime mortgages, asset-backed securities, credit-default swaps, the viability of certain financial institutions and hedge funds, the freezing of credit markets and expectation of an economic downturn, to mention a few. This was followed by policy responses that included short-selling restrictions, falling interest rates and, for some markets, quantitative easing, along with targeted recapitalisation plans, such as the US Troubled Asset Relief Program (TARP), and a similar plan in the UK. This paper seeks to examine how this wave of new information impacted market transmission mechanisms and whether it led to a long-run or short-run influence on market behaviour. To do this we consider a cointegrating VAR (vector autoregression) with MV-GARCH (multivariate-generalised autoregressive conditional heteroscedasticity) errors in order to allow the capture of information from stock price movement in both the long- and short-run as well as within volatility. Notably, this will allow us to determine the direction of causality between markets and thus the flow of information for both the mean and variance of the stock return process. Of notable interest therefore, is whether the events that began with Lehman's bankruptcy affected the transmission of information between markets. We focus on the behaviour of European markets, which have been additionally buffeted by the sovereign debt crisis.

Relevant for this work, shortly after Lehman Brothers filed for bankruptcy, a short selling ban was imposed.[2] Thus, the market received a substantial amount of news in a short period of time. This makes it difficult to disentangle the different effects impacting on market

[1] The filing for bankruptcy occurred on the 15th September
[2] Note that the short selling ban (19/9/2008) occurs shortly after the collapse of Lehman Brothers (14/9/2008) so it is difficult to separate out the effects of the two events.

behaviour. Therefore, in order to consider these different effects, we study both the long and short-run effects of information transmission on the market before and after the start of these events. If we observe a long run shift in the behaviour of markets, this may support the argument that the liquidity freeze and extreme volatility initiated by the demise of Lehman Brothers altered investor's perception of economic conditions. Thus, it would be expected that the market remained volatile. In contrast, if only short-run effects are reported then this may be due to temporary effects, such as the short sell ban and other measures taken by regulatory bodies. Thus, the additional understanding of examining news on short-term spillovers between markets would help us comprehend whether regulatory restrictions are effective in such circumstances. Therefore, we seek to contribute to the literature by investigating both long-run and short-term information flows and price movements before and after the events surrounding the Lehman Brothers collapse in 2008.

In this study we examine information transmission from above three described perspectives. In order to do so, we construct two European stock index based portfolios: one relating to 'safe' markets and the other to 'risky' markets. Specifically, we examine the nature of the long-run dynamics in the underlying market structure through cointegration tests across the selected European stock market portfolios. If the markets are affected by common (global) shocks, we would expect to see a common stochastic trend between the two sets of markets. However, if market specific information dominates the movement of the price series of the two portfolios, we would not observe co-movement. We impose a breakpoint date in order to partition our data sample into two sub-periods. While the date we choose is relatively arbitrary, we use the introduction of the short sell ban, other dates (e.g., Lehman's collapse) produce similar results to those reported. Furthermore, we also consider the Gregory and Hansen (1996) cointegration test with breaks with similar results.

To further understand the instantaneous information shock transmission mechanism within European markets and their interaction with the global market, we also look at the nature of causality between them. Under normal conditions we might expect information to disseminate from the safer (larger) markets; however, it is of interest to know whether this remains true under periods of stress. In addition to causality in the conditional mean, we apply a multivariate GARCH model to study the shock transmission through the time-varying factor loading among the European markets and this explains the causation structure in variance/volatility. This would fully echo our interest in understanding the information transmission structure, the direction of information flows and whether these changes are the result of the market turbulence at the time. We examine all these aspects in both the price generating process (non-stationary) and the return process (stationary).

Our findings suggest that following the bankruptcy of Lehman Brothers, this led to an end of the cointegrating relation between European countries. The 'safe' stock markets of the UK, Germany and France no longer exhibit co-movement with the 'risky' markets of Spain, Italy, Ireland and Greece after September 2008. We argue that the disappearance of the long-run cointegrating relation between these two groups of stock markets is due to the extreme events that distorted market order and its underlying dynamics. More importantly, we note that the imposition of short selling restrictions did not lead to the re-establishment of the long-run relation between these markets. In addition, Granger causality results suggest that information transmission between the selected markets prior to September 2008 was from the low-risk group of countries to the high-risk group. After this point the causality became bi-directional. This suggests the flow of information has changed following September 2008. This, we argue, is due to the inability of investors to sell high-risk country stocks, following the imposition of short selling restrictions. Finally, evidence from the volatility tests suggests a reversal of the usual transmission of spillover effects from low- to high-risk markets after the start of the crisis, although this reverted back as the Eurozone crisis began.

Overall, we provide evidence of the long run co-movement disappearance and the reversal of the spillover effects in both return and volatility processes. This suggests changes in information transmission flows between markets due to enhanced risk arising from the influx of news and adding a layer of complexity in decision-making. Our results also suggest that while an understandable reaction by regulatory authorities, the short selling ban had little effect in mitigating the distorting effects that began with the collapse of Lehman's. Arguably, while the crisis is closely related to the speculative trading in high-risk derivatives like CDS/CDOs, the regulators were left with no better choices but to impose the ban primarily on equities and thus perhaps the wrong asset class. Hence, market distortions remained.

2. Related Literature.

This paper seeks to examine how information transmission is affected by conditions of market stress and, in particular, the events surrounding the bankruptcy of Lehman Brothers, the subsequent introduction of short selling restrictions and other policy measures. Therefore, we briefly consider the existing literature on information transmission and the effect of crises.

The empirical literature on information transmission has identified the existence of both mean and variance spillovers between markets. Koutmos and Booth (1995) study the transmission mechanism of price and volatility spillovers across the stock markets of New York, Tokyo and London. Their EGARCH modelling approach suggests that good and bad news impacts the daily market returns asymmetrically. In particular, volatility spillovers are strongly affected by a sequence of news arrivals across different markets. They also argue that significant market information events, such as the 1987 crisis, leads to an increase in asymmetry in volatility spillovers.

Tse et al. (1996) examine the information transmission between three Eurodollar futures markets in IMM, SIMEX and LIFFE. They find that these geographically segmented markets, in the long run, trade as one continuous market, driven by a common stochastic trend. However, there are short-lived causalities arising from deviations from the cointegrating vector, arising due to the trading sequence between markets. Tse (1998) finds a similar result that information flow impacts the domestic market (Japan) more than the foreign market (US). In terms of the response to information shocks, domestic markets are also more proactive. Similarly, Baur and Jung (2006) find that intra-day trading activities affect the short-lived mean spillovers between DAX and DOW indices, but more so on the domestic returns (DAX) than the foreign market returns (DOW).

