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Spillovers in Risk of Financial Institutions*

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Abstract

We analyse the total and directional spillovers across a set of financial institution systemic risk state variables: credit risk, real estate market risk, interest rate risk, interbank liquidity risk and overall market risk. A multiple structural break estimation procedure is employed to detect sudden changes in the time varying spillover indices in response to major market events and policy events and policy interventions undertaken by the European Central Bank and the Bank of England. Our sample includes five European Union countries: core countries France and Germany, periphery countries Spain and Italy, and a reference country, the UK. We show that national stock markets and real estate markets have a leading role in shock transmission across selected state variables; whereas the role of the other variables reverses over the course of the crisis. Real estate market risk is also found to be mostly affected by country specific events. The shock transmission dynamics of interest rate risk and interbank liquidity risk differs for the UK and Eurozone countries; empirical results imply that interest rate changes lead changes in interbank liquidity.

Keywords: macro-financial state variables, financial crisis, spillover effects, credit default swaps, real estate risk. JEL Classification: G01, G15, G20

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1 Introduction

The recent global financial crisis has highlighted the importance of the financial sector to the functioning of the economy as a whole in most countries. Deficient financial regulation, together with a failure of market discipline, has been associated with significant harm to the economy. During the crisis policy actions undertaken by the European Central Bank and Bank of England were specifically designed to restore the stability of the financial sector. The crisis management approaches, such as sovereign bailouts, policy rate decreases and unconventional monetary policy measures, became the basis for a whole new strand of literature. It became apparent that pinpointing the exact drivers of financial systemic risk is an impossible task and that the dynamics driving the risk is of a highly complex nature (see Giglio et al. (2016), for an empirical evaluation of systemic risk measures). In this paper we analyse spillover dynamics within a set of commonly cited systemic state variables. The state variables included in the analysis are widely recognised as conditioning variables that can shift the conditional mean and the conditional volatility of various systemic risk measures. See for example, Adrian and Brunnermeier (2016) and Bessler and Kurmann (2014). The selected state variables include the change in the financial institution credit default swap (CDS) spread index, the real estate sector return, the change in the slope of the yield curve, the change in the short-term TED spread and the stock market return. All state variables are country specific and the spillover analysis is undertaken within five European Union countries: core countries France and Germany, periphery countries Spain and Italy, and a reference country the UK for the period January 2004 to December 2012 encompassing the financial crisis. Studying the spillovers between the systemic state variables brings us a step closer to understanding the complex interactions taking place in the macro-financial environment. We examine the response of the spillover level within a set of commonly cited systemic macro-financial state variables to a number of initiatives undertaken by the European Central Bank (ECB) and the Bank of England (BoE). Monetary authorities can use policy instruments at their disposal to influence some state variables directly, for example financial and macroprudential regulation for bank CDS spreads and return on the real estate market, policy rates for the slope of the yield curve, and unconventional monetary policy for the TED spread. The return on the market can be influenced indirectly through a monetary policy-stock market transmission channel (Chami et al. (1999) provide a comprehensive overview of the stock market channel of monetary policy). Our empirical findings show these state variables are multi-dimensional and exhibit high level of interaction. Thus, policymakers need to understand the complex dynamics behind many interdependent relationships in order to be able to formulate effective policies.

We adopt the econometric method proposed in Diebold and Yilmaz (2012) to measure dynamic total and directional spillovers within a set of systemic state variables. This is of particular interest since measuring and revealing spillover trends could help indicate early signs of distress in the macro-financial environment. The Diebold-Yilmaz method proves to be particularly useful when estimated on a moving window basis as it allows us to see how spillover trends vary over time.

In order to give structure to the analysis of net spillover indices and trace the effect of the policy interventions it is important to find significant turning points within the spillover series. Bai and Perron (1998, 2003) propose a procedure that allows estimating any linear regression model with an unknown number of structural breaks that occur at unspecified dates. Since this paper analyses five variables in five countries that are affected by both country specific and cross border events, the dynamics of spillovers can differ significantly for each country. Moreover, the policy interventions by the ECB and BoE are likely to affect the national state variables at different times and with differing intensity. The Bai-Perron method proves to be a flexible data-driven method for identifying multiple structural breaks in the series without imposing break dates or the number of breaks a priori.

The contribution of this paper to the existing literature is threefold. First, we investigate the relative importance of individual systemic state variables over time without imposing any particular structural model. By studying multidimensional spillover effects we avoid difficulties inherent in causal analysis, such as parameter identification issues and reverse causation. Dynamic spillover levels may constitute systemic risk warnings or may act as additional signals for regulators to review their policies. Second, we introduce a significant variable into the analysis that has not been widely studied in this context before, namely returns on the real estate market. Real estate and associated mortgage book performance is fundamntal to the business and well-being of financial institutions. So far, the link between the real estate market and systemic risk has only sparsely been considered. For example, Adrian and Brunnermeier (2016) include the return on the real estate market as a conditioning state variable when studying systemic risk in the US financial sector. Bessler and Kurmann (2014) include the return on the real estate market when analysing the risk factors of European and the US bank risk exposures. Third, the Bai and Perron (2003) procedure is applied to test for multiple structural breaks in net spillovers of the risk variables. This allows for a detection of the exact dates when relationships between the selected state variables changed. The setup applied highlights the importance of policy events that have occurred within the macro-financial environment of the European Union during the financial crisis. The multiple structural breaks test also draws attention to heterogeneity of the spillover dynamics across countries in the sample: the shock transmission channels differ significantly from country to country.

This paper is related to the research literature on measurement of systemic risk within the financial sector and the connectedness of financial institutions. For example Adrian and Brunnermeier (2016), Acharya et al. (2012), Brownlees and Engle (2017) and Diebold and Yilmaz (2014) propose alternative methods for capturing an individual financial institution's contribution or sensitivity to economy-wide systemic risk. Giglio et al. (2016) and Arsov et al. (2013) quantitatively examine a large collection of systemic risk measures proposed in the literature. The recent growth in the literature in these areas highlights the importance of understanding of complex interrelationships within both the financial sector and macro-financial environment.

A number of salient implications can be drawn from the empirical results reported in this study. Our results indicate that the systemic state variables are multidimensional, the relative importance of individual state variables is time-varying and exhibit strong country specific features. Overall, returns on the national stock market indices and the real estate indices appear to lead the shock transmission across the five state variables. This lends support to the view that the shocks to the equity market and the real estate sector have a strong influence on the stability of the macro-financial environment. The spillover dynamics of the real estate variable differs significantly within the countries in the sample. This indicates that real estate market risk is mostly affected by country specific events. We also document that the shocks to the slope of the yield curve appear to transmit to TED spreads rather than vice versa; this is suggestive that interest rate changes lead the changes in funding liquidity. As for the country specific dynamics, the most obvious outliers appear to be the UK and Spain; the variation from other countries is most pronounced when looking at the liquidity variable. The national stock markets are the most globalised across the variables in the sample as the net stock market spillovers are strongly co-moving for all countries.

The paper is organised as follows. Section two motivates the choice of the systematic risk variables and provides details on the data sources. Section three describes the methodological approach used for empirical analysis. Section four presents the empirical findings of the paper. Section five concludes.

2 Financial Institution Systemic Risk State Variables

The framework for measuring spillovers is applied to five commonly cited systematic macro-financial state variables: the change in the financial institution credit default swap (CDS) spread index, the real estate sector return, the change in the slope of the yield curve, the change in the short-term TED spread and the stock market return. All state variables are country specific and the data covers the five largest European economies: France, Germany, Italy, Spain and the UK. The data frequency of all series is daily and covers the period from 1st of January 2004 to 31st of December 2012, with a total of 2348 observations for each series.

The change in the national financial institution CDS spread index: Credit default swaps (CDS) can best be thought of as a simple insurance product, providing protection against corporate default. Periodic payments are exchanged against a lump sum payment contingent on default. Thus, it is widely accepted in the literature that CDS spreads reflect market perceptions about the stability of financial institutions and can be used as indicators of warning signals regarding financial stability (Bessler and Kurmann, 2014; Annaert et al., 2013). It is argued that due to financial institutions' risky lending activities the borrower's default risk is directly reflected in the institutions' credit risk that is captured by the CDS spread.

Data: CDS spreads of individual financial institutions are obtained from Datastream and a country specific index is calculated by taking an arithmetic mean of all CDS spreads relating to each country. Datastream provides Credit Market Analysis Ltd. (CMA) CDS data for the period January 2004 until September 2010. Starting from October 2010 until December 2012 Datastream provides CDS quotes obtained from Thomson Reuters. A total of 73 credit institutions are included in the sample for which CDS contracts trade. The selection of the financial institutions was made based on the data availability of CDS quotes in the Thomson Reuters Datastream database. The 5-year CDS contract quotes on senior debt were chosen as these are the most actively traded contracts on the market. First differences of the daily series are used in the empirical analysis.

The return on the real estate market index: The real estate sector is an important constituent of financial institution portfolios in countries with highly developed financial systems. Goodhart and Hofmann (2008) find that due to the banks' role as mortgage lenders and the frequent use of real estate as collateral, sustained imbalances in real estate markets can threaten the stability of the financial sector. An increase in real estate prices may raise the economic value of a financial institution's real estate portfolio, which in turn may increase the value of loans collateralised by real estate, decrease perceived risk of real estate lending and further increase the price of real estate. In contrast, a decline in the real estate prices can have a negative effect on financial institution's capital to the extent the latter own real estate. As a result, financial institutions are vulnerable to a decline in real estate prices and may face default if greatly exposed to real estate lending.

Herring and Wachter (1999) analyse how real estate cycles and banking crises are related and show that even in very different institutional settings real estate booms often end in banking busts. Koetter and Poghosyan (2010) find that house price deviations from their fundamental value contribute to financial institution instability. In terms of the macro-financial regulation, the recent crisis has shifted the policy consensus away from the "benign neglect"to careful consideration of the role of real estate booms in financial stability (Dell'Ariccia and Rabanal, 2011).

*Data:*The FTSE/European Public Real Estate Association (EPRA, for short) country specific price indices were obtained from Datastream. These are stock market index series jointly managed by FTSE and EPRA incorporate Real Estate Investment Trusts (REITs) and Real Estate Holding & Development companies.

The indices are designed to represent general trends in eligible real estate equities. FTSE defines relevant real estate activities as the ownership, sales and development of income-producing real estate. It has become general practice to use listed real estate as a proxy for direct real estate. The indices for direct real estate markets are compiled at a monthly frequency at best (most often quarterly) because they are based on the valuations of individual properties; whereas listed real estate is available daily (see Cotter and Roll (2014) for a comprehensive study of the properties of listed real estate returns). Concern that the performance of listed real estate is primarily driven by stock markets is valid, particularly in the short term. However, numerous authors show that the medium to long-term performance of listed real estate correlates significantly with the development of direct real estate markets (Hoesli and Oikarinen, 2012). For the purposes of the current analysis daily percent changes are computed.

The change in the slope of the yield curve: The slope of the yield curve, otherwise known as the interest rate term spread is extensively used as a predictor of real economic activity (Harvey, 1989; Adrian and Estrella, 2008). However, the effort to model the yield curve in the academic literature has been much more significant. The literature in this area can be usefully categorised by the extent and nature of the linkages permitted between financial and macroeconomic variables. Many yield curve models ignore macroeconomic linkages (for example, Duffie and Kan (1996), Dai and Singleton (2000)), but many explicitly incorporate macroeconomic factors (Ang and Piazzesi, 2003; Wu, 2002). Diebold et al. (2006) establish an important bidirectional link from the yield curve to the economy and back again. Using the US data they also find a close connection between the monetary policy instrument variable and the slope of the yield curve. Thus, the slope of the yield curve is an important variable when analysing the link between the monetary policy and systemic risk.

