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Bank Fragility and Contagion: Evidence from the CDS market

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Abstract

Using bank CDS data we provide a framework for the evaluation of contagion among international banks in different countries and regions during a period of prolonged financial distress. Following a Generalized VAR (GVAR) approach, we distinguish between two types of contagion: systematic contagion (linked to global factors), and idiosyncratic contagion (linked to bank specific factors). While the overall contagion was driven by the systematic component during the global financial crisis, with US banks being net transmitters, the idiosyncratic component becomes more relevant during the eurozone crisis. US banks are not receiving instability from eurozone banks. Banks in euro-peripheral countries are net transmitters of idiosyncratic contagion whereas banks in euro-core countries are net transmitters of systematic contagion.

Keywords: CDS spreads, contagion, GVAR, financial stability, financial crisis

JEL classification: G15, G21, C58

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1. Introduction

The turmoil which hit in the world's financial systems in the summer of 2007 has spurred a new debate on bank fragility and contagion. This has been compounded by the sovereign debt crisis in the eurozone, which highlighted the link between bank and country risk. When the eurozone crisis intensified in late 2011, the euro area banking systems became increasingly under pressure, as the adverse interaction between sovereigns and banks deepened, mainly via banks' portfolio exposure to weakened foreign sovereign bonds, amid fears of financial contagion.

Using bank credit default swaps (CDS) spreads as indicators of bank risk, this paper aims to identify the transmission mechanism of risk in the banking sector during the prolonged crisis period. We aim to shed some light on how contagion works among financial institutions, as this is the key to understanding the propagation of financial crises.

Although a very intuitive concept, "contagion" is difficult to define and measure empirically. Financial institutions are highly interconnected through a network composed by the interbank market, the payment system, the financial markets and so on. Similarly, economies are interconnected through financial and trade linkages. Interconnectedness describes situations when financial distress in one institution (country) significantly increases the probability of financial distress in other institutions (countries). The increased globalization of trade and markets has strengthened these linkages or interconnections, which are also described as spillovers channels of interdependence. In the first instance, contagion can be defined as the transmission of shocks over and above what is expected by the interdependence described above. Dornbusch *et al.* (2000), Kaminsky *et al.* (2003), Bae *et al.* (2003) and Longstaff (2010), among others, define contagion as an episode in which there is a significant increase in cross-market linkages when a shock occurs. According to Forbes and Rigobon (2002) when two markets exhibit a high degree of co-movement during stable periods, and these co-movements do not increase significantly after a shock, then it is interdependence rather than contagion. However, increased co-movements heighten the risk that financial distress originating in a few institutions can spread to many others and distort the supply or credit to the real economy (Yang and Zhou, 2013). Bekaert *et al.* (2014) define contagion as the co-movement in excess of what can be explained by fundamentals taking into account their evolution over time.

A common approach to measure contagion is the analysis of correlation coefficients across markets or assets returns and an increase in correlation is seen as evidence of contagion. Pericoli and Sbracia (2003) review different definitions and related measures of contagion that are frequently used in the literature, including changes in the probability of currency crises; volatility spillovers (commonly based on the estimation of multivariate GARCH models); Markov-switching models to test for jumps between multiple equilibria; correlation or co-movements in financial markets and changes in the transmission mechanism, that is when a country-specific shock becomes global. All methodologies have limitations and a number of caveats often apply.

In this study, we define contagion as the change in the propagation mechanism when a shock occurs and we measure it in terms of return spillovers. In addition, we propose an innovative framework to distinguish between two types of contagion: systematic contagion (linked to global factors), and idiosyncratic contagion (linked to bank specific factors). In line with recent literature we use the credit default swap (CDS) spreads of major banks as an indicator of bank risk.[2] CDS spreads have a number of advantages in proxing for risk, including a more accurate measurement of default risk and higher liquidity (Blanco *et al.*, 2005; Longstaff *et al.*, 2005; Zhang *et al.*, 2009; Yang and Zhou, 2013). Despite these characteristics, the use of CDS data on financial institutions is fairly recent and came to prominence only as a consequence of the global financial crisis (Stulz, 2010; Eichengreen *et al.*, 2012).