Fung et al. (1997) use a GARCH model to examine both mean and volatility spillovers between the US dollar and Eurodollar markets. Both GARCH and impulse response analysis provide strong evidence that the domestic market exhibits a longer lasting feedback effect to information shocks than the foreign markets, although both mean and volatility feedback were sharp.

Further, the contagion literature identifies a number of possible mechanisms to explain why a shock in one market may spill over into other markets. Kiyotaki and Moore (2002) and Kaminsky et al. (2003) demonstrate how negative shocks in one market represent the arrival of new information that directly affects the values or cash flows associated with securities in another market. This transmission mechanism can be seen as information flowing from more liquid markets to less liquid markets. A representative model of this channel of transmission is that of King and Wadhwani (1990) in which contagion occurs as rational agents attempt to infer information from price changes in other markets. A second transmission mechanism is described in Allen and Gale (2000) and Brunnermeier and Pedersen (2009). They show how investors who suffer losses in one market may find their ability to obtain funding impaired, leading to a downward spiral in market liquidity. They argue that in times of crisis, reductions in market liquidity and funding liquidity are mutually reinforcing, leading to a liquidity spiral. This in turn induces a flight to liquidity (quality) as traders switch capital to markets where liquidity is better. In the work of Vayanos (2004), Acharya and Pedersen (2005) and Longstaff (2008) a severe negative shock in one market may imply an increase in the risk premium in other markets. Thus, negative returns in the distressed market affect subsequent returns in other markets via a time-varying risk premium.

Of particular interest here, Longstaff (2010) provides evidence that the 2007 subprime crisis resulted in significant changes in the patterns of trading activity, liquidity, and funding in financial markets. This is consistent with both the Brunnermeier and Pedersen (2009) funding/illiquidity contagion mechanism as well as with the portfolio rebalancing implications of Allen and Gale (2000), and supports the view that contagion during the subprime crisis was spread through a liquidity channel.[3]

Most regulators responded to the crisis of 2008 by restricting short sales on assets that were considered the cause of sudden price crashes. A similar mentality was adopted by European regulators when dealing with the European sovereign debt crisis between 2011 and 2012. Brunnermeier and Oehmke (2014) argue that a ban can prevent a stock price decline that may force a bank to sell-off assets (typically at fire sale prices), to prevent them from hitting a leverage ratio constraint. However, Beber et al (2017) find that such short selling bans, on the contrary, increase the default probability of vulnerable financial institutions and can further destabilize the market. Notably, they argue that the market may interpret the inception of the ban as an indicator that bank fundamentals are weaker than previously thought. Combined with lower levels of liquidity in the market, this may drive down bank

[3] The impact of short-selling ban on market liquidity and volatility is also considered by, for example, Battalio and Schultz (2011), Battalio et al. (2011), Beber and Pagano (2013), Boehemer et al (2013), Crane et al. (2016) and Marsh and Payne (2012).

share prices anyway. Related, in terms of the negative aspects of the ban, Fang et al (2015) argue that managerial behaviour is worse during the ban period.

Liu (2015) show that prevention of short sales could stop price falls. This is because the strategic short sellers tend to deteriorate the funding conditions and set back the restoration of an orderly market where investors would be confident to trade and raise new funds. Through prohibition of short sales, the fundamental values of stocks would gradually stabilize through a price discovery process (similar to Miller, 1977; Diamond and Verrecchia, 1987; Bai et al., 2006; Hong and Stein, 2003).

In summary, the existing literature supports the contention that changes to the flow of information and its transmission across markets can be impacted by shocks arising from extreme market events. In this paper, we attempt to identify changes to information transmission resulting from the shock that began with the demise of Lehman Brothers in 2008. Of particular note, we wish to see whether the market turbulence induced portfolio re-balancing by market participants such that investors take more notice of information emanating from risky markets.

3. Hypotheses and Empirical Methodology.

Hypothesis Formation

The key aim of this paper is to consider the effect of the market turmoil that began with the collapse of Lehman's, the introduction of the short selling ban and other news revealed to the market impacted the transmission of information between European markets. We split the markets into two categories, namely high risk ('risky) and low risk ('safe') country groups based around the core and periphery markets. We also include the a proxy for the world portfolio. It is our contention that the events that began with Lehman's, upset the usual information transmission between markets, notably increasing the amount of idiosyncratic risk within the system. In particular, prior to the events beginning with Lehman, we would argue that these three groups of markets would be affected by similar shocks and thus, may exhibit a long-run relation between each other. That is, global shocks would dominate local shocks in determining the movement of prices. However, after the start of the crisis, idiosyncratic shocks would have a relatively greater effect on price movements such that high and low risk stocks would move apart. With respect to spillovers in both mean and variance, we would anticipate that prior to the crisis spillovers would largely emanate from low risk towards high risk markets as these would contain global effects; however, after the crisis, shocks to high risk markets would now spillover to other markets due to the potential for greater instability.

Therefore, we postulate three hypotheses concerning the information transition mechanism between high and low risk European markets. First, we hypothesise that any long-run cointegrating relation between high and low risk markets broke down following the events of September 2008. While our second and third hypotheses consider the direction of causality between these markets. In particular, hypothesis two concerns causality in mean, while hypothesis three concerns causality in variance. Specifically, we argue that the direction of causality in stock market returns and volatility will be reversed from low-risk to high-risk markets pre September 2008 to high-risk to low-risk after, as information emanating from high-risk markets becomes more important, whereas in more tranquil times information from the larger markets dominates.

In order to consider these hypotheses, as noted in Table 1, we estimate a VECM with MV-GARCH disturbances to the evolution of dividend-adjusted log-equity indices for the high and low risk countries (see the data section for the specification of risk groups) as well as the MSCI Global index. This is undertaken with three aims: first, to examine the nature of any cointegrating relation between the series; second, to examine return spillovers (Granger causality) in the VAR component to study the direction of short-run information flows; third, we wish to examine the nature of volatility spillovers between the three markets and to consider any changes to those spillovers over time. As noted above, we expect changes in the nature of these relations across the country groups (see Table 2) following the bankruptcy of Lehman, the onset of the short selling ban and other information that emerged at this time.