Data: The slope of the yield curve is computed as the difference between 10-year government bond yield and 3-month yield on the respective government bond. Country specific debt security yield series for both maturities are obtained from Datastream. First differences of the daily series are used in the analysis.

The change in the TED spread: We use the spread between the EURIBOR rate and respective government bond rate, as a state variable capturing the funding liquidity in the economy. A rising liquidity spread is considered a sign of increasing risk in the financial system as financial institutions opt to hedge their funds by buying government bonds, instead of lending to other banks at the prevailing EURIBOR or LIBOR rate. Thus, that interbank liquidity is being withdrawn (Angelini et al., 2011). Consistent with our application, this measure is the European counterpart of the TED spread used by, among others, Brunnermeier (2009) and Pelizzon et al. (2016) to measure funding liquidity. Throughout the current analysis we refer to this measure as the *TED spread*.

Data: The TED spread is computed as the difference between the 3-month Euro Interbank Offered Rate (EURIBOR) (London Interbank Offered Rate (LIBOR) in case of the UK) and the 3-month respective government bond rate. The series are obtained from Datastream and first differences of the daily series are included in the empirical analysis.

The return on the national stock market index: National stock market indices are used as proxies for the overall state of the local economies following Annaert et al. (2013), Collin-Dufresne et al. (2001), Ericsson et al. (2009), Galil et al. (2014). General business climate improvements are widely associated with decreases of the probabilities of default within the financial sector and will also increase the recovery rates. Thus, it is expected that positive changes in the stock market indices would result in decreased risk in the financial sector.

Data: MSCI country specific stock indices are used as proxies for the overall state of the local economies. MSCI stock market indices were obtained from Bloomberg. Further, daily percentage changes were calculated.

3 Data

Both Bloomberg and Datastream databases skip weekends and a few major holidays (Christmas and New Year's Day) but reproduce yesterday's closing price on the day on which a particular national exchange is closed. To keep the panel dataset balanced, closing prices on days on which three or more of the five series included do not trade are ignored, and such a day is treated as the weekend. All original series exhibited non-stationarity and data transformations were computed to achieve stationarity of the series prior to applying the econometric framework of Diebold and Yilmaz (2012). For the spread variables a daily change and for the price indices a daily percentage change was computed. Augmented Dickey-Fuller and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests were applied to ensure that the transformed series are stationary, results of this analysis are not reported in this paper, but are available from the authors upon request.

Table 1 reports the means, standard deviations and the minimum and maximum percentage values for each of the five country specific series: financial institutions' CDS spreads, real estate market indices, term spreads, liquidity spreads and national stock indices. Columns 1-4 in the upper section of the table report the main statistics of the banks' CDS spreads of each individual country. The CDS spread ranges are wide for all countries reflecting a significant shift in the credit risk of banks; the widest range can be observed for the UK from .18% to 10.09% and Spain from .08% to 8.47%. Summary statistics for the real estate index (columns 5-8, upper section) reflect the nature of the real estate market for the sample period. Minimum and maximum values show a significant fall and rise of the real estate markets, attributable to the crisis and non-crisis period, respectively. The stock market index summary statistics (columns 9-12, upper section) show a similar picture in financial markets. Summary statistics for the term spread series (columns 1-4, lower section) reflect the difference in sovereign credit risk between the periphery and core countries of the EU: average term spread is highest for Italy and Spain and the minimum and maximum values suggest the same (ranging from .5% to 6.44% for Italy and from .15% to 6.43% for Spain in comparison to Germany: $-.28\%$ to 4.11%). Columns 5-8 (lower section) report the summary statistics for the liquidity spread variable. It can be seen that the range of the liquidity spread variable is significantly wider for the UK (ranging from -1.05% to 3.78%) than for interbank liquidity proxy of the Eurozone countries (liquidity spread for Germany ranges from -.34% to 3.11%).

Table 2 shows the sample correlation matrices of the state variables for each individual country. The sample correlation coefficients are reported for the following variables: CDS spreads, real estate market indices, interest rate term spreads, interbank liquidity spreads, and national stock market indices. The sample correlation coefficients reveal a general pattern of the relationships among the variables across all five countries in the sample: highest pairwise correlation levels can be observed between CDS spreads and real estate indices, CDS spreads and stock market indices, and real estate and stock market indices.

4 Methodology

4.1 Measurement of Directional Spillovers

This paper adopts the framework developed in Diebold and Yilmaz (2012) to measure total and directional spillovers within a group of variables. As in Diebold and Yilmaz (2012) spillovers are measured from/to each time series i, to/from all other times series, added across i.

Consider a covariance stationary N-variable vector autoregressive (VAR) model of order p,

$$x_t = \sum_{i=1}^{p} \Phi_i x_{t-i} + \varepsilon_t, \text{ where } \varepsilon \sim iid(0, \Sigma). \tag{1}$$

Equation (1) can be rewritten as the infinite moving average (MA) representation,

$$x_t = \sum_{i=0}^{\infty} A_i \varepsilon_{t-i}, \tag{2}$$

where the $N \times N$ coefficient matrices A_i can be obtained using the following recursion:

$$A_i = \Phi_1 A_{i-1} + \Phi_2 A_{i-2} + \ldots + \Phi_p A_{i-p}, \tag{3}$$

with $A_0 = I_N$ and $A_i = 0$ for $i < 0$. The dynamics in the system is captured by these moving average coefficients. Diebold and Yilmaz (2012) proceed by using the forecast error variance decompositions to uncover the interrelationships among the variables in the system. Specifically, they use the variance decompositions to measure the fraction of the H-step ahead error variance in forecasting x_i that is due to shocks to x_j, for each i, $\forall j \neq i$. Whereas the "standard" way to carry out the analysis of variance decompositions is using the orthogonal innovations, methods such as Cholesky factorisation is not invariant to ordering of the variables in the VAR. Pesaran and Shin (1998), building on Koop et al. (1996), propose a generalized VAR to avoid this issue. The generalised approach allows for correlated innovations using the historically observed distribution of the innovations.

Diebold and Yilmaz (2012) define own variance shares as the fractions of the H-step ahead forecast error variances of x_i that are due to shocks in x_i, for $i = 1, 2, \ldots, N$, and cross variance shares, or spillovers, as the fractures of the H-step ahead forecast error variances of x_i that are due to shocks in x_j, for $i, j = 1, 2, \ldots, N \mid i \neq j$.

Following the notation in Pesaran and Shin (1998), the forecast error variance decompositions for $H = 1, 2, \ldots,$ are denoted by $\theta_{ij}^{g}(H)$:

$$\theta_{ij}^{g}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e_i' A_h \Sigma e_j)^2}{\sum_{h=0}^{H-1} e_i' A_h \Sigma A_h' e_i}, \; i, j = 1, \ldots, m \tag{4}$$

where Σ is the variance matrix for the vector of innovations ε, σ_{jj} is the standard deviation of the error term for the jth equation, and e_i is the selection vector, with one as the ith element and zeros otherwise.

Note that as the innovations to each variable are not orthogonalized, the sum of the contributions to the variance of the forecast error is not necessarily one: $\Sigma_{j=1}^{N}\theta_{ij}^{g}(H) \neq 1$. Each entry of the variance decomposition matrix is then normalized by the row sum in order to use the information contained in the variance decomposition matrix to express the spillover index:

$$\tilde{\theta}_{ij}^{g}(H) = \frac{\theta_{ij}^{g}(H)}{\sum\limits_{j=1}^{N}\theta_{ij}^{g}(H)}, \tag{5}$$

by construction, $\Sigma_{j=1}^{N}\tilde{\theta}_{ij}^{g}(H) = 1$ and $\Sigma_{i,j=1}^{N}\tilde{\theta}_{ij}^{g}(H) = N$.

Spillover measures, by construction, are divided into total spillovers, directional spillovers and net pairwise spillovers. The total spillover index measures the contribution of spillovers of shocks across the five time series to the total forecast error variance. Using the return contributions from the variance decompositions, the total spillover index can be constructed as:

$$S^{g}(H) = \frac{\Sigma_{i,j=1,i\neq j}^{N}\tilde{\theta}_{ij}^{g}(H)}{\Sigma_{i,j=1}^{N}\tilde{\theta}_{ij}^{g}(H)} * 100 = \frac{\Sigma_{i,j=1,i\neq j}^{N}\tilde{\theta}_{ij}^{g}(H)}{N} * 100. \tag{6}$$

Directional spillovers are calculated using the normalized elements of the generalized variance decomposition matrix. Directional spillovers to time series i from all other time series j is measured as:

$$S_{i\leftarrow\circ}^{g}(H) = \frac{\Sigma_{j=1,i\neq j}^{N}\tilde{\theta}_{ij}^{g}(H)}{\Sigma_{i,j=1}^{N}\tilde{\theta}_{ij}^{g}(H)} * 100 = \frac{\Sigma_{j=1,i\neq j}^{N}\tilde{\theta}_{ij}^{g}(H)}{N} * 100, \tag{7}$$

and, directional spillovers from time series i to all other time series j is measured as:

$$S_{\circ\leftarrow i}^{g}(H) = \frac{\Sigma_{j=1,i\neq j}^{N}\tilde{\theta}_{ji}^{g}(H)}{\Sigma_{i,j=1}^{N}\tilde{\theta}_{ji}^{g}(H)} * 100 = \frac{\Sigma_{j=1,i\neq j}^{N}\tilde{\theta}_{ji}^{g}(H)}{N} * 100. \tag{8}$$

The net spillover from time series i to all other time series j is calculated as the difference between the gross volatility shocks transmitted to and those received from all other series:

$$S_i^g(H) = S_{\circ\leftarrow i}^g(H) - S_{i\leftarrow\circ}^g(H). \tag{9}$$

Finally, the net pairwise spillovers are measured as:

$$S_{ij}^g(H) = \left(\frac{\tilde{\theta}_{ji}^g(H)}{\Sigma_{i,k=1}^N \tilde{\theta}_{ik}^g(H)} - \frac{\tilde{\theta}_{ij}^g(H)}{\Sigma_{j,k=1}^N \tilde{\theta}_{jk}^g(H)} \right) * 100 = \left(\frac{\tilde{\theta}_{ji}^g(H) - \tilde{\theta}_{ij}^g(H)}{N} \right) * 100. \tag{10}$$

Although both total and directional spillover indices reveal a lot of useful information, they do not take into consideration the time-varying nature of the events that potentially may drive the changes in spillover levels. To account for this, all spillover indices described above are estimated based on a 260-day rolling window for each individual country.

4.2 The Bai-Perron Test for Multiple Structural Changes

Bai and Perron (1998, 2003) propose a procedure that allows estimating a model with an unknown number of structural breaks that occur at unspecified dates. In the specified procedure the number of breaks and their timing are estimated simultaneously with the autoregressive coefficients. The model considered is an AR(1) process with m breaks, or, equivalently, $m+1$ regimes:

$$x_t = \alpha_j + \beta_j x_{t-1} + \varepsilon_t, j = 1, \ldots, m+1. \tag{11}$$

Equation (11) allows for m breaks, where the coefficients shift from one stable autoregressive relationship to a different one. The first break occurs at t_1, so the duration of the first regime is from $t = 1$ to $t = t_1$, the duration of the second regime is from $t_1 + 1$ to t_2 and so forth until the mth break that lasts from $t_m + 1$ until the end of the dataset. The goal is to determine the number and location of the breakpoints T_j, $j = 1, \ldots, m$. The computation of the coefficient estimates and the breakpoints can be done by applying

OLS segment by segment without constraints. The resulting minimal residual sum of squares is given by

$$RSS(i,j) = \sum_{i=1}^{j} rss(i,j), \tag{12}$$

where $rss(i,j)$ is the minimal residual sum of squares at time j obtained using the sample that starts at date i. Bai and Perron present the following recursive relation:

$$RSS(i,j) = RSS(i,j-1) + rss(i,j)^2. \tag{13}$$

All the relevant information is contained in the values of the triangular matrix $RSS(i,j)$ for the relevant combinations (i,j). The number of matrix inversions needed is of order $O(T)$.