We contribute to the literature in the following ways. We bring together the literature on financial contagion and the literature on systematic risk, to provide a better understanding of how contagion works in the banking sector. An understanding of the dynamics of international risk transmission is key to regulators and policy makers who need put in place framework for the prevention of contagion in financial markets. In addition, we provide evidence of the time variation of

[2] A CDS is essentially an insurance contract against a credit event of a specific reference entity. The CDS spread is the periodic rate that a protection buyer pays on the notional amount to the protection seller for transferring the risk of a credit event for some period. Since late 2008, the CDS market has attracted considerable attention and CDS are considered a good proxy for bank riskiness and default probability.

the credit risk transmission at different stages of the prolonged global crisis by analysing contagion in US and European banking markets during the period January 2004 to March 2013. We do so in a rolling framework, which enables us to analyse the evolution of contagion over time and during a number of "phases" of market instability.

The methodological approach follows a two-stage procedure. In the first stage, we identify common patterns from individual bank CDS returns, estimated following Berndt and Obreja (2010). To extract the common factors underlying the correlations among the CDS returns series of individual banks, we use principal components analysis (PCA) over the sample period, using 200-day rolling windows. Throughout the analysis, bank CDS returns series are decomposed in two non-observable components, a common (systematic) and a residual component, that is, the idiosyncratic bank CDS return. More specifically, the systematic returns capture the part of CDS returns due to changes in the common global risk factor, whereas the idiosyncratic component captures the part which is explained by changes in bank fundamentals. In this respect, our analysis differs from the strand of the literature which focuses on the determinants of CDS spreads, such as, for example, Collin-Dufresne *et al.* (2001); Ericsson *et al*. (2009).

In a further step, we classify banks according to their country of origin and build four equally weighted portfolios of CDS returns. We distinguish among banks headquartered in the following geographical areas: United States; "eurozone core" (i.e. Austria, Belgium, France Germany and Netherlands); "eurozone peripheral" (Greece, Italy, Portugal and Spain) and finally, “non-eurozone” (Denmark, Norway, Sweden, Switzerland and UK). The use of portfolios provides an efficient way to summarize all the information included in individual bank CDS returns, with the advantage of smoothing the noise presents in the data, mainly due to transitory shocks in individual insitutions.

Following a Generalized VAR (GVAR) approach (Diebold and Yilmaz, 2012) we estimate contagion, in terms of return spillovers, between banks CDS returns portfolios. We estimate contagion for both the total and the idiosyncratic CDS returns, and we interpret the difference between the two as systematic contagion. In addition, the examination of net directional return spillover measures enables us to identify group of banks in countries that can be seen as net transmitters and receivers of contagion.

As a way of preview, our main results are as follows. The proportion of variance of banks' CDS returns series explained by common factors changes considerably during the sample period. Up until mid-2007, banks' CDS returns exhibited a limited amount of co-movement, and the contribution of common factors was limited. The picture changed after July 2007, with the results indicating an increasing amount of commonality in banks' CDS returns. These changes in the co-movement dynamics can be interpreted as first evidence of contagion.

This outcome is confirmed by the results of the GVAR estimations, which evidence systematic contagion across markets during the global financial crisis (2007-2009) and subsequent eurozone crisis (from 2009). Prior to 2007, total return spillovers were low and mostly idiosyncratic in nature. From July 2007 onwards, the total spillover index climbed from 10% to around 60%. While the increase can be attributed to both the idiosyncratic and systematic components, at the height of the financial crisis contagion seem to be overwhelmingly driven by the systematic component. Interestingly, while the idiosyncratic component quickly returns to previous levels following a shock; the systematic component remains high, thereby causing the total spillover index to remain high. This seems to indicate that between 2007 and 2009 contagion happened and was mainly due to common components, i.e. to systematic risk. The picture changed during the eurozone crisis, as the impact of the idiosyncratic component became more pronounced. Similarly to previous trends, idiosyncratic shocks triggered a sharp temporary increase in the idiosyncratic contagion index, which then translated in the systematic contagion index remaining high for longer periods of time.