The model estimation is conducted on both the full sample, over the period from 2003 to 2013, and on two sub-samples. The choice of sub-sample date is somewhat arbitrary, we choose a date according to the onset of the short-sell ban, but results are robust to alternative dates (e.g., Lehman's bankruptcy), we also implement a test that endogenously determines the breakpoint. Thus, the date used in our analysis below is 19/09/2008.[4]

[INSERT TABLE 1 HERE]

Empirical Methodology

Our empirical approach is categorized in two parts to test the three hypotheses. First, the VECM analysis on the multivariate price series is used to examine the cointegrating relation among the country portfolios. Here, we use the Johansen trace and maximum eigenvalue tests to ensure robust test results. This approach is widely adopted in the literature, e.g., Zhang et al. (2006) and Brooks and Ragunathan (2003). To consider the impact of a break on the cointegrating relations, we implement the test of Gregory and Hansen (1996) and examine the possibility of breaks in the level, trend and slope of the cointegrating vector.[5]

Defining a time series vector, y_t, the standard Vector Autoregressive Regression (VAR) model is given as follows:

[4] We believe , provides a natural extension of the literature in applying either long or short run modelling to look for evidence of structural dynamics in a market (for example, Brooks and Ragunathan, 2003; Buckland et. al, 2011).

[5] As alternative approaches for dealing with structure change in the relations we could consider the tests of Bai and Perron (1998, 2003) or apply a Chow type test. However, given the events of September 2008, it is unlikely that the data would satisfy the necessary distributional assumptions necessary for these tests. A time-varying VECM could also be considered, such as the one proposed by Bierens and Martins (2010). However, this type of modelling usually requires full stochasticity in the price time series (or the cointegrating vectors) with smooth changes in order to get robust results. Again, this is not consistent with the distortions arising from the extreme events over this time period.

$$y_t = \sum_{i=1}^{p} \Pi_i L^i y_t + \mu + u_t \ , \tag{1}$$

where L is the backward shift operator, and therefore $L^i y_t = y_{t-i}$. Π_i is the autoregression coefficient matrix, μ is constant vector and u_t a vector of residuals. When considering an error correction framework, the equivalent representation is given by:

$$\Delta y_t = \Phi y_{t-1} + \sum_{i=1}^{p-1} \Psi_i L^i \Delta y_t + \mu + u_t \tag{2}$$

Where:

$$\Phi = \sum_{i=1}^{p} \Pi_i - I \text{ and } \Psi_i = -\sum_{j=i+1}^{p} \Pi_j \tag{3}$$

Following Johansen (1988, 1991, 1994) and Johansen and Juselius (1990), we use a FIML (Full-Information Maximum Likelihood) test to identify cointegrating vectors. It tests for cointegration by examining the rank of the matrix Φ.

Where the rank of Φ is zero then we have no long-run cointegrating relation, where the rank is full then the vector y_t only contains stationary variables. The interesting case is where the rank is greater than zero and less than full, which indicates the number of cointegrating vectors. That is, in a VAR where the number of series is given by *n* and *k* is the number of cointegrating vectors, where the rank of the matrix Φ is k such that $0 < k < n$, then cointegration exists with *n-k* the number of stochastic trends. Let $\hat{\lambda}_1 > \hat{\lambda}_2 > \hat{\lambda}_3 > \cdots > \hat{\lambda}_n$ be the eigenvalues of the estimated matrix $\hat{\Phi}$. The trace test of the null hypothesis that there are at most h cointegrating relations, i.e. $H_0 : k \le h$, against the alternative hypothesis $H_1 : k > h$ is based on the statistic

$$\Lambda^{trace} = -T \sum_{i=h+1}^{n} \log(1 - \hat{\lambda}_i) \tag{4}$$

A test of the null hypothesis $H_0 : k = h$ against the alternative $H_1 : k = h + 1$ is based on the statistic

$$\Lambda^{\max} = -T \log(1 - \hat{\lambda}_{h+1}) \tag{5}$$[6]

To examine the return and volatility spillovers, we utilise the stationary component $\Delta \mathbf{y_t}$ of the VECM to estimate the VAR-MV-GARCH model.[7] Notably, the VAR elements can be used to examine Granger-causality in mean effects. Further, we compute the time-varying beta/factor loading for a multi-factor CAPM, using the VECH specification of Bollerslev et al. (1988), which is jointly estimated with the mean model under maximum likelihood estimation (MLE):

$$\Delta \mathbf{y}_t = \sum_{i=1}^{r} \Pi_i L^i \Delta \mathbf{y}_t + \mathbf{c} + \Sigma_t \boldsymbol{\omega} + \Sigma_t^{\frac{1}{2}} \varepsilon_t \tag{6}$$

$$vech\left(\Sigma_t\right) = \mathbf{k} + \sum_{i=1}^{p} \Lambda_i vech\left(\Sigma_{t-i}^{\frac{1}{2}} \varepsilon_{t-i} \left(\Sigma_{t-i}^{\frac{1}{2}} \varepsilon_{t-i} \right)' \right) + \sum_{j=1}^{q} \Gamma_j vech\left(\Sigma_{t-j}\right) \tag{7}$$

In the above equations ε_t is an white noise innovation vector, so that the residuals $\Sigma_t^{\frac{1}{2}} \varepsilon_t$, have dispersion matrix Σ_t and ω is a constant vector of premium loadings. The term $vech\left(.\right)$ denotes the column-stacking operator of the lower triangular portion of a symmetric matrix. The terms $\mathbf{k}, \Lambda, \Gamma$ are constant arrays of respective dimension

[6] Buckland, Chen and Williams (2012) proposed a bootstrap approach to enhance the robustness of these two tests. The method is to collect the eigenvalues $\Lambda^{trace}, \Lambda^{\max}$ and resample them with two residual series collected from the polynomial projection process described in formula (2). Then, they re-compute the canonical correlation series and their distributions following Johansen and Juselius (1990) and MacKinnon et al. (1999). Finally, they compare the two sets of critical statistics to decide whether the results of cointegration tests are robust or not.

[7] An open question concerns the choice of multi-variate GARCH model. Notably, common alternatives to the VECH model here include the BEKK (Engle and Kroner, 1995) and (A)DCC (Engle, 2002; Cappiello et al, 2006) approaches. Each approach has its own merits and demerits based on parameterisation, computational feasibility and efficiency; see, the useful discussion in Tsay (2014). For example, the BEKK approach can suffer from over-parameterisation, while the DCC may be viewed as too simplistic. We chose the VECH model as providing the best balance between these (de)merits.