Bai and Perron (2003) propose applying a version of the dynamic programming algorithm for pure and structural change models. The optimal segmentation satisfies the recursion

$$RSS(\{T_{m,T}\}) = \min_{mh \le j \le T-h} [RSS(\{T_{m-1,j}\}) + RSS(j+1,T)]. \tag{14}$$

See Bai and Perron (2003) for details on this dynamic algorithm and for discussion of assumptions underlying the methodology applied.

Applying the Diebold-Yilmaz framework on a rolling window basis, the method potentially introduces serial autocorrelation in the resulting spillover time series. This may further lead to a bias in the Bai-Perron estimation procedure. To reduce this bias, the Bai-Perron procedure has been applied to quarterly net spillover series, which has been obtained by selecting every 65th rolling window estimate of each net spillover series.

5 Empirical Findings

We now document the findings from our spillover analysis. We start the discussion by presenting the static analysis, move on to the dynamic spillover of the individual state variables and conclude with the pairwaise spillover examination.

5.1 Total Spillover Index: Static Analysis

Table 3 reports the full-sample total spillovers within the variables. This is a static analysis where the ijth entry is the estimated contribution to the forecast error variance of market i coming from innovations to market j. The off-diagonal row sums (labeled contributions *from* others) and column sums (labeled contributions *to* others) are the "*from*" and "*to*" directional spillovers, and the "*from* minus *to*" differences are the net spillovers of shocks. The diagonal elements (own connectedness) tend to be the highest individual elements of the table.

The "directional *to* others" row and "directional *from* others" column show that for all five countries the stock index seems to be the most significant transmitter and receiver of shocks (the spillover index is largest for most countries in the sample, with the exception of "directional *from* others" for Spain). The real estate index comes second for all countries except Spain.

The total spillover index appears in the lower right corner of the spillover table. It is approximately the total off-diagonal row sum relative to the total row sum including diagonals, expressed as a percentage. The total spillovers index shows what percentage of the total forecast error variance in all five variables comes from spillovers. It is lowest for Spain at 9% suggesting a low connectedness level within the variables, and it is highest for France at 27.7%. For Germany, Italy and the UK it ranges from 19.8% to 24.1%. In summary of Table 3, both the total and directional spillovers over the full sample period were rather low. The full-sample spillover index analysis provides a good overall picture of the connectedness between the variables. However, it is likely to miss the rich dynamics within the macro-financial state variables during the sample period of January 2004 to December 2012.

5.2 Total Spillover Index: Full-sample and 260-day Rolling Window Estimation

Next, the total spillover index is estimated using the 260-day rolling samples which are reported in Figure 1. In the pre-crisis period the spillover index among the five state variables ranged from below 10% to 20% for all countries. After the onset of the financial crisis in Q2 2007, however, the spillovers suddenly jump to 40% and fluctuate strongly in the region 12% to 55% over the remaining sample period. Four distinctive waves can be observed in the total spillover index. First, June 2007 to November 2007 coincides with the onset of the financial crisis in the EU. Q3 2007 witnessed liquidity shortages worldwide and slowdown in the interbank lending, which is reflected by the first steep rise in the total spillover index. Financial markets became increasingly vulnerable in response to the subprime crisis that hit the US.

5.2.1 The Total Spillover Index and Monetary Policy Interventions

We now turn to the impact of monetary policy interventions on the dynamic spillover index. Tables 4 and 5 report a series of monetary policy intervention announcements by the ECB and the BoE during the sample period. The ECBs policy response to the crisis was mainly oriented towards ensuring the provision of liquidity and repairing the bank-lending channel. The Bank of England chose a more radical and unconventional response to the crisis in terms of monetary policy when they made a quick decision to implement large-scale asset-purchases programmes. Figure 1 shows that the total spillover index started increasing rapidly from the beginning of Q3 2007. From July to September the spillover index increased from 17.3% to 32.4% for the UK and all other countries in the sample followed closely.

During the period mid-September to mid-October 2008 a sharp increase in the total spillover index can be observed. September and October 2008 saw a series of major events in Europe and the US, such as the Lehman Brothers filing for bankruptcy, the bailout of major commercial banks by the Bank of England and collapse of the three biggest commercial banks in Iceland. As a response to the increasing tensions a co-ordinated easing in monetary policy took place between the European Central Bank, the Bank of Canada, the European Central Bank, the US Federal Reserve, Sveriges Riksbank, the Swiss National Bank and the Bank of Japan on the 8th of October 2008. Around the same date the total spillover index decreases notably (for example, it falls by 10% for Italy from 10th of October to 3rd of November 2008, and it falls by 9% from 7th of October to 22nd of October 2008 for France).

The next jump in the total spillover index corresponds with the period of mounting concern over the Greek banking system. It became apparent in Q1 2010 that Greece would require financial assistance from the ECB. The agreement between the Euro area leaders and IMF to offer financial support to Greece was eventually finalised in Q2 2010. The ongoing uncertainty and carrying out of the bailout programmes result in the increasing spillover index; the gradual increase lasted for 6 months. In April 2011, Portugal admits to difficulties with its finances and applies for the financial assistance programme. In May, the eurozone and the IMF approve a 78bn-euro bailout for Portugal. This corresponds with a very significant fall in the total spillover index (for example, the spillover index fell by 13% for the UK between 2nd of May and 6th of June 2011 and by 7% for France during the same period). Q3 2011 saw another surge in the spillover index (index increased by 15% between 21st of July and beginning of December 2011 for the UK and other countries followed closely with the exception of Spain). This upsurge corresponds with the developments around the second Greek bail-out programme. Overall significant changes in the spillover index can be seen in response to the news on the financial assistance programmes.

5.3 Net Spillover Analysis

Figures 2 to 6 reports net spillovers for changes in CDS spread, real estate, term spread, liquidity spread and stock index variables within the five countries, respectively. In order to understand the dynamics of the spillover series and the relationship between the variables at a deeper level, the net spillover indices need to be analysed in conjunction with

Bai-Perron break date estimation results reported in Table 4. The Bai-Perron test reveals interesting structural breaks for each individual country, however, we want to concentrate only on the breaks that are common to all or most of the countries in the sample. This allows us to concentrate on common major events that resulted in the changes of spillover levels. As a reminder to the reader, the net spillover *from* time series i *to* all other time series j is calculated as the difference between the gross volatility shocks transmitted *to* and those received *from* all other series. The directional spillover index series (corresponds to "contributions *from* others "and "contributions *to* others "columns in the total spillover table - Table 3) are not reported in this paper, but are available from the authors upon request.

Following the terminology in Diebold and Yilmaz (2012), when the index is negative the variable is called a net receiver of shocks and when positive it is called a net transmitter of shocks. In practice, when a particular variable is a net transmitter of shocks its estimated contribution *to* the forecast error variance of all other variables is larger than the estimated contribution *from* all other variables. Hence, it can be concluded that the effects of shocks to variable i affect other variables more than the effects of shocks to other variables affect variable i.

5.3.1 Credit Risk of Financial Institutions

Figure 2 shows that until the beginning of 2007 the net CDS spillover series have been broadly unchanging. Overall, the CDS variable became a net receiver of shocks during the crisis period (Q3 2007 onwards). From this it can be concluded that the credit risk of financial institutions reflected strongly the shocks transmitted through all other macro-financial state variables in our sample.

A closer look at the individual countries reveals that the sensitivity of the CDS variable was most pronounced for France, Germany and Italy as the fluctuations of the index is strongest for these countries. Table 4 reports that the Bai-Perron first structural break in the net CDS spillover series common to all countries in the sample is in Spring 2010. This corresponds with the period of mounting concern over the Greek banking system.

It became apparent in Q1 2010 that Greece would require financial assistance from the ECB and the agreement between the Euro area leaders and IMF to offer financial support to Greece was signed in Q2 2010. The Bai-Perron test detected another structural break common for France and Germany in May 2011, which corresponds with the timing of Portugese financial assistance developments.

5.3.2 Real Estate Market

Figure 3 illustrates the net real estate spillover index series for the five countries over the sample period January 2004 to December 2012. Overall, the net real estate spillover index seems to be a net transmitter of shocks, but fluctuations of the country specific series move quite independently of each other. The net real estate spillover for Spain fluctuates around zero largely throughout the whole sample period.

The Bai-Perron procedure detects a common structural break in the sample countries in September 2008 (the structural breaks is detected in all the countries except Spain) (see Table 4). Note that September and October 2008 saw a series of major events in Europe and the US, such as the Lehman Brothers filing for bankruptcy, the bailout of major commercial banks by the Bank of England and collapse of the three biggest commercial banks in Iceland.

5.3.3 Interest Rate Yield Curve

Figure 4 reports the net term spread spillovers series for the five countries in the sample. The net spillover series move closely together until the beginning of 2010 for four countries: France, Germany, Italy and Spain. The net term spread spillover index for the UK follows an independent path and since the beginning of 2010 the series for all five countries became less correlated. The Bai-Perron procedure detects three common structural breaks: September 2008 (France, Germany, Italy and Spain), March 2009 (France, Italy, and Spain) and April 2010 (France, Spain and the UK).

5.3.4 Interbank Liquidity Risk

Figure 5 reports the net liquidity spread spillover index over the sample period. The variable is mostly a net receiver of shocks from other variables. The dynamics of the index is quite similar between all the Eurozone countries and moves somewhat independently for the UK. The liquidity spread is commonly used as an indicator to measure funding liquidity in general financial markets (Angelini et al. (2011)). The empirical findings in this paper imply that the liquidity spread reflects turmoil in financial markets and not vice versa.

5.3.5 Equity Markets

Figure 6 reports the net stock index spillovers for the respective equity markets. Stock market variable is a net transmitter of shocks over the whole sample period. In Q2 2007 the spillover index increases significantly for all countries in the sample. For example, the spillover index increased by 25% for Germany from Q3 2007 to Q2 2008. The co-movement between the country-specific spillover indices is highest among the state variables analysed. The lower heterogeneity in shock transmission across countries can be partly explained by the globalization of equity markets.

5.4 Net Pairwise Spillover Indices

In this section we analyse the net pairwise spillover indices estimated on a rolling window basis to determine the strongest shock transmission channels within our framework. Net pairwise spillovers are calculated as the difference between the gross shocks transmitted from variable i to variable j and those transmitted from j to i. The resulting measure of the net spillover is somewhat hard to interpret directly, but is easily seen that if the net pairwise spillover is positive, shocks from variable j transmit to variable i in net terms rather than vice versa. For example, if the net pairwise spillover measure between real estate market return series and stock market return series is positive shocks transmit from the real estate market to stock market in net terms. Figures 7-10 present net pairwise spillover indices for the state variables over time. We find the strongest shock transmission from the following variables:

CDS spreads: The strongest shock transmission from the CDS spread is observed to the Liquidity spread variable (Figure 7(c)). For most countries in the sample the net pairwise spillover index between CDS spread and the Liquidity spread varies from 0.2% to around 5%, reaching 18.56% in September 2009 for the UK and around 10% for Italy for the last three quarters of 2010 and November 2011 to October 2012.

Real Estate Returns: Shocks to the Real Estate returns variable appear to transmit to the Liquidity spread variable (Figure 8(b)). The strongest shock transmission can be observed for Germany, especially for the periods October 2008 to September 2009 (spillover index increased from around 5% to about 12%). The shock transmission becomes stronger for all countries in the sample in the Q2 of 2010 and remains relatively high until the end of the sample period. Shocks to the Real Estate returns variable also transmit to the CDS spread variable (Figure 7(a)). For most countries in the sample the shock transmission becomes stronger at the onset of the crisis in Q2 2007 and remains high throughout our sample period.