In summary, we find evidence of contagion in banking markets, evidenced by an increase in co-movement in CDS returns. Contagion came in different waves, from July 2007 onwards, with the financial and eurozone crises being distinct episodes. While during the financial crisis contagion was systematic in nature, during the eurozone crisis the idiosyncratic part played a more dominant role.

US banks appear to be net transmitters of contagion, particularly during the 2007-2009 period, with all EU countries being net receivers. Unsurprisingly, during the eurozone crisis, banks in "eurozone peripheral" countries were net transmitters in terms of idiosyncratic spillovers (particularly from May 2010 onwards). Eurozone troubles are barely affecting US banks, and only "eurozone core" and "non-eurozone" countries' banks appear to be net receivers, with the latter group receiving more contagion than the “eurozone core”. Interestingly, the role of net transmitters of systematic contagion belongs to banks in "eurozone core" countries with the "eurozone peripheral" being net receivers, particularly in the latter stages of the crisis and during the Cyprus episode. This suggests that banks in "eurozone peripheral" countries are perceived as extremely fragile as they are seen as transmitter of idiosyncratic contagion and as receivers of systematic contagion. The differences in vulnerability to contagion within the European Union and even within the eurozone are remarkable, with the eurozone periphery more exposed to systematic contagion.

The remainder of the paper is organised as follows. Section 2 describes the data and preliminary analysis. Section 3 discussed the methodological approaches. Section 4 presents the results while section 5 concludes.

2. Data and Preliminary Analysis

The data set consists of daily CDS spreads for banks in Europe and US, collected from the Thomson Datastream database and provided by CMA New York.[3] Following Jorion and Zhang (2007) and Eichengreen *et al.* (2012), among others, we select 5-year CDS quotes, since these contracts are generally considered the most liquid and constitute the majority of the entire CDS market The CDS spread shows the 5-year CDS premium mid expressed in basis points.

The sample period covers almost a decade, from January 2004 to March 2013.[4] This relatively long time period allows us to investigate both a more stable period (i.e. the pre-crisis period, from January 2004 to June 2007); the global financial crisis period (July 2007 - September 2009) and the European sovereign debt crisis period (October 2009 - March 2013).[5]

[3] Although daily data are subject to more noise compared to weekly and monthly data, there are also some advantages. Using daily data provides us with more observation points and, therefore enhances the estimation efficiency (Elyasiani *et al.*, 2015). In addition, daily data better capture short-lived co-movements and spillover effects Eun and Shim (1989); Hamao *et al.* (1990); De Santis and Gerard (1998). Mayordomo *et al.* (2014) conclude that among the six most widely used CDS data bases CMA is the data source leading the others.

[4] Although data on CDS spreads are available from January 2003, only a very small number of banks (around 18% of the banks in the sample) traded in CDS during 2003, while the majority of banks in our sample started to take part in CDS activities after 2004.

[5] Note that the indication of the reference period as "pre-crisis"; "global financial crisis" and "eurozone crisis" is only an approximation for ease of discussion. We do not impose specific time periods, as the estimations are carried out on a 200-day rolling window and let the data tell us when the changes occur.

We collect CDS data on all European and US banks with actively traded CDS and exclude only those banks which trade too infrequently.[6] This leads to a sample coverage of over 90% of all banks trading CDS. Our sample is composed of 55 large banks, headquartered in 15 countries (50 European banks and 5 US banks).[7] More specifically, this results in 122,984 (unbalanced) panel observations for 2,407 days. Table 1 illustrates the sample banks, the available number of observations and the total assets value for each bank.