$\frac{1}{2}n\left(n+1\right)´\ 1,\frac{1}{2}n\left(n+1\right)´\ \frac{1}{2}n\left(n+1\right),\frac{1}{2}n\left(n+1\right)´\ \frac{1}{2}n\left(n+1\right)$. The likelihood function can be written as:

$$\begin{aligned}\mathcal{L}\left(\theta\right) &= -\frac{nT}{2}\log 2\pi - \frac{1}{2}\sum_{t=1}^{T}\log\left|\Sigma_t\right| \\ &\quad -\frac{1}{2}\sum_{t=1}^{T}\left(\Delta\mathbf{y}_t - \sum_{i=1}^{r}\Pi_i L^i \Delta\mathbf{y}_t - \mathbf{c} - \Sigma_t \mathbf{w}\right)' \Sigma_t^{-1}\left(\Delta\mathbf{y}_t - \sum_{i=1}^{r}\Pi_i L^i \Delta\mathbf{y}_t - \mathbf{c} - \Sigma_t \mathbf{w}\right)\end{aligned} \tag{8}$$

where the values of the parameter vector are collected as:

$$q = \left[\mathrm{P}_1,\ldots,\mathrm{P}_r,\mathbf{c},\mathbf{w},\mathbf{k},\mathrm{L}_1,\ldots,\mathrm{L}_p,\mathrm{G}_1,\ldots,\mathrm{G}_q \right] \tag{9}$$

For a given value of q the series $\left\{ \mathrm{S}_t \right\}_{t=1}^{T}$ can be calculated recursively from equations (6) and (7) and the likelihood computed from equation (8). Then a search method can be used to obtain the maximal values of the parameter vector $\hat{q}$ and the associated estimated covariance matrices $\left\{ \hat{\mathrm{S}}_t \right\}_{t=1}^{T}$.

The volatility transmission of shocks from the j^{th} variable to i^{th} variable is the time-varying quantity derived from the estimated residual covariance matrix $\hat{\mathrm{S}}_t$, which uses Bollerslev et al. (1988) to compute the time-varying beta B_t loading of an I-CAPM model in equation (10):

$$b_{ij,t} = \hat{s}_{ij,t} / \hat{s}_{jj,t} \tag{10}$$

4. Data.

In order to investigate the effect of the Lehman's collapse and subsequent effects on information transmission across European stock markets, we construct two portfolios, which can be regarded as a safe and risky portfolio. The UK, France and Germany are selected as the (relatively) low-risk ('safe') group of countries within Europe as they are the dominant markets in Europe (in terms of market capitalization, see Table 2) and maintained relative financial stability during the 2008/09 period (seen in their lower standard deviations of national stock market indices reported in Table 3). In contrast, Spain, Greece, Ireland and Italy (the ‘risky’ group) were repeatedly reported in the news media as having financial difficulties during the crisis period and higher volatility in their respective stock market indices as evidenced by the higher standard deviations. Other European countries such as, Switzerland, Netherland, Belgium, Norway, Denmark, Austria, Portugal, Luxemburg and Iceland either have small stock markets or remained relatively stable during the crisis period and thus are not included. Our focus here is to test the interactions between countries struggling with financial distress and those with (relatively) less financial difficulties.

[INSERT TABLE 2 HERE]

For the selected countries, we use the total market index (coded as ‘TOTMxxx’ and in US dollars)[8] for each country to ensure consistency. These indices are at daily level and are converted into total return market indices. Alongside the price, the daily market capitalizations of the selected countries are also collected over the sample period 01/01/2003 to 29/03/2013.[9] This sample period also allows for an approximately equal sub-sample around the date of 19/09/2008 as discussed above.

After deciding on the country selections, we use the total market price indices for individual countries to construct the country group indices. For simplicity, we calculate the average market capitalization-weighted price and return indices to build the high- $\left(j=1\right)$ and low-risk $\left(j=2\right)$ country indices. The MSCI Global Index (labelled MSWRLD) is used as an external benchmark index. The price indices are calculated as:

[8] France does not have a direct dollar index but the data extracted are in US$.
[9] In order to consistently reflect the size of the equity of the market, we use total market US$ indices (coded as ‘TOTMXXX’) to ensure consistency in the construction of the country group indices instead of some well-known representative indices such as FTSE100, CAC40, DAX30 and so on.

$$PI_{high,t} = \sum_{i=1}^{4} \frac{y_{i,t} \times mv_{i,t}}{\sum_{i=1}^{4} mv_{i,t}}$$

$$PI_{low,t} = \sum_{i=1}^{3} \frac{y_{i,t} \times mv_{i,t}}{\sum_{i=1}^{3} mv_{i,t}}$$

$$RI_{j,t} = \Delta \log\left(PI_{j,t}\right) \; j \in \left(1,2\right)$$

Descriptive statistics are reported in Table 3.

[INSERT TABLE 3 HERE]

5. Empirical Analysis.

5.1 Cointegration tests

The results of the Johansen cointegration tests for the high and low-risk European groups with the world portfolio are reported in Table 5.[10] These results reveal some interesting differences between the two sub-sample periods, while overall they suggest a lack of cointegration between the three portfolios. Examining the results in greater details, we can see that in the first sub-sample, which runs from January 2003 to September 2008, there is evidence of cointegration, with one and possibly two cointegrating vectors.[11] The existence of a cointegrating long-run relation in this period confirms our view that these markets respond to global shocks and thus follow the same stochastic trend. Over this period of time, which includes the early stages of the financial crisis, this result suggests that common (world) shocks prevailed in moving markets, hence, evidence of co-movement. For the second sub-period there is no evidence of cointegration and hence, in comparison to the first sub period, the disappearance of the common trend. This is consistent with our view that the onset of the

[10] Unit Root and optimal lag structure tests are done prior to the cointegration tests (see Tables 4 and 5).
[11] See Table 6. The Johansen trace test suggests one cointegrating vector and the maximum eigenvalue test indicates no more than two long run co-movements.

crisis caused markets to move in different directions as idiosyncratic shocks became more important in moving markets. In particular, where markets are characterised by different levels of risk, then the effect of such shocks will lead to divergence. For the full sample, unsurprisingly given the sub-sample results, there is no evidence of cointegration. That is, where we have non-stationary behaviour in one sub-sample, this will cause the full sample to also exhibit non-stationary behaviour.[12]

[INSERT TABLES 4 AND 5 HERE]

[INSERT TABLE 6 HERE]

[INSERT FIGURE 1 HERE]

5.2 Granger causality test

The results of the Granger causality test, for each of the three portfolios are presented in Table 7. Again, these results reveal an interesting pattern across the two sub-samples. Taking the first sub-sample, which is prior to the fall of Lehman's, the short selling ban and related events, we can see that the high-risk group of markets do not Granger cause movement in the low-risk group of markets or the global market. However, in the post-Lehman period there is Granger causality running from the high-risk group to both the low-risk group and world markets. In contrast, there is causality running from the low-risk group and the world market to the high-risk group in both sub-periods. Moreover, we identify bi-directional causality between the low-risk group and the world market in both periods but only uni-directional

[12] We implement the test of Gregory and Hansen (1996) and consider the possibility of breaks in the level, trend and slope of the cointegrating vector. The test effectively utilises the ADF approach and considers in a recursive manner potential break dates and reports the minimum ADF statistic. The test statistics (5% critical values) for a break in the level, level and trend, level and slope and level, trend and slope respectively are: -3.74 (-4.92), -4.52 (-5.29), -5.01 (-5.50) and -6.23 (-5.96). As such these tests do not support cointegration unless we assume a full regime break between the two sub-samples. This is implicitly what we assume by separating the sample as discussed above. Furthermore, the break date determined in the test (21/10/08) is similar to that imposed in the sub-samples. Therefore, given that the Johansen procedure is preferred when we have more than two variables and the Gregory-Hansen test employs the ADF procedure, we proceed on the belief of no cointegration.

causality between the global and high-risk portfolios as well as the low- and high-risk groups in some of the periods.