Term Spread: Shocks to term spread variable transmit to liquidity spread variable (Figure 9(a)), the effect is pronounced for Germany until Q1 2008 and then starts increasing for all countries in the sample around the second Greek bailout in July 2011. This shock transmission channel indicates that the interest rate changes lead the changes in interbank liquidity and not vice versa.

Stock Index Returns: Shocks to the stock market returns appear to consistently transmit to all variables in our sample which leads us to conclude that the stock market returns is the most significant shock transmission channel. The strongest shock transmission is from the stock market returns to liquidity spread (Figure 10(a)). The effect is pronounced for Germany, the UK and France. For Germany and the UK, the spillover index increases from 2% just before the onset of financial crisis in Q2 2007 to 11% by the end of August 2007. The spillover index increased to 15% in January 2008 for Germany. This corresponds to the news announcement in the US of the largest single-drop in US home sales in twenty five years.

Shocks to the stock market returns also transmit strongly to CDS spreads (Figure 7(d)) and term spreads (Figure 9(b)). The net pairwise spillover index between the stock market returns and the CDS spreads is strongly co-moving between the countries in the sample and ranges from 4% to 12% over the sample time period. This is supportive of the view that the shocks to the equity markets have a strong influence on the stability of the financial institutions. We can also conclude that the shocks to the equity markets lead changes in the interest rates.

6 Conclusion

This paper analyses the total and directional spillovers across a well-motivated set of systemic state variables, namely credit risk, real estate market risk, interest rate risk, interbank liquidity risk and market risk, using daily data from January 2004 to December 2012. The spillover analysis is undertaken within five European Union countries: core countries France and Germany, periphery countries Spain and Italy, and a reference country the UK. A multiple structural break estimation procedure is employed to detect sudden changes in shock transmissions. A number of salient implications can be drawn from the econometric results reported in this study.

Our results indicate that the relative importance of individual state variables is time-varying and exhibit strong country specific features. Overall, the national stock market indices and the real estate indices appear to lead the shock transmission across the five state variables. This lends support to the view that the shocks to the equity market and the real estate sector have a strong influence on the stability of financial institutions. The spillover dynamics of the real estate risk variable differs significantly within the countries in the sample. This indicates that real estate market risk is mostly affected by country specific events. We also document that the shocks to interest rate term spreads appear to transmit to interbank liquidity spreads rather than vice versa; this is suggestive that interest rate changes lead the changes in interbank liquidity.

The net real estate index spillovers exhibit a strong country specific dynamics. This is to be expected somewhat as every country experienced downturn in real estate prices at different times. The national stock markets are the most globalised across the variables in the sample as the net stock market spillovers are strongly co-moving for all countries.

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Table 1: Summary statistics

	Banks' CDS spread 5-yr				Real Estate Price Index			
	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max
France	1.32	1.13	0.11	4.48	0.03	1.20	-6.08	6.12
Germany	0.94	0.74	0.09	2.71	0.00	1.13	-7.10	6.76
Italy	1.36	1.43	0.09	5.97	-0.02	1.96	-10.77	26.80
Spain	1.99	2.16	0.08	8.47	-0.05	2.47	-14.14	61.66
UK	1.49	1.50	0.18	10.09	0.01	1.64	-9.29	9.29

	Term Spread				Liquidity Spread			
	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max
France	2.47	1.21	0.38	4.19	0.45	0.40	-0.17	3.39
Germany	2.07	1.09	-0.28	4.11	0.28	0.49	-0.36	2.86
Italy	3.36	1.66	0.50	6.44	0.11	0.60	-4.54	3.71
Spain	2.96	1.75	0.15	6.43	0.22	0.56	-3.71	2.77
UK	1.33	1.82	-1.38	3.89	0.36	0.38	0.05	2.25

	Equity Market Price Index			
	Mean	Std Dev	Min	Max
France	0.01	1.43	-8.89	10.92
Germany	0.03	1.41	-7.12	11.77
Italy	-0.01	1.52	-8.27	11.61
Spain	0.01	1.58	-9.61	15.63
UK	0.01	1.32	-8.95	9.98

Notes: This table reports the daily mean, standard deviation, minimum and maximum value of financial institutions' CDS spread, real estate index, national stock market index, term spread and liquidity spread variables. The values for the real estate and stock market indices report summary statistics on percentage changes rather than the original price indices. The statistics reported for the period 1st of January 2004 to 31st of December 2012.

Table 2: Sample correlation matrices

France

	CDS	Real Estate	Term Spread	Liquidity Spread	Stock Index
CDS	1.00				
Real Estate	-0.44	1.00			
Term Spread	-0.06	0.10	1.00		
Liquidity Spread	-0.01	-0.01	-0.06	1.00	
Stock Index	-0.48	0.72	0.16	0.02	1.00

Spain

	CDS	Real Estate	Term Spread	Liquidity Spread	Stock Index
CDS	1.00				
Real Estate	-0.14	1.00			
Term Spread	0.03	-0.03	1.00		
Liquidity Spread	-0.06	0.02	0.00	1.00	
Stock In	-0.34	0.23	-0.11	0.03	1.00

Germany

	CDS	Real Estate	Term Spread	Liquidity Spread	Stock Index
CDS	1.00				
Real Estate	-0.24	1.00			
Term Spread	-0.16	0.21	1.00		
Liquidity Spread	0.12	-0.04	-0.05	1.00	
Stock Index	-0.30	0.60	0.30	0.00	1.00

UK

	CDS	Real Estate	Term Spread	Liquidity Spread	Stock Index
CDS	1.00				
Real Estate	-0.34	1.00			
Term Spread	-0.06	0.04	1.00		
Liquidity Spread	0.07	-0.02	-0.06	1.00	
Stock I Index	-0.34	0.66	0.07	-0.04	1.00

Italy

	CDS	Real Estate	Term Spread	Liquidity Spread	Stock Index
CDS	1.00				
Real Estate	-0.38	1.00			
Term Spread	0.16	-0.07	1.00		
Liquidity Spread	-0.08	0.00	0.04	1.00	
Stock Index	-0.50	0.58	-0.14	-0.03	1.00

Notes: This table reports the sample correlation matrices for the five original (before transformation due to non-stationarity) series of financial institution risk factors (CDS spreads, real estate index, interest rate term spread, interbank liquidity spread, and national stock market index) for each individual country: France, Germany, Italy, Spain and the UK. All data is daily and covers the period 1st of January 2004 to 31st of December 2012.

Table 3: Total spillover indices for the full sample

France	CDS	Real Estate	Term Spread	Liquidity Spread	Stock Index	Directional FROM others
CDS	65.3	13.8	1.4	0.1	19.5	35
RLE	10.7	57.2	1.1	0.3	30.7	43
Term Spread	1.1	2.3	86.6	5.8	4.2	13
Liquidity Spread	0.4	0.2	1.4	97.4	0.6	3
Stock Index	13.8	29	1.9	0.5	54.8	45
Directional TO others	26	45	6	7	55	139
Directional including own	91	102	92	104	110	27.70%

Spain	CDS	Real Estate	Term Spread	Liquidity Spread	Stock Index	Directional FROM others
CDS	81.8	3.3	0.3	0.5	14.1	18
RLE	1.4	93.2	0.1	0.1	5.2	7
Term Spread	0.1	0.1	98.4	0.1	1.2	2
Liquidity Spread	0.6	0.1	0.6	98.1	0.6	2
Stock Index	10.9	4.4	1.2	0.1	83.3	17
Directional TO others	13	8	2	1	21	45
Directional including own	95	101	101	99	104	9.00%

Germany	CDS	Real Estate	Term Spread	Liquidity Spread	Stock Index	Directional FROM others
CDS	78.5	6.1	4.1	0.2	11	21
RLE	3.9	68.2	2.9	0.1	24.8	32
Term Spread	2.9	3.6	86.1	0.1	7.3	14
Liquidity Spread	1.7	5.2	3.9	83.1	6.1	17
Stock Index	6.4	23.1	5.4	0.2	64.8	35
Directional TO others	15	38	16	1	49	119
Directional including own	93	106	102	84	114	23.80%

UK	CDS	Real Estate	Term Spread	Liquidity Spread	Stock Index	Directional FROM others
CDS	79.4	9.2	0.3	0.3	10.9	21
RLE	7.7	64.2	0.1	0.1	27.9	36
Term Spread	0.4	0.1	98.5	0.5	0.5	2
Liquidity Spread	0.6	0.5	1	95.2	2.6	5
Stock Index	8	27.6	0.4	0.2	63.9	36
Directional TO others	17	37	2	1	42	99
Directional including own	96	102	100	96	106	19.80%

Italy	CDS	Real Estate	Term Spread	Liquidity Spread	Stock Index	Directional FROM others
CDS	66.1	10	1.9	0.4	21.5	34
RLE	9.3	65.9	1	0	23.8	34
Term Spread	2.8	0.5	94.2	0.4	2	6
Liquidity Spread	4.9	0.5	0.3	93.1	1.2	7
Stock Index	16.9	21.2	1.6	0.1	60.3	40
Directional TO others	34	32	5	1	49	120
Directional including own	100	98	99	94	109	24.10%

Notes: This table reports the full-sample total spillovers within the five transformed variables (first differences of the financial institutions' CDS spreads, percentage change of the real estate indices, first differences of the term spreads, first differences of the liquidity spreads, and percentage change of the national stock market indices) for each individual country: France, Germany, Italy, Spain and the UK. All data is daily and covers the period 1st of January 2004 to 31st of December 2012. See Eq (6) for calculation of the total spillovers index.

Table 4: Structural breaks for the full sample

France	Germany	Italy	Spain	UK	France	Germany	Italy	Spain	UK
		CDS Spreads					**Real Estate Market Returns**		
January 2008	January 2008	July 2007	October 2006	February 2009	September 2008	May 2006	November 2007	-	September 2008
August 2008	August 2009	April 2010	May 2007	February 2010	September 2009	September 2008	September 2008		February 2010
April 2009	April 2010	December 2010	April 2010		July 2010	September 2009	April 2010		October 2010
March 2010	May 2011	November 2011	November 2010		October 2011	September 2011			May 2011
May 2011			September 2011						January 2012
		Interest Rate Term Spreads					**TED Spreads**		
September 2008	May 2006	September 2008	September 2008	October 2009	March 2006	October 2005	October 2008	July 2006	August 2007
March 2009	November 2006	March 2009	March 2009	April 2010	October 2006	January 2008	April 2010	September 2007	March 2008
September 2009	January 2008	March 2011	April 2010	May 2011	September 2008	September 2009	December 2010	March 2008	February 2010
April 2010	September 2008	October 2011	August 2011	November 2011	September 2009	July 2011	July 2011	November 2011	September 2010
December 2011	July 2010					June 2012	January 2012		
		Stock Market Returns							
January 2008	July 2007	July 2011	March 2007	May 2006					
August 2008	January 2008		June 2011	February 2007					
October 2009	July 2008			August 2007					
April 2010	August 2011			October 2008					
July 2011	June 2012			May 2011					

Notes: This table reports the Bai-Perron estimation procedure results for the monthly net spillover series of the five financial institutions risk factors in the sample (first differences of the financial institutions' CDS spreads, percentage change of the real estate indices, first differences of the term spreads, first differences of the liquidity spreads, and percentage change of the national stock market indices) for each individual country: France, Germany, Italy, Spain and the UK. The sample period is 1st of January 2004 to 31st of December 2012.