<Insert Table 1 around here>

The main difficulty in constructing CDS returns is that there is no time series data on actual transaction prices for a specific default swap contract. To overcome this issue, we follow the intuitive framework proposed by Berndt and Obreja (2010) and use daily CDS spreads to calculate CDS returns, using a strategy that replicates the payoff of the contract.[8] CDS returns computed this way capture the change in default risk due to increments in CDS spreads. In addition, CDS returns also incorporate, among other things, the level of CDS spreads in the probability of default. One additional advantage of using CDS returns is that it allows us to obtain stationary returns series.

In a next step, we build four equally weighted portfolios, using average CDS data for each bank headquartered in a country within a specific area.[9] The first portfolio consists of banks headquartered in Greece, Italy, Portugal and Spain. We define this portfolio as Euro-Peripheral, as it includes banks

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[6] CDS trading activity is heterogeneous among market participants. Chen *et al.* (2011) present data on market composition and trading dynamics on global CDS transactions and report that trade frequency in single-name CDS was on average relatively low (less than once a day), with market activity dropping off quickly after the top set of traded names. Notably, the financial sector reference entities includes the largest share of the actively traded CDS.

[7] Our sample is larger than those used in previous studies. For example Eichengreen *et al.* (2012) have a sample of 45 banks and Yang and Zhou (2013) of 43 banks as they include only the largest financial institutions in a smaller number of countries.

[8] See Appendix A for methodological details.

[9] We build equally weighted portfolios with the aim to obtain CDS portfolios which reflect the average bank credit risk in a specific geographical area. As a robustness check, we repeat the analysis using portfolios, weighted by bank total assets. Weighted portfolios would reflect the average credit risk for a specific area, giving greater weight to larger banks. The results of the estimations derived from the use of weighted portfolios are similar to the ones obtained with equally weighted portfolios, with two main differences. In the period before January 2007, systematic credit risk spillover is on average higher (30% level). In addition, the total spillover for the whole sample period is about 20% higher than the total spillover with equally weighted portfolios. This seems to indicate that using weighted portfolios overestimates the level of total spillovers.

in countries with the more severe debt problems within the eurozone. The second portfolio consists of banks headquartered in the so-called euro-core countries (Austria, Belgium, France, Germany and Netherlands); we label this portfolio as Euro-Core. The third portfolio comprises banks from European countries but outside the eurozone (Denmark, Norway, Sweden, Switzerland and the UK); we label this portfolio Non-Euro. Finally, our fourth portfolio consists of US banks.

<Insert Table 2 about here>

Figure 1 illustrates the daily time evolution of CDS spread and return series for the four portfolios; descriptive statistics are reported in Table 2. It can be easily seen that from July 2007 CDS spread started to increase dramatically, both in level and volatility. CDS spreads were relatively stable, at around 16 bps (and this is fairly homogeneous regardless of the country), until July 2007, when they started to grow considerably, mainly for US banks, in response to the sub-prime crisis. In March 2009, CDS spreads peaked at over 216 bps for Euro-Peripheral countries' banks; 274 bps for Euro-Core; 228 bps for Non-Euro and 338 bps for US banks respectively. Note that all the banks in the sample experienced positive CDS returns (on average) during the pre-crisis period, whereas throughout the global financial crisis returns became negative on average. This may suggests that during periods of instability CDS spreads are not fully explained by banks' credit risk (default component), but are also driven by the overall market situation (common global component). For US banks, negative average returns were around 50% lower than CDS returns for European banks. Outside the US, countries whose banks were the most affected by the global financial crisis were Belgium, Greece and Spain. With hindsight, this can be seen as a prelude to the trouble their banks faced in more recent times.