As with the cointegration results, these results suggest that, in the context of the crisis, both the dynamics and directions of the flow of information between markets has changed. A possible explanation for this is that following the start of the crisis, investors have sought to reduce the risk of their portfolios, in particular by selling any assets associated with these high risk markets. More generally, investors would become more sensitive to price movements in these markets. So, information from high-risk markets becomes important in driving price changes in both low-risk markets and the rest of the world. This again highlights the role of idiosyncratic information perhaps becoming more important in the crisis period. Prior to the crisis, when global information dominates we see Granger causality running from the world portfolio and low risk markets to high risk markets. However, during the crisis, information from high risk markets spills over to other markets.

[INSERT TABLE 7 HERE]

5.3 VAR-MV-GARCH

In order to examine the effect of the ban period on volatility transmission between markets, Figure 1 presents the charts that document the spillover effects between each of the three markets. To coincide with these important market events, we mark the time when they occurred in red. Evident from these charts is the presence of several large spikes in the volatility process of the high-risk portfolio. In particular, just prior to the fall of Lehman and the start of the short-sale ban period we can see spikes in the volatility factor of the high-risk group emanating from the low-risk portfolio and the world market ($\beta_{high, low}$ and $\beta_{high, mswrld}$). Following a fall in volatility as the short-sale ban began, we see volatility further increase, instead of decrease, with several (smaller) spikes resulting from the onset of the Eurozone sovereign debt crisis. When examining the volatility factor for the low-risk group of markets we do not observe the same spikes in volatility. Indeed for the low-risk portfolio as affected by the high-risk portfolio. Of interest, we see volatility falling just prior to the short-sale ban but increasing after the ban starts. Furthermore, we observe higher volatility towards the end of the sample, during 2011 and 2012 as the Eurozone sovereign debt crisis worsens. Regarding the low-risk groups volatility as affected by the world market we observe falling volatility after the Lehman's event but then higher volatility during the period characterised by the later Eurozone debt crisis. Finally, the volatility process of the world market appears to fluctuate around a relatively constant level throughout the sample period with a small number of heightened volatility spikes following the collapse of Lehman and during the Eurozone crisis.

Overall, our results suggest that the time-varying loading of the high-risk portfolio is both more volatile and at a higher average level compared to the low-risk country portfolio. Furthermore, evident from the charts, volatility transmission is predominantly from the world market to the European markets and from the low-risk portfolio to the high-risk group. However, in terms of how the short-sale ban and the crisis affected the volatility transmission between these three markets, we can see that the effect was to lower volatility for the high-risk group, although that later increased again due to sovereign debt crisis. Furthermore, volatility in the low-risk and world markets generally increases following the Lehman's collapse and related events shortly afterwards (e.g., the short sale ban), and particularly so as shocks emanate from the high-risk market; although was notably lower just prior to the ban period (this is most evident from the graphs labelled $\beta_{low,\ high}$, $\beta_{mswrld,\ high}$ and $\beta_{mswrld,\ low}$). These results may suggest the introduction of the ban reduced spillover effects towards the high-risk market but increased them in the low-risk and world markets and thus reversed the usual volatility transmission mechanism. However, that reversal quickly ended as the

Eurozone debt crisis took prominence. Again, such results clearly indicate that following the onset of the crisis, information from high-risk markets affected low risk markets in a way that did not occur prior to the crisis period.

6. Conclusion.

This paper examines the impact of the wave of news that began with the collapse of Lehman's on the information transition mechanism between European stock markets. We group key European stock markets into high- and low- risk market portfolios and find that the cointegrating relation between these groups that existed before the demise of Lehman Brothers disappeared following that event. The imposition of short selling restrictions that followed does not appear to re-establish this long run relation. We also find, using Granger causality, that stock return information transmission prior to September 2008 was from low-risk to high-risk stock markets. After this date the causality becomes bi-directional suggesting that investors in low-risk stock markets now take greater notice of information emanating from high-risk markets due to their instability. Evidence also supports the view that volatility spillover emanate from high-risk to low-risk stocks after this date, reversing the pattern that existent prior to it.

In sum, our results show that following the onset of the crisis the long-run relation between markets broke down. Equally, the short-run information transmission through both the mean and variance showed a change in behaviour with high-risk markets influencing low-risk markets, in contrast to the reverse pattern that existed prior to the crisis. It is hoped that the results presented here will be useful to both policy makers and academics in understanding the interaction between markets.

Bibliography

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

Allen, F. and D. Gale (1991). Arbitrage, Short-Sales, and Financial Innovation. *Econometrica*, 59 (4), pp 1041-1068.

Allen, F. and Gale, D. (2000). *Financial contagion. Journal of Political Economy*, 108, pp 1-33

Autore, D., Billingsley, R. and T. Kovacs (2011). The 2008 short sale ban: Liquidity, dispersion of opinion, and the cross-section of returns of US financial stocks. *Journal of Banking and Finance*, 35(9), pp 2252 – 2266

Bai, Y, Chang, E. C. and J. Wang (2006). Asset Prices under Short-Sale Constraints. University of Hong Kong working paper.

Bai, J. and P. Perron (1998). Estimating and testing linear models with multiple structural changes. *Econometrica*, 66 (1), pp 47–78.

Bai, J. and P. Perron (2003). Computation and analysis of multiple structural change models. *Journal of Applied Econometrics*, 18 (1), pp 1–22.

Battalio, R., Mehran, H. and P. Schultz (2011). Market Declines: Is Banning Short Selling the Solution? Federal Reserve Bank of New York Staff Reports, no. 518.

Baur, D. and Jung, R. (2006). Return and volatility linkages between the US and the German stock market. *Journal of International Money and Finance*, 25, pp 598-613

Beber, A. and M. Pagano (2013). Short-Selling Bans around the World: Evidence from the 2007-09 Crisis. *The Journal of Finance*, 68 (1), pp 343-381.