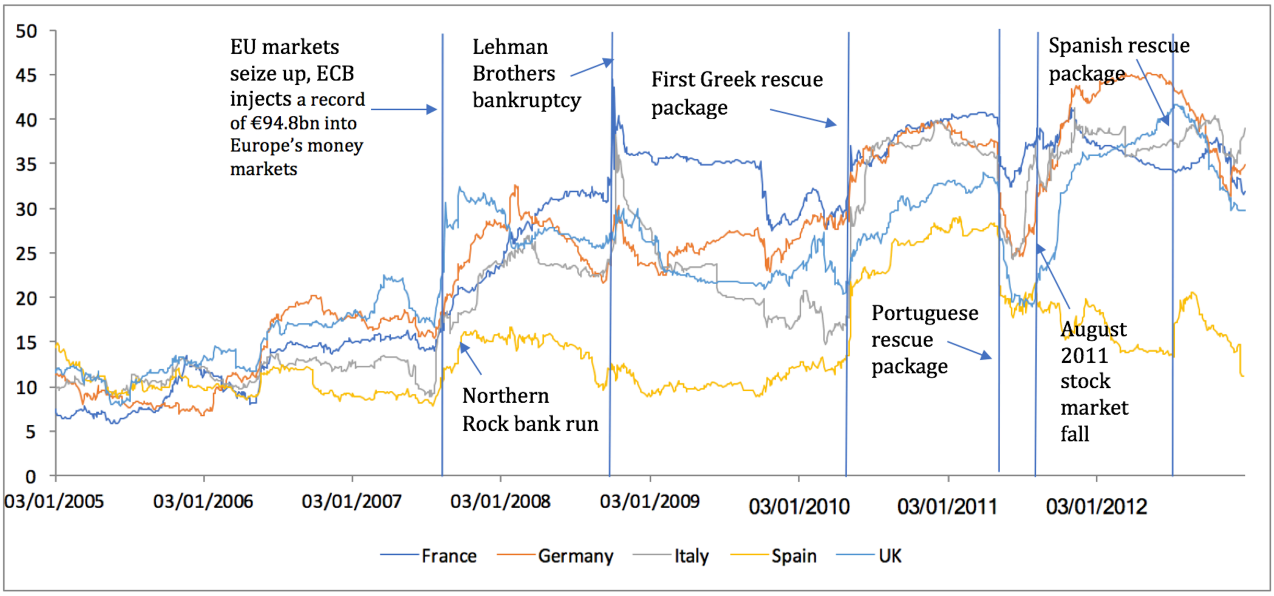
Table 5: ECB Unconventional Monetary Policies Announcements Timeline

Announcement Date	ECB Unconventional monetary policies announcements
August 9 - September 5 2007	On the morning of 9 August a dislocation of the money market took place, characterised by a very small trading volume and a sudden increase in short-term money market rates. In order to reduce the tensions observed in the money market in the period from 8 August to 5 September, the ECB carried out additional liquidity-providing open market operations over and above the pre-scheduled operations.
December 12, 2007	Joint action between the ECB and the Federal Reserve by offering US dollar funding to Eurosystem counterparties.
October 8, 2008	Co-ordinated easing in monetary policy between the European Central Bank, the Bank of Canada, the European Central Bank, the US Federal Reserve, Sveriges Riksbank, the Swiss National Bank and the Bank of Japan.
July 2, 2009	The Eurosystem launched its first covered bond purchase programme (CBPP1).
May 2, 2010	First Greek rescue package
May 10, 2010	Securities Market Programme (SMP) was introduced. Creation of the temporary European Financial Stability Facility (EFSF), euro area's first financial assistance fund.
November 28, 2010	Irish rescue package.
March 18, 2011	Following the earthquake and tsunami which hit Japan the previous week, the G7 group of industrial nations announced a concerted intervention in foreign exchange markets.
May 5, 2011	Portugese rescue package.
July 21, 2011	Second Greek rescue package.
August 7, 2011	Expansion of the Securities Markets Programme.
November 3, 2011	The Eurosystem launched a second covered bond purchase programme (CBPP2).
December 8, 2011	Two 3-year Long Term Refinancing Operations (LTRO) were announced.
December 13, 2011	Introduction of the Macroeconomic Imbalance Procedure (MIP). The MIP is part of the EU's so-called 'six-pack' legislation, which aims to reinforce the monitoring and surveillance of macroeconomic policies in the EU and the euro area.
December 21, 2011	The first allotment of the LTRO.
February 29, 2012	The second allotment of the LTRO.
March 2, 2012	Euro area Member States agree to make the goal of balanced budgets part of their national constitutions. The fiscal compact is part of a treaty known as the Treaty on Stability, Coordination and Governance, which entered into force in January 2013.
March 12, 2012	Third Greek rescue package.
June 12, 2012	Spanish rescue package.
September 6, 2012	The European Central Bank (ECB) announces its Outright Monetary Transactions bond-buying programme.
October 8, 2012	The European Stability Mechanism (ESM) becomes operational.

Table 6: BoE Unconventional Monetary Policies Announcements Timeline

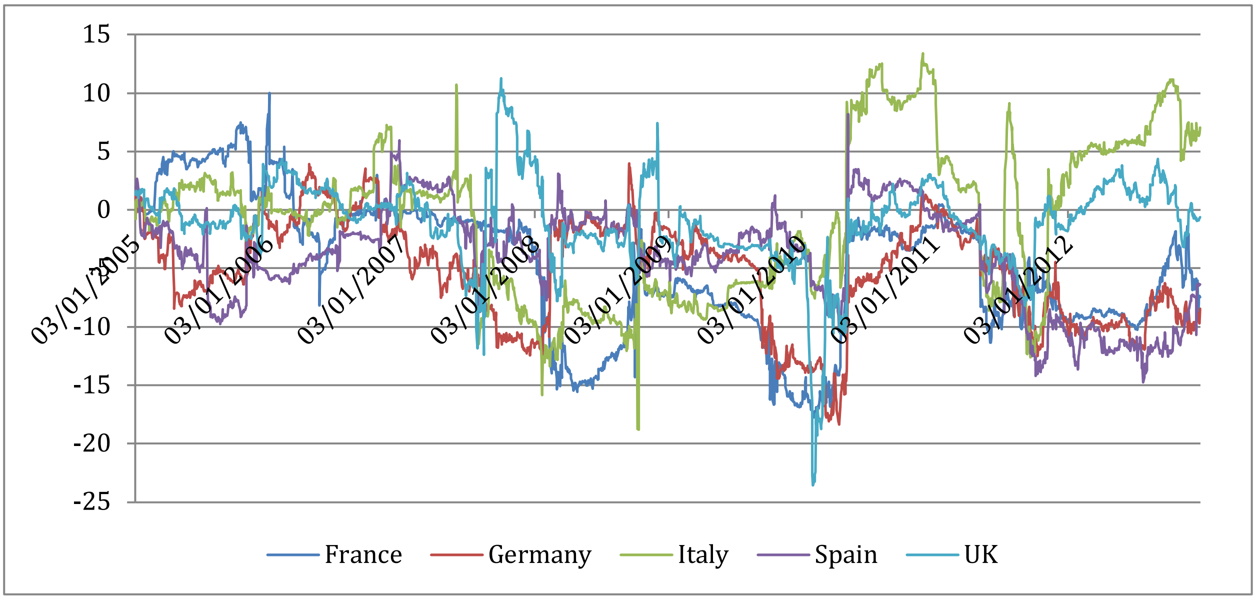
Announcement Date	BoE Unconventional monetary policies announcements
September 14, 2007	Northern Rock announced that "extreme conditions" in financial markets forced it to approach the Bank of England for assistance.
September 18, 2007	Following the run on Northern Rock, the Bank supplied additional reserves in open market operations to meet the markets' increased demand.
December 14, 2007	The Bank held the first "extended collateral", three month long-term repo operation, where counterparties could bid for reserves against either collateral routinely eligible in the Bank's OMOs or against a broader set of collateral.
April 21, 2008	The Bank announced the launch of the Special Liquidity Scheme to allow banks to swap temporarily their high quality, but currently illiquid, mortgage-backed and other securities for UK Treasury bills.
September 19, 2008	Alongside other central banks, in response to pressures in US dollar short-term funding markets, the Bank conducted its first US Dollar operation, lending dollars overnight.
October 8, 2008	In response to the financial crisis, the MPC convened a day earlier than scheduled and agreed to reduce Bank Rate by 50 basis points, as part of a co-ordinated easing in monetary policy, in conjunction with the Bank of Canada, the European Central Bank, the US Federal Reserve, Sveriges Riksbank, the Swiss National Bank and the Bank of Japan.
October 13, 2008	The British government bails out several banks, including the Royal Bank of Scotland, Lloyds TSB, and HBOS, to avert the collapse of the UK banking sector,
March 5, 2009	First round of the quantitative easing announced by the BoE, the programme ended in January 2010.
January 8, 2010	The Bank held its first operation offering to sell corporate bonds from the Asset Purchase Facility with the intention of improving secondary market liquidity.
June 15, 2010	The Bank conducted the first operation of its permanent indexed long-term repo facility. This was designed to enable funds to be lent against different types of collateral depending on the degree of stress in the system.
March 18, 2011	Following the earthquake and tsunami which hit Japan the previous week, the G7 group of industrial nations announced a concerted intervention in foreign exchange markets.
October, 2011	Second round of the quantative easing was announced - asset purchases were resumed in October 2011, largely in response to the impact of the growing euro crisis.
Jul-12	Third round of the quantative easing was announced that concluded in November 2012.
July 13, 2012	Funding for Lending Scheme launched by the BoE and HM Treasury.

Figure 1: Total spillover index: 260-day rolling window estimation



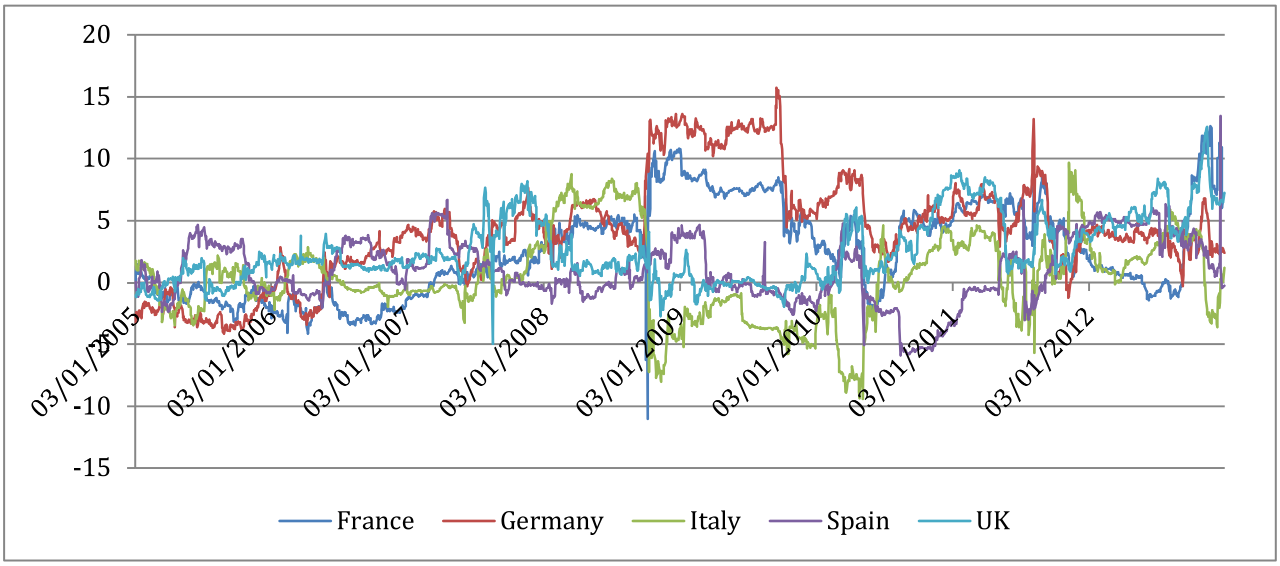
Notes: This figure illustrates the total spillover index time series from the DY (2012) estimation procedure based on 260-day rolling window sample. Total number of observations is 2085 and the rolling sample estimation uses 260 observations. All numbers are in percentages. See Eq (6) for calculation of the total spillovers index. The series covers the period 3rd of January 2004 to 31st of December 2012. Four distinctive waves can be observed in the total spillover index: pre-crisis period when the spillover level is relatively low, increase in the spillover index during the onset of the crisis and uncertainty period between 2007-2010, an elevated spillover index between 2010-2011, and a period of asymmetric spillover index behaviour from 2012 onwards.