<Insert Figure 1 about here>

In months following the peak of the sub-prime crisis, the level of CDS spreads for US and European banks began to fall, but still remained higher compared to the pre-crisis period. After

December 2009, substantial differences can be evidenced between US and EU banks. In the US, CDS spreads peaked in March 2009, at over 338 bps (increasing by 600% in means). The trend then reverted reaching a minimum in December 2009 and spreads have remained fairly stable since. Indeed, in the period, 2009-2013 US banks CDS spreads stabilised at values below those seen previously but higher than pre-crisis period values. In Europe, however, the recovery phase was short lived and turmoil persisted during the 2009-2013 period. For Eurozone banks, CDS spreads started increasing gradually during the last quarter of 2009 and displayed record peaks in November 2011 and then again in May 2012. It is during this period that the differences between US and EU banks CDS spreads became more evident, thus indicating that, while EU banks were badly affected by the sub-prime crisis, US banks were relatively immune to eurozone banks' troubles. Indeed, US banks are the only banks with positive average CDS returns during the most recent part of our sample period.

From October 2009, differences also become apparent between EU banks. Specifically, banks from Euro-Peripheral countries exhibit larger increase in CDS spreads. This was driven by increased spreads on bank CDS from Greece (up to a peak of 4,191 bps), Portugal (with a peak of 1,484 bps) and, to a lesser degree, Spain (peak 770 bps), Belgium (peak 709 bps) and Italy (peak 695 bps). These exceptionally high values are linked to national debt crisis. In contrast, CDS spreads for German and UK banks barely rose during the same time period. In addition, banks from countries outside the eurozone showed, on average, lower levels and volatility compared to the CDS spread curve for their Eurozone counterparts.

3. Empirical methodology

Using CDS spreads as an indicator of bank fragility, we analyse the contagion effect among banks over time. We define contagion as the change in the propagation mechanism when a shock occurs and we measure it in terms of return spillovers. In addition, we distinguish between two types of contagion, systematic contagion, linked to global factors, and idiosyncratic contagion, due to bank specific factors.

The methodology combines principal component analysis (PCA) and Generalized Vector Autoregressive framework (GVAR) and follows a two-stage empirical procedure.

3.1. First stage: Identification of common patterns

The first step of the analysis consists of the identification of common factors in bank CDS spreads. Principal component analysis (PCA) allows us to extract the common factors that can satisfactorily explain the correlations over time among the returns series in order to determine idiosyncratic bank CDS returns.

Let Y be the $T \times k$ CDS returns data matrix, where T is the sample size and k is the number of banks considered in the analysis. We project the data matrix on a d-dimensional plane of the form

$$Y = PC \cdot W' + \upsilon \quad (1)$$

where the columns of the $k \times d$ matrix W are d eigenvectors corresponding to the largest d eigenvalues of the correlation matrix YY'/T, the columns of the $T \times d$ matrix PC are the first d principal components, while the resulting residuals are gathered in the columns of the $T \times k$ matrix υ.

Throughout this analysis, bank CDS returns series are decomposed in two non-observable components, the common and the residual component, that is, the idiosyncratic bank CDS return. Using these residuals we construct the same four portfolios sorted by geographical zones as in the previous section. This way, we have the idiosyncratic CDS returns of the four portfolios in addition to their total CDS returns. This enables us to study contagion, in the next step, in terms of return spillovers, both for the total and the idiosyncratic CDS returns portfolios. The difference between the two components can be interpreted as systematic contagion.

If the CDS returns for individual banks are not correlated, then we can assume that the risk of failure of a bank is related to bank-specific factors. On the other hand, if there is an increasing amount of co-movement, then we can assume that all banks are exposed to a common (systematic) risk.

In addition to that, PCA provides us with a measure of the percentage of variance explained by each principal component, which is computed as the ratio between the d eigenvalues divided by the sum of all eigenvalues. Moreover, if we observe a significant increase in cross-market co-movements around the sample period this can be considered as an indicator that contagion has occurred.[10]

3.2. Second stage: Return spillover estimation

The return spillover effects are obtained following the Generalized Vector Autoregressive framework (GVAR) methodology developed by Diebold and Yilmaz (2009; 2012), which is a VAR-based spillover index particularly suited for the investigation of systems of highly interdependent variables. Spillovers are measured from a particular variance decomposition associated with an *N*-variable vector autoregression framework, which allow us to parse the forecast error variances of each variable into parts which are attributable to the various system shocks. The main advantage of this approach is that it eliminates the possible dependence of the results on ordering, in contrast to the traditional Cholesky factorization.[11] In addition to that, it includes directional contagion indicators from/to a particular series, not only the total spillovers.