Beber, Fabbri, Pagano and Simonelli (2017). Short-Selling Bans and Bank Stability. Center for Studies in Economics and Finance working paper, No. 423.

Bierens, H.J. and L. F. Martins (2010). Time Varying Cointegration. *Econometric Theory*, 26 (05), pp1453–1490.

Boehmer, E. and J. Wu (2013). Short Selling and the Information Efficiency of Prices. *Review of Financial Studies*, 26 (2), pp 287-322.

Boehmer, E., Jones C. M., and X. Zhang (2013). Shackling short sellers: The 2008 Shorting Ban. *Review of Financial Studies*, 26 (6), pp 1363-1400.

Bollerslev, T., Engle, R. F. and J. M. Wooldridge (1988). A Capital Asset Pricing Model with Time-Varying Covariances. *Journal of Political Economy*, 96 (1), pp116-131.

Bris, A., Goetzmann, W. N. and N. Zhu (2007). Efficiency and the Bear: Short Sales and Markets around the World. *The Journal of Finance*, 62 (3), pp 1029-1079.

Brooks, R. and V. Ragunathan (2003). Returns and volatility on the Chinese stock markets. *Applied Financial Economics*, 13 (10), pp 747–752.

Brunnermeier, M., Pedersen, L., (2009). Market liquidity and funding liquidity. *Review of Financial Studies,* 22, pp 2201–2238.

Buckland, R., Chen, J. & J. Williams (2011). Regulatory changes, market integration and spill over effects in the Chinese, A, B and Hong Kong equity markets. *Pacific-Basin Journal of Finance*, 19(4), pp 351-373.

Chang, E. C., Cheng, J. and Y. Yu. (2007). Short-Sales Constraints and Price Discovery: Evidence from the Hong Kong Market. *The Journal of Finance*, 62 (5), pp 2097-2121.

Chow, Gregory C. (1960). Tests of Equality between Sets of Coefficients in Two Linear Regressions. *Econometrica*, 28 (3), pp 591–605.

Diamond, D. W. and R. E. Verrecchia (1987). Constraints on Short-selling and Asset Price Adjustment to Private Information. *Journal of Financial Economics,* 18, pp 277-311.

Diether, K., Lee, K. & I. Werner (2009). It's SHO Time! Short-Sale Price-Tests and Market Quality. *The Journal of Finance*, 64, pp 37-73.

Figlewski, S. (1981). The Informational Effects of Restrictions on Short Sales: Some Empirical Evidence. *Journal of Financial and Quantitative Analysis,* 16, pp 463-476.

Figlewski, S. and Webb, G. (1993). Options, Short Sales and Market Completeness. *The Journal of Financ*e, 48 (2), pp 761-777.

Fung, H-G and Lee, H. (1997) International interest rate transmission and volatility spillover. *International Review of Economics & Finance,* 6, pp 67-75

Gregory A. W. and B. E. Hansen (1996). Residual-Based Tests for Cointegration in Models with Regime Shifts. *Journal of Econometrics*, 70, pp 99-126.

Harrison, J. M. and D. M. Kreps (1978), Speculative Investor Behavior in a Stock Market with Heterogeneous Expectations. *Quarterly Journal of Economics*, 92, pp 323-336.

Hendershott, T., Namvar E., and Phillips, B. *(2013)*. The Intended and Collateral Effects of Short-sale Bans as a Regulatory Tool. *Journal of Investment Management*, Vol. 11, No. 3, (2013), pp. 5–13

Hong, H. and Stein, J. C. (2003). Differences of Opinion, Short-Sale Constraints, and Market Crashes. *Review of Financial Studies*, 16, pp 487–525.

Jarrow, R. A. (1980). Heterogeneous Expectations, Restrictions on Short Sales, and Equilibrium Asset Prices. *The Journal of Finance,* 35 (5), pp1105-1113.

Johansen, S. (1988). Statistical Analysis of Cointegration Vectors. *Journal of Economic Dynamics and Control*, 12, pp 231–254.

Johansen, S. (1991). Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models. *Econometrica*, 59, pp 1551–1580.

Johansen, S. (1994). The Role of the Constant and Linear Terms in Cointegration Analysis of Non-stationary Variables. *Econometric Reviews*, 13 (2), pp 205–230.

Johansen, S., Juselius, K. (1990). Maximum Likelihood Estimation and Inference on Cointegration with Applications to the Demand for Money. *Oxford Bulletin of Economics and Statistics,* 52, pp 169–210.

Kaminsky, G., Reinhardt, C. and Vegh, C. (2003). The unholy trinity of financial contagion. *Journal of Financial Perspectives*, 17, pp 51-74

King, M. and Wadhwani, S. (1990). Transmission of volatility between stock markets. *Review of Financial Markets*, 3, 5-33

Kiyotaki, N. and Moore, J. (2002). Evil is the root of all money. *American Economic Review: Papers and Proceedings*, 92, pp 62-66.

Koutmos, G. and G. Booth, (1995). Asymmetric Volatility Transmission in International Stock Markets. *Journal of International Money and Finance,* 14, pp 747-762.

Liu, Xuewen (2014), "Short-Selling Attacks and Creditor Runs," Hong Kong University of Science and Technology Working Paper, forthcoming in *Management Science*.

Lobanova, O., Hamid, S. and A. Prakash (2010). The Impact of Short-Sale Restrictions on Volatility, Liquidity and Market Efficiency: The Evidence from the Short-Sale Ban in the U.S. Florida University Working Paper.

Longstaff, F., (2008). Flight-from-leverage in distressed asset markets. Unpublished working paper, UCLA.

Longstaff, F., (2010). The subprime credit crisis and contagion in financial market. *Journal of Financial Economics*, 97, pp 436-50

MacKinnon, J. G., Haug, A. A. and L. Michelis (1999). Numerical distribution functions of likelihood ratio tests for cointegration. *Journal of Applied Econometrics,* 14 (5), pp 563 - 577.

Miller, E. M. (1977). Risk, Uncertainty, and Divergence of Opinion. *The Journal of Finance,* 32, pp 1151-1168.

Ofek, E., Richardson, M. and Whitelaw, R. F. (2003). Limited Arbitrage and Short Sales Restrictions: Evidence from the Options Market. *NBER working paper*, no. 9423.

Scheinkman, J. and W. Xiong (2003). Overconfidence and Speculative Bubbles. *Journal of Political Economy*, 111, pp 1183-1219.

Senchack, A. J. and L. Starks (1993). Short Sale Restrictions and Market Reactions to Short-Interest Announcements. *Journal of Financial and Quantitative Analysis,* 28, pp177-194.