Figure 2: Net CDS spreads spillover indices



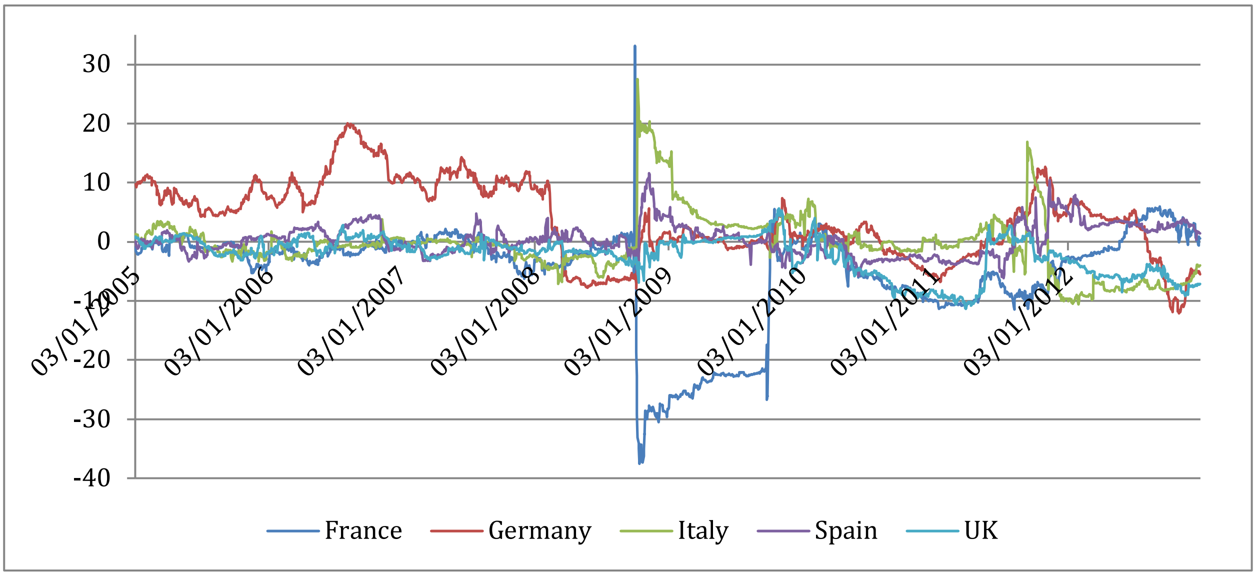
Notes: This figure illustrates the net CDS spread spillover index time series from the DY (2012) estimation procedure based on 260-day rolling window sample. Positive values of the index indicate that the variable is a net "shock transmitter" to all other variables and negative values indicate that the variable is a net "shock receiver" from all other variables in the sample. Total number of observations is 2085 and the rolling sample estimation uses 260 observations. All numbers are in percentages. See Eq (9) for calculation of the net spillovers index. The series covers the period 3rd of January 2004 to 31st of December 2012. Overall, the CDS variable was a net "receiver" of shocks during the period from mid 2007 to 2010 and a net "transmitter" of shocks during 2011-2012 and after 2012 there is a significant asymmetry between the net spillover index for the countries in the sample.

Figure 3: Net real estate indices spillover series



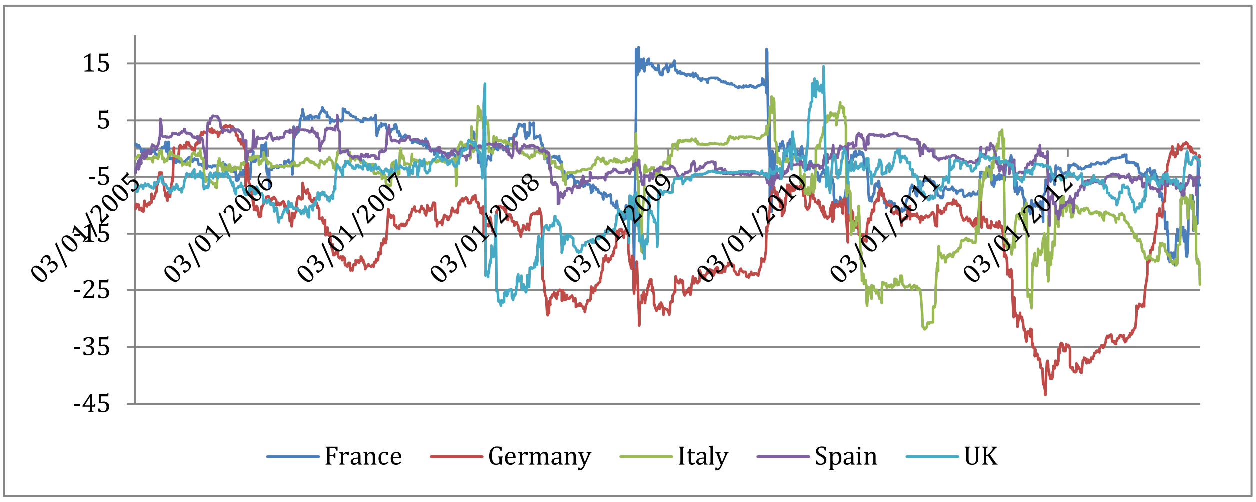
Notes: This figure illustrates the net real estate index spillover time series from the DY (2012) estimation procedure based on 260-day rolling window sample. Positive values of the index indicate that the variable is a net "shock transmitter" to all other variables and negative values indicate that the variable is a net "shock receiver" from all other variables in the sample. Total number of observations is 2085 and the rolling sample estimation uses 260 observations. All numbers are in percentages. See Eq (9) for calculation of the net spillovers index. The series covers the period 3rd of January 2004 to 31st of December 2012. The figure indicates that the real estate risk variable was a net "transmitter" of shocks over the sample period and that the dynamics of the net spillover index for this variable varies strongly between the sample countries.

Figure 4: Net term spreads spillover indices



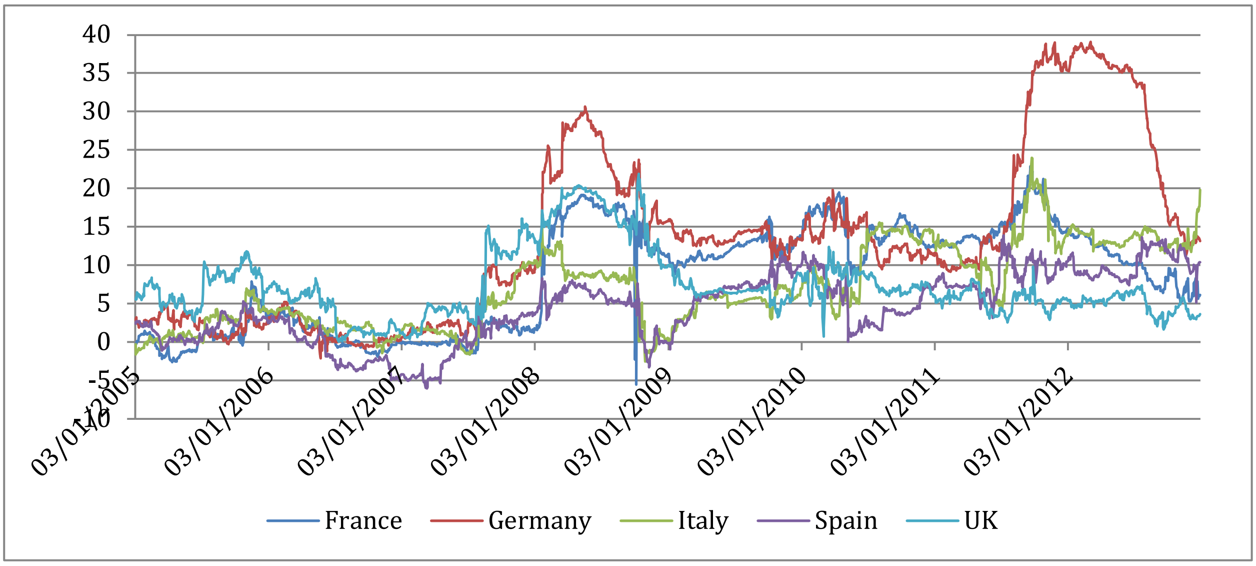
Notes: This figure illustrates the net term spread spillover index time series from the DY (2012) estimation procedure based on 260-day rolling window sample. Positive values of the index indicate that the variable is a net "shock transmitter" to all other variables and negative values indicate that the variable is a net "shock receiver" from all other variables in the sample. Total number of observations is 2085 and the rolling sample estimation uses 260 observations. All numbers are in percentages. See Eq (9) for calculation of the net spillovers index. The series covers the period 3rd of January 2004 to 31st of December 2012. The figure indicates that the interest rate risk variable was a net "transmitter" of shocks over the sample period and that the dynamics of the net spillover index for this variable varies strongly between the sample countries.

Figure 5: Net liquidity spreads spillover indices



Notes: This figure illustrates the net liquidity spread spillover index time series from the DY (2012) estimation procedure based on 260-day rolling window sample. Positive values of the index indicate that the variable is a net "shock transmitter" to all other variables and negative values indicate that the variable is a net "shock receiver" from all other variables in the sample. Total number of observations is 2085 and the rolling sample estimation uses 260 observations. All numbers are in percentages. See Eq (9) for calculation of the net spillovers index. The series covers the period 3rd of January 2004 to 31st of December 2012. The figure indicates that the interbank liquidity risk variable was a net "receiver" of shocks over the sample period.

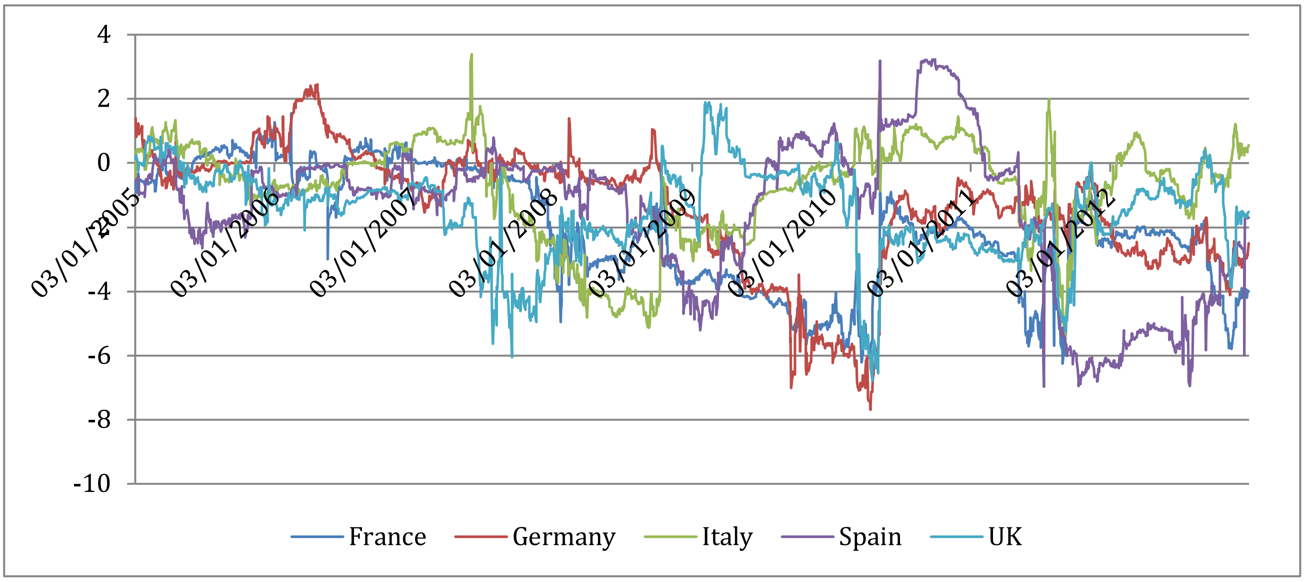
Figure 6: Net stock indices spillover series