More specifically, this approach consists of two steps. First, we consider a covariance stationary N-variable VAR(p)

$$x_t = \sum_{i=1}^{p} \phi_i \, x_{t-i} + \varepsilon_t \qquad (2)$$

where $\varepsilon \sim (0, \Sigma)$ is a vector of independently and identically distributed disturbances and x_t denotes a N-variable vector of CDS returns. In particular, since the analysis is performed twice, x_t will be first, the total and second, the idiosyncratic CDS returns of the four portfolios previously built. To ease the analysis the model is written as the moving average representation $x_t = \sum_{i=0}^{\infty} A_i \varepsilon_{t-i}$, where the

[10] See Gentile and Giordano (2013) and Andernmatten and Brill (2011), among others.
[11] This problem is circumvented by exploiting the generalized VAR framework of Koop *et al.* (1996) and Pesaran and Shin (1998), among others.

$N \times N$ coefficient matrices are estimated by $A_i = \phi_1 A_{i-1} + \phi_2 A_{i-2} + \cdots + \phi_p A_{i-p}$, with A_0 being the identity matrix and $A_i = 0$ for $i < 0$.

Next, we calculate the variance decompositions. The variance shares defined as the fractions of the *H*-step-ahead error variances in forecasting x_i that are due to shocks to x_j, for $H = 1,2, \ldots$, are given by

$$\theta^G_{j\to i}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} \left(e_i' A_h e_j\right)^2}{\sum_{h=0}^{H-1} \left(e_i' A_h \Sigma A_h' e_i\right)}, \text{ for } i, j = 1,2, \ldots, N \tag{3}$$

where σ_{jj} is the standard deviation of the error term for the *j*th equation, i.e. the squared root of the diagonal elements of the variance-covariance matrix Σ and e_i is the vector with one as the *i*th element and zeros otherwise. As the shocks to each variable are not orthogonalized, the row sum of the variance decomposition is not equal to 1. Thus, each entry of the variance decomposition matrix can be normalized by the row sum as

$$\tilde{\theta}^G_{j\to i}(H) = \frac{\theta^G_{j\to i}(H)}{\sum_{j=1}^{N} \theta^G_{j\to i}(H)} \times 100, \text{ for } i, j = 1,2, \ldots, N \tag{4}$$

where the multiplication by 100 is just to have it in percentage terms. Note that, by construction $\sum_{j=1}^{N} \tilde{\theta}^G_{j\to i}(H) = 100$ and $\sum_{i,j=1}^{N} \tilde{\theta}^G_{j\to i}(H) = N \times 100$.

Note that return spillovers show the degree of variation in CDS returns of portfolio *i* which is not due to the historical information of the CDS returns of portfolios *i* and *j* but to shocks (innovations) in CDS returns of portfolio *j*. This indicator takes higher values as the intensity of the contagion effect, caused by the specific shocks of *j*'s CDS returns, increases. In the extreme case in which there are no spillovers from one series to the other, the indicator is equal to zero.

Using the above normalized variance contributions we can then construct some different spillover measures. The *total return spillover* index, which measures the contribution of spillovers of return shocks across all *N* series to the total forecast error variance is given by:

$$TS^G(H) = \frac{\sum_{\substack{i,j=1 \\ i \neq j}}^{N} \tilde{\theta}_{j \to i}^{G}(H)}{N} \tag{5}$$

It indicates on average the percentage of the forecast error variance in all the series that comes from spillovers (from contagion due to shocks).