Tse, Y., Lee, T-H. and Booth G. (1996). The international transmission of information in Eurodollar futures markets: A continuously trading market hypothesis. *Journal of International Money and Finance,* 15, pp 447-465

Tse, Y. (1998). International transmission of information: evidence from the Euroyen and Eurodollar futures markets. *Journal of International Money and Finance*, 17, pp 909-929

Vayanos, D., (2004). Flight to quality, flight to liquidity, and the pricing of risk. Unpublished working paper, London School of Economics.

Wang, J. (1993). A model of Intertemporal Asset Prices under Asymmetric Information. *Review of Economic Studies*, 60, pp 249-282.

Wang, J. (1994). A model of competitive stock trading volume. *Journal of Political Economy*, 102, pp127-168.

Woolridge, J. and A. Dickinson (1994). Short Selling and Common Stock Prices. *Financial Analysts Journal*, 50 (1), pp 20-28.

Zhang, D., Dickinson, D.G., Barassi, M. (2006). Structural breaks, cointegration and B share discount in Chinese stock market. Conference paper in Ecomod.net International conference of Policy modelling, Hong Kong, 2006.

Tables and Figures

Table 1: Model specifications and information.

This table summarises the specifications of the multi-variate empirical models we used in this study: VECM, Granger Causality and VAR-MV-GARCH. The first two models are operated on the non-stationary price series and the last one on the stationary return series of the country groups established, namely: high risk, low risk and global index portfolios.

Model Name	Endogenous	Exogenous
VECM	$y_t = \left[\log PIHIGH,\ \log PILOW,\ \log MSWORLD \right]$	c
Causality	$y_t = \left[\log PIHIGH,\ \log PILOW,\ \log MSWORLD \right]$	c
VAR-MV-GARCH	$y_t = \left[\mathrm{D}\log PIHIGH,\ \mathrm{D}\log PILOW,\ \mathrm{D}\log MSWORLD \right]$	c

Table 2: Country Selection.

Panel (a): Average Market Value of markets and rankings. This table reports the market capitalisation of the country equity market index of all European countries, which applied the short selling ban during the 2008 crisis period. For each country, the market capitalisation has been collected across two years (the year of 2008 and 2009) and averaged (see column 2). The ranking based on these represents the size of the equity market in a specific country and its relative financial position in the European market.

Country	**Avg. (2008-2009)**	**Rank**	**Country**	**Avg. (2008-2009)**	**Rank.**
UK	672,063,162.0	1	**Norway**	56,422,533.5	9
France	459,635,772.5	2	**Denmark**	45,287,957.0	10
Germany	348,779,933.0	3	**Austria**	33,724,273.5	11
Switzerland	256,192,126.0	4	**Greece**	33,219,194.5	12
Italy	181,426,731.5	5	**Portugal**	23,256,557.0	13
Spain	168,189,878.5	6	**Ireland**	20,176,104.0	14
Netherland	121,605,026.0	7	**Luxemburg**	6,997,378.0	15
Belgium	62,146,307.0	8	**Iceland**	2,788,826.5	16

Table 3: Country and Country Indices Descriptive Statistics.

Panel (a): Country Descriptive Statistics. This table provides descriptive statistics of each country component we have used to build the risk group indices. We can clearly see the high-risk portfolio component countries have higher standard deviations but relatively lower average return in comparison to the low risk portfolio component countries. High risk group countries tend to have positive skewness apart from Greece while low risk group countries exhibit negative skewness.

Country	**UK**	**France**	**Germany**	**Italy**	**Spain**	**Greece**	**Ireland**
DS Code	**RTOTMUK$**	**RTOTMKFR**	**RTOTMBD$**	**RTOTMIT$**	**RTOTXTES**	**RTOTMGR$**	**RTOTMIR$**
Mean	7.73	7.78	7.22	6.66	6.31	6.33	7.31
Median	7.74	7.77	7.24	6.61	6.28	6.38	7.18
Max	8.18	8.29	7.73	7.25	6.95	7.29	8.11
Min	7.1	7.06	6.35	6	5.6	4.79	6.43
Std. Dev.	0.22	0.25	0.27	0.31	0.32	0.61	0.41
Skewness	-0.31	-0.07	-0.5	0.2	0.2	-0.46	0.29
Kurtosis	2.84	2.79	3.19	1.97	2.42	2.41	1.8
Jarque-Bera	46.34	6.99	115.47	135.67	54.89	134.13	198.08
Prob.	0.00	0.03	0.00	0.00	0.00	0.00	0.00
Obs.	2673	2673	2673	2673	2673	2673	2673

Panel (b): Country indices Descriptive Statistics. This panel reports the same set of descriptive statistics for the country group indices. We find similar results that the high risk portfolio has higher standard deviation and positive skewness. However, the low risk portfolio has lower standard deviation and its skewness is negative which is similar to the world index.

	LOW	**HIGH**	**MSWRLD$**
Mean	7.74	7.18	7.08
Median	7.74	7.06	7.09
Maximum	8.21	7.95	7.43
Minimum	7.09	6.35	6.53
Std. Dev.	0.23	0.40	0.18
Skewness	-0.17	0.32	-0.50
Kurtosis	2.80	1.80	2.85
Jarque-Bera	18.03	207.37	115.96
Prob.	0.00	0.00	0.00
Observations	2673	2673	2673

Table 4: Unit Root Tests.

This table presents results of three unit root tests including ADF, PP and KPSS. These three tests are used to robustly test the stationarity/non-stationarity of the time series we constructed in order to fit multi-variate models. The results are consistent showing that low, high and MSWLDR price series are non-stationary throughout the sample period.

	ADF		**PP**		**KPSS**	
Low	-2.06 (0.26)	**I(1)**	-1.98 (0.29)	**I(1)**	0.95	**I(1)**
High	-1.10 (0.71)	**I(1)**	-1.08 (0.73)	**I(1)**	2.14	**I(1)**
MSWRLD	-1.99 (0.29)	**I(1)**	-1.96 (0.31)	**I(1)**	1.07	**I(1)**

Table 5: Optimal Lag Structure.

This table presents statistics of lag structure of the vector formed by the low, high and MSWRLD series. Both Akaike and Schwarz criteria are applied and the results are reported. The optimal lag revealed under the Akaike criteria is 3 but there is no clear indication of an optimal lag from the Schwarz criteria. We follow the optimal lag decided by the Akaike criteria.

	lag=2	**lag=3**	lag=4	lag=5	lag=6
Akaike	24.022	**24.013**	24.014	24.012	24.011
Schwarz	24.081	24.093	24.113	24.131	24.150

Table 6: Cointegration Tests

This table reports results on two different cointegration tests: Johansen trace and maximum eigenvalue tests. We test for pre and post ban periods and the entire sample period to see if there is any long run cointegrating relation among the low-risk, high-risk and world portfolios. The Johansen trace test suggests one cointegrating vector and the max-eigenvalue test indicates no more than two cointegrating vectors during the post-ban period.