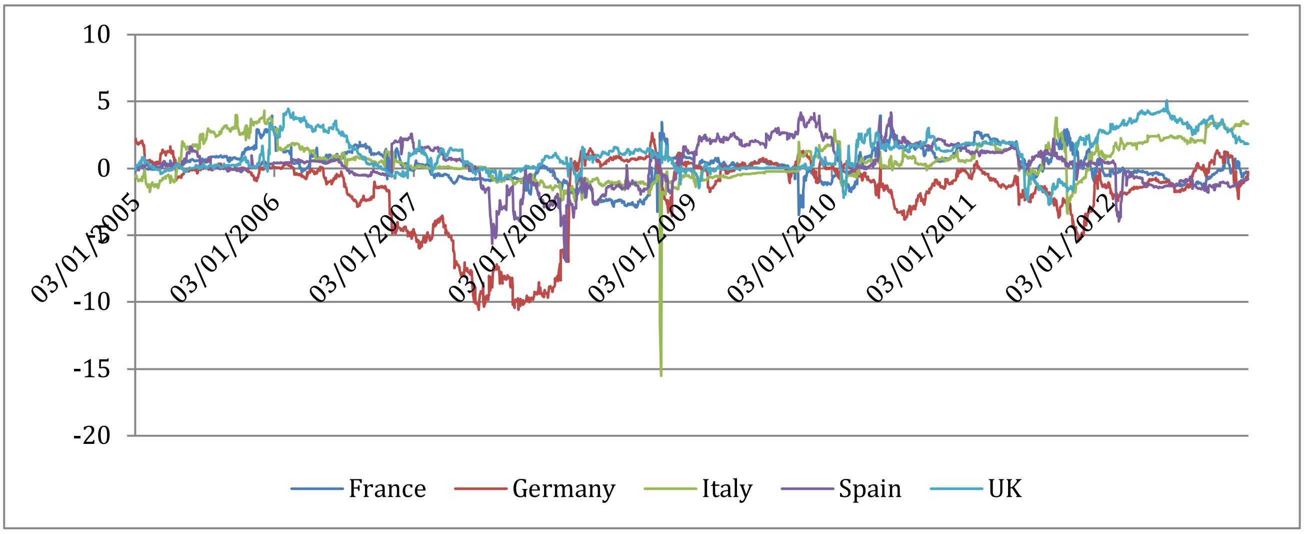
Notes: This figure illustrates the net stock index spillover time series from the DY (2012) estimation procedure based on 260-day rolling window sample. Positive values of the index indicate that the variable is a net "shock transmitter" to all other variables and negative values indicate that the variable is a net "shock receiver" from all other variables in the sample. Total number of observations is 2085 and the rolling sample estimation uses 260 observations. All numbers are in percentages. See Eq (9) for calculation of the net spillovers index. The series covers the period 3rd of January 2004 to 31st of December 2012. The figure indicates that the overall market risk variable was a net "transmitter" of shocks over the sample period.

Figure 7: Net pairwise spillovers: CDS spreads and other variables

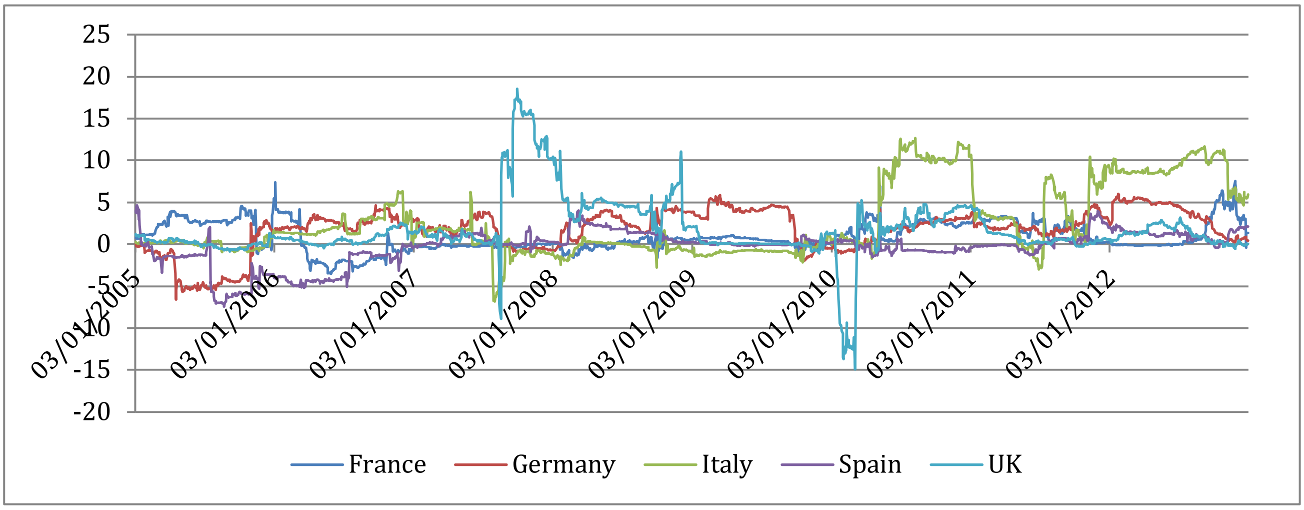
(a) Net pairwise spillovers: CDS spreads and real estate indices



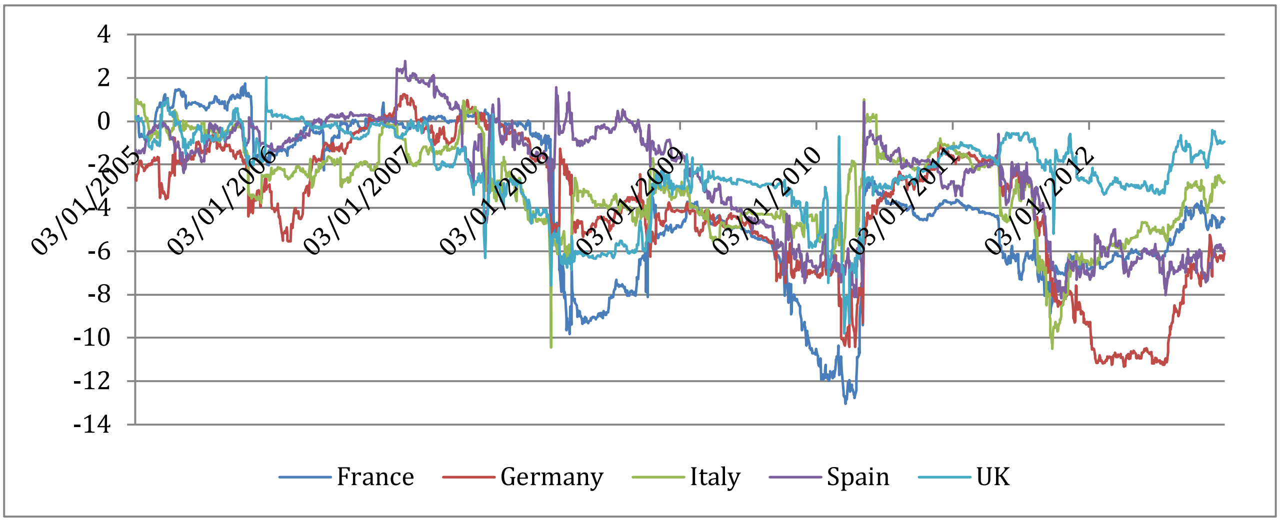
(b) Net pairwise spillovers: CDS spreads and term spreads



(c) Net pairwise spillovers: CDS spreads and liquidity spreads



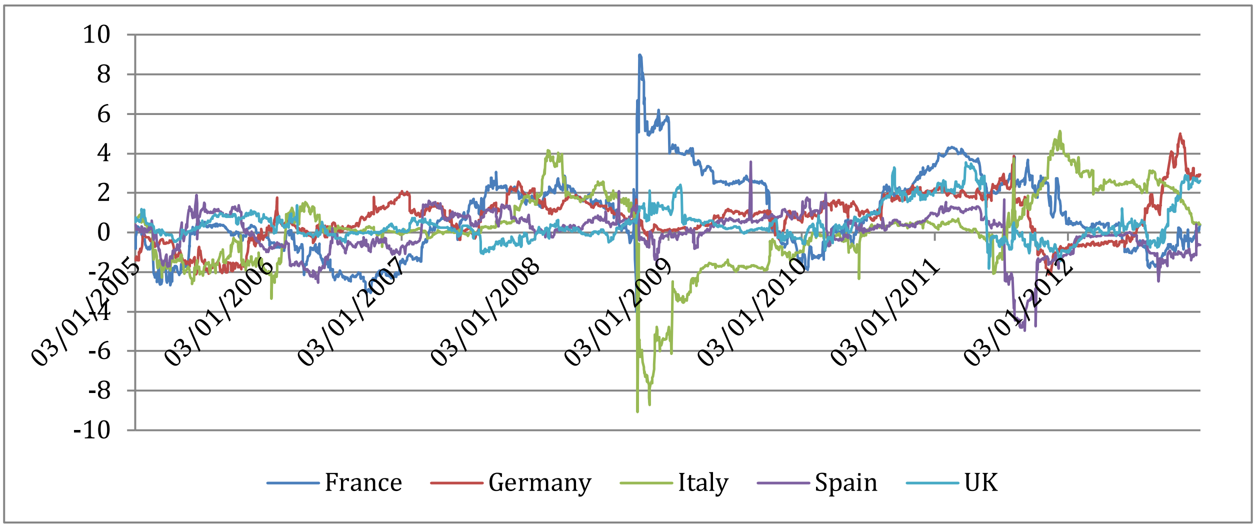
(d) Net pairwise spillovers: CDS spreads and stock indices



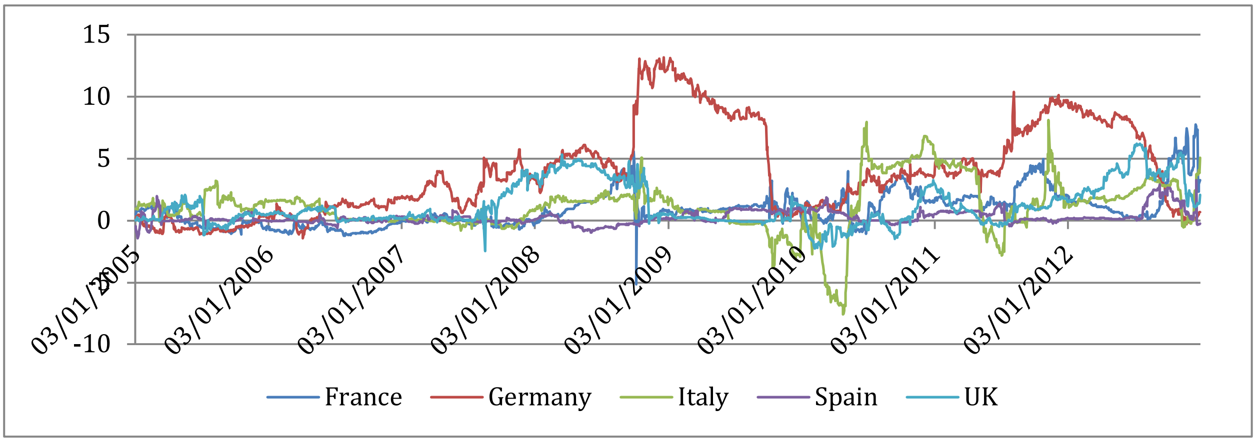
Notes: This figure illustrates the net pairwise spillover time series from CDS to other variables from the DY (2012) estimation procedure based on 260-day rolling window sample. Positive values on the index indicate that the first variable transmits "more" shock to the second variable and negative values indicate the opposite. Total number of observations is 2085 and the rolling sample estimation uses 260 observations. All numbers are in percentages. See Eq (10) for calculation of the net pairwise spillovers index. The series covers the period 3rd of January 2004 to 31st of December 2012. The figure indicates the relationship of the credit risk variable with all other risk factors in the sample reversed over the sample period. The credit risk variable was a net "transmitter" of shocks to the overall market risk variable (d) in the 2010-2011 period. It was a net "receiver" of shocks from this variable during the rest of the sample period. The credit risk variable was a net "transmitter" of shocks to the real estate (a), interest rate (b) and interbank liquidity (c) risk variables since the beginning of the crisis whereas it was a net "receiver" of shocks prior to the crisis.