The *net directional return spillover* indices measure the spillover transmitted by portfolio i to all others

$$NDS_{i \to all}^{G}(H) = \sum_{\substack{j=1 \\ i \neq j}}^{N} \tilde{\theta}_{i \to j}^{G}(H) - \sum_{\substack{j=1 \\ j \neq i}}^{N} \tilde{\theta}_{j \to i}^{G}(H), \text{ for } i = 1,2,\dots,N \tag{6}$$

This is the difference between the gross return shocks transmitted by *i* to all other portfolios and those received by *i* from all other portfolios. Positive (negative) values of the NDS index indicate that portfolio *i* is a transmitter (receiver) of return spillover effects, in net terms.

Finally, the *net pairwise return spillover* indices between series *i* and *j* are defined as

$$NPS_{i \to j}^{G}(H) = \tilde{\theta}_{i \to j}^{G}(H) - \tilde{\theta}_{j \to i}^{G}(H), \text{ for } i,j = 1,2,\dots,N \tag{7}$$

This is the difference between the gross return shocks transmitted from *i* to *j* and those transmitted from *j* to *i*. Hence, it is positive (negative) when the impact of *i*'s shocks is higher (lower) than vice versa, indicating that portfolio *i* is net transmitter (receiver) of return spillovers to (from) portfolio *j*.

4. Empirical results

4.1 Common factors in bank CDS returns

The first step to understand contagion is to explore the pair-wise correlations between the returns of CDS spreads for banks in the sample. A preliminary correlation analysis indicates that the pair-wise correlations between the bank CDS returns are high, not only among banks from the same country, but also among banks from different countries.[12] Given these results, it is necessary to explore bank CDS returns co-movements over time in more detail. To do so, we perform a PCA with a rolling sample framework using 200-day rolling windows.

<Insert Figure 2 about here>

Figure 2 plots the time evolution of the proportion of variance explained by the first four principal components[13] of bank CDS returns series. [14] The analysis shows that the contribution of common factors to the total variation in CDS returns changes largely through the sample. Before mid-2007, the proportion of variability due to common factors was varied between 10% and 40% (with an increasing trend over time). On average, in stable periods, bank CDS returns exhibit a limited amount of co-movement. The first four factors explain on average the 33% of the total variance of the returns, thus suggesting that during stable periods bank credit risk may be mainly linked to bank fundamentals and not be driven by global macroeconomic factors.

The picture changes after the onset of the sub-prime crisis on July 2007. The co-movements in CDS returns increase significantly, fluctuating between 40% and 70%. After July 2007, the contribution of the first four components doubled and the percentage of total variance explained by the four components became, on average the 44%, 50%, 56% and 60% respectively. These results indicate that common factors play an important role in bank CDS market during periods of financial distress. It is possible to identify significant events in financial markets' recent years and observe the corresponding increase in co-movement in CDS returns.

[12] Not shown, available upon request.
[13] The fifth principal component individually explains less than 4 percent of the variance. Thus, the rolling PCA is based on the first four principal components.
[14] In order to check the potential presence of serial correlation in bank CDS returns correlation matrix we have filtered for autocorrelation. The results are robust and available upon request.

In the period between January 2007 and March 2008, the portion of variance explained by the first four components jumped from 30% to 63% (increasing by 110%). During this period we observe three main peaks. On August 2007 co-movement increases quickly up to 58%; in January 2008 co-movement increases to 62%, and in March 2008 (at the time of the Bear Stearns troubles) co-movement in CDS returns rises to 64%. Following Bearn Stearns' rescue, the percentage of variance explained by common components remained high, at 50-60%. Following Lehman Brothers' failure, the increase in co-movement became even more evident. Further increases in co-movement were related to episodes of the eurozone sovereign debt crisis. For example, in May 2010, at the time of the Greek bailout, we observe the highest share of explained variance accounted by principal components: it reached 73%, and remained very high until February 2011.

In summary, the results of the PCA indicate that there is a significant amount of commonality in CDS returns across all the 55 banks. These results are consistent with the idea that during periods of international financial crises, correlations between assets and markets are higher and this is often a key element in the underestimation of risk in stress periods. Changes in the co-movement dynamics among