		Critical Value			01/01/2003-29/03/2013	01/01/2003-19/09/2008	19/09/2008-29/03/2013
		1%	5%	10%			
Trace	0	35.46	27.80	27.07	19.75	40.02***	17.71
	1	19.94	15.49	13.43	5.49	16.07**	5.82
	2	6.63	3.84	2.71	2.42	2.04	1.12
Max Eigenvalue	0	25.86	21.13	18.89	14.27	24.51**	11.89
	1	18.52	14.26	12.3	3.07	14.00*	4.70
	2	6.63	3.84	2.71	2.42	2.75*	1.12

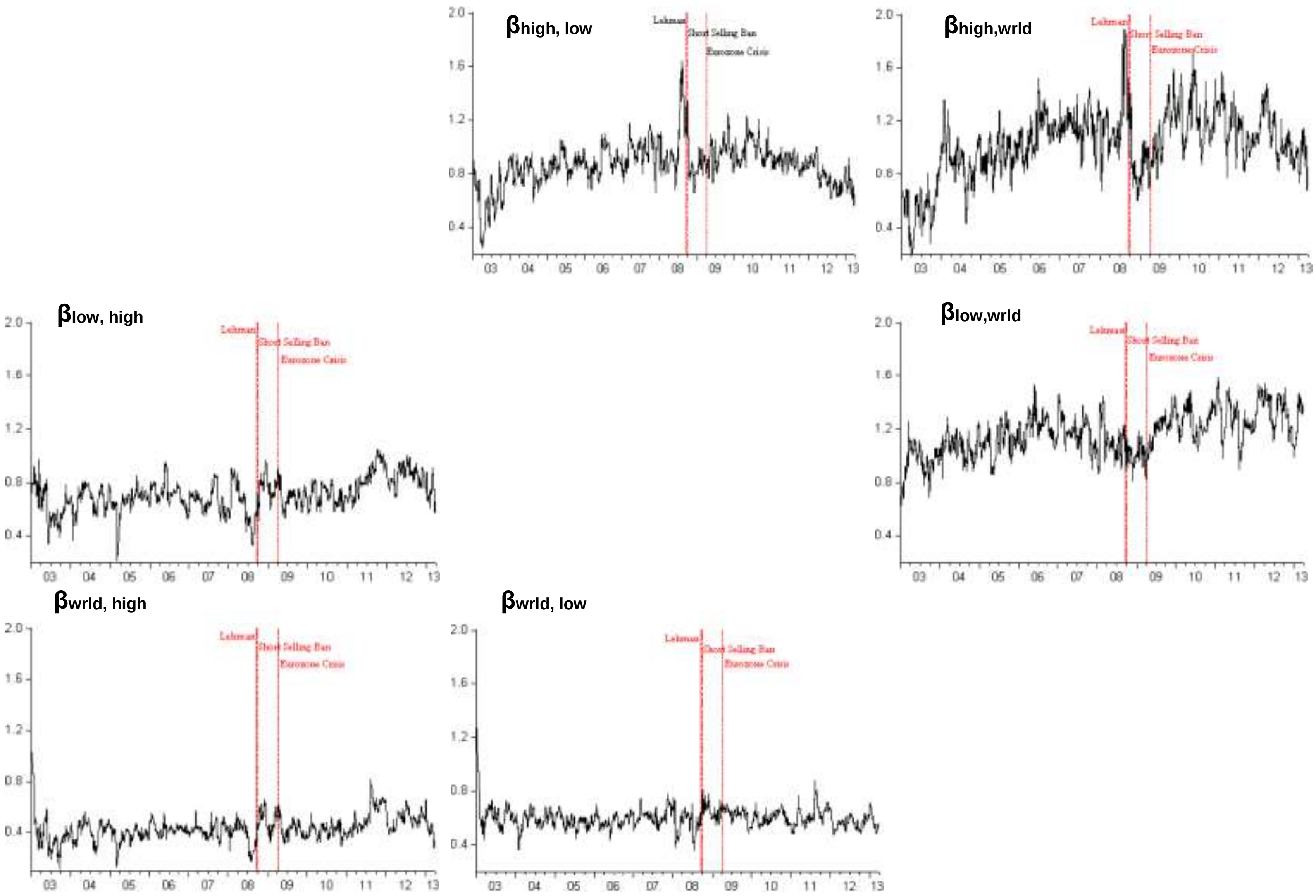
Table 7: Granger Causality Test

This table reports results from the Granger causality tests for the whole sample and two sub samples. The causation structure for each component in the vector and its dependence on other components both separately and collectively are reflected by the test statistics.

		01/01/2003-29/03/2013	01/01/2003-19/09/2008	19/09/2008-29/03/2013
PILOW	*PIHIGH*	13.36 (0.00)***	0.47 (0.92)	14.28 (0.00)***
	MSWRLD	339.85 (0.00)***	187.26 (0.00) ***	145.84 (0.00)***
	All	357.58 (0.00)***	188.12 (0.00)***	166.43 (0.00)***
PIHIGH	*PILOW*	131.64 (0.00)***	75.05 (0.00)***	54.15 (0.00)***
	MSWRLD	317.33 (0.00)***	171.28 (0.00)***	140.10 (0.00)***
	All	323.16 (0.00)***	175.33 (0.00)***	146.20 (0.00)***
MSWRLD	*PILOW*	23.18 (0.00)***	12.90 (0.00)***	13.42 (0.01)***
	PIHIGH	10.00 (0.02)***	1.07 (0.78)	11.92 (0.00)***
	All	33.38 (0.00)***	21.00 (0.00)***	20.99 (0.00)***

Figure 1: VAR-MV-GARCH

This figure shows the short run shock transmission reflected in the time varying factor loadings among the low, high risk and global market (segments). The dotted red lines indicate the events of the failure of Lehman's Brothers, the application of the short selling ban and the onset of the Eurozone sovereign debt crisis. In terms of the off-diagonal factor loadings, they are the beta of the portfolio relative to itself, which is literally one. In the diagram, it would be represented by a horizontal line, which we do not show.



βhigh, low
βhigh,wrld
βlow, high
βlow,wrld
βwrld, high
βwrld, low
Lehman
Short Selling Ban
Eurozone Crisis
2.0
1.6
1.2
0.8
0.4
03
04
05
06
07
08
09
10
11
12
13