Figure 8: Net pairwise spillovers: Real estate indices and other variables

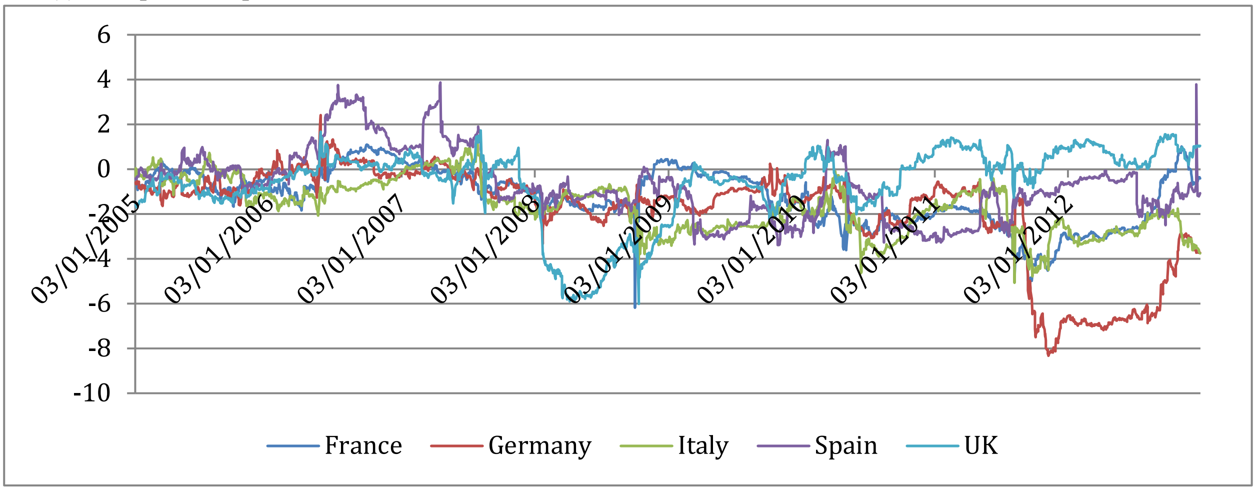
(a) Net pairwise spillovers: real estate indices and term spreads



(b) Net pairwise spillovers: real estate indices and liquidity spreads



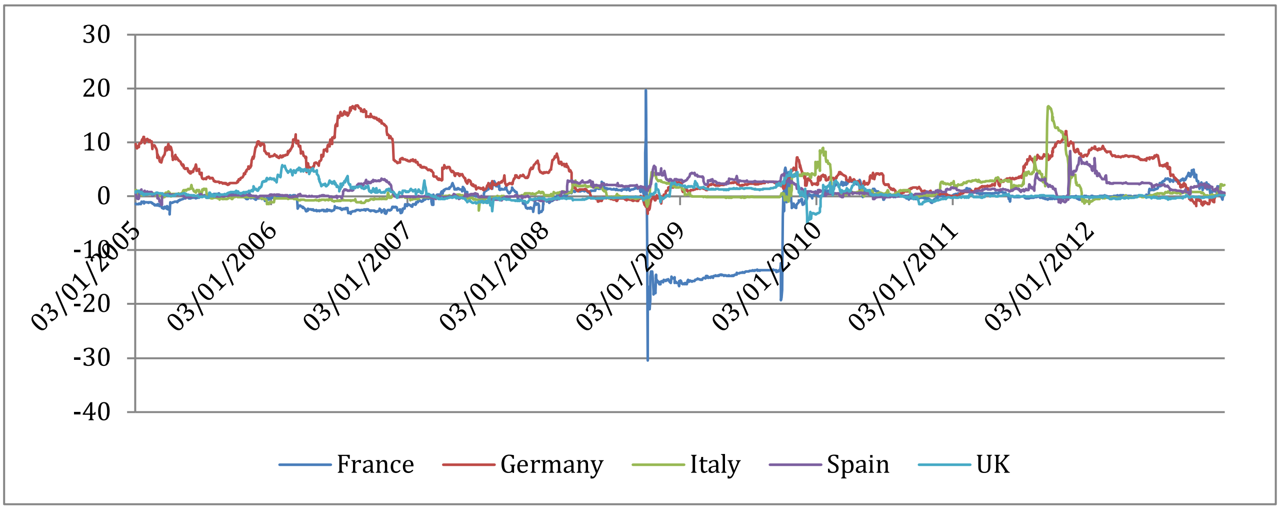
(c) Net pairwise spillovers: real estate indices and stock indices



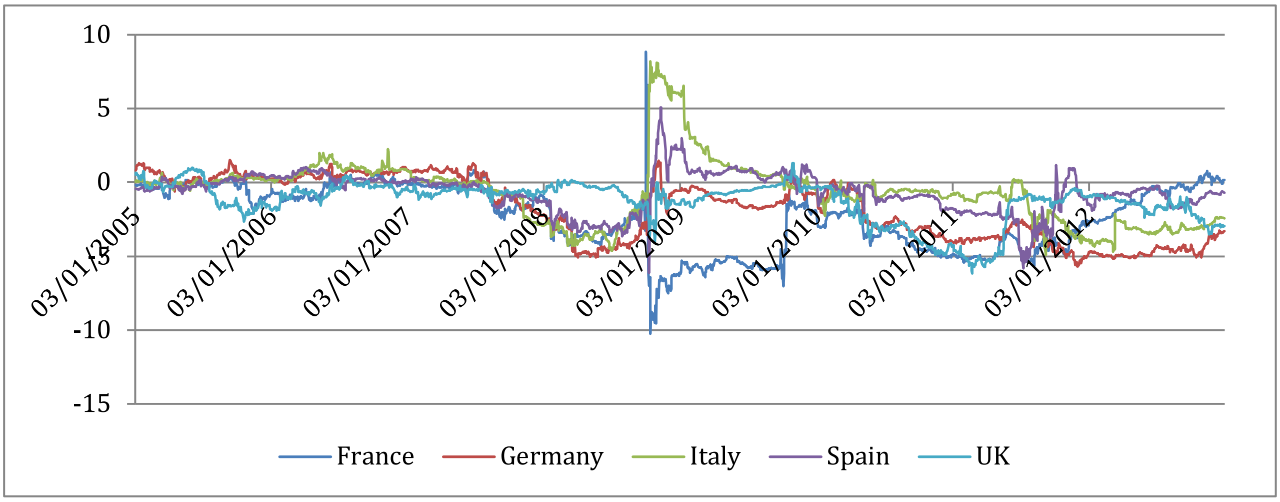
Notes: This figure illustrates the net pairwise spillover time series from real estate index to other variables from the DY (2012) estimation procedure based on 260-day rolling window sample. Positive values on the index indicate that the first variable transmits "more" shock to the second variable and negative values indicate the opposite. Total number of observations is 2085 and the rolling sample estimation uses 260 observations. All numbers are in percentages. See Eq (10) for calculation of the net pairwise spillovers index. The series covers the period 3rd of January 2004 to 31st of December 2012. The figure indicates that overall, the real estate risk variable was a net "transmitter" of shocks over sample period and that there are strong differences in the net spillover index dynamics within the countries in the sample.

Figure 9: Net pairwise spillovers: term spreads and other variables

(a) Net pairwise spillovers: term spreads and liquidity spreads



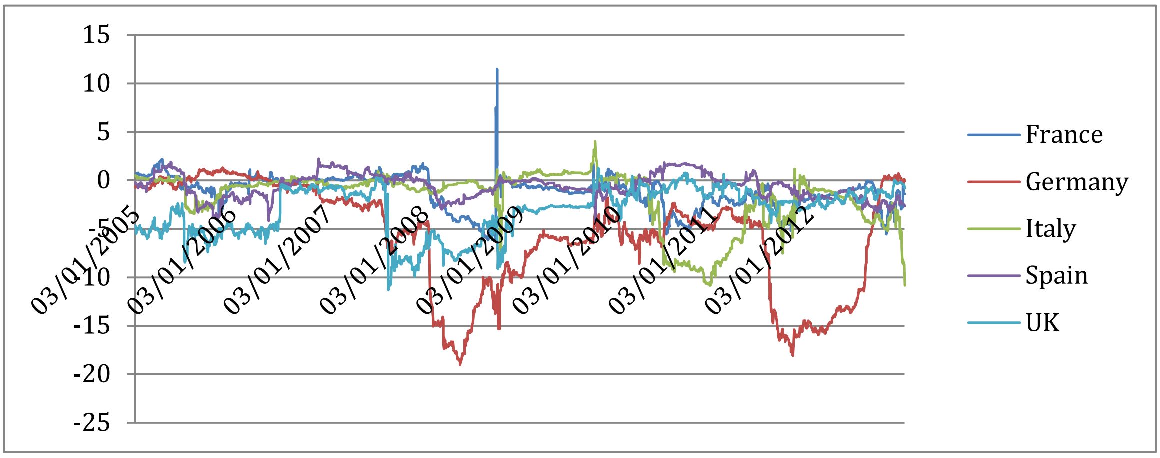
(b) Net pairwise spillovers: term spreads and stock indices



Notes: This figure illustrates the net pairwise spillover time series from term spread to other variables from the DY (2012) estimation procedure based on 260-day rolling window sample. Positive values on the index indicate that the first variable transmits “more” shock to the second variable and negative values indicate the opposite. Total number of observations is 2085 and the rolling sample estimation uses 260 observations. All numbers are in percentages. See Eq (10) for calculation of the net pairwise spillovers index. The series covers the period 3rd of January 2004 to 31st of December 2012. The figure indicates that the interest rate risk variable was a net “transmitter” of shocks to the credit risk (a), real estate risk (b) and overall market risk (c) variables prior to the crisis. Since the beginning of the crisis the variable was a net “receiver” of shocks and the dynamics of the net spillover series varies strongly from country to country.

Figure 10: Net pairwise spillovers: liquidity spreads and other variables

(a) Net pairwise spillovers: liquidity spreads and stock indices



Notes: This figure illustrates the net pairwise spillover time series from liquidity spread to other variables from the DY (2012) estimation procedure based on 260-day rolling window sample. Positive values on the index indicate that the first variable transmits "more" shock to the second variable and negative values indicate the opposite. Total number of observations is 2085 and the rolling sample estimation uses 260 observations. All numbers are in percentages. See Eq (10) for calculation of the net pairwise spillovers index. The series covers the period 3rd of January 2004 to 31st of December 2012. The figure indicates that the interbank liquidity risk variables was a net "receiver" of shocks from all other variables during most of the sample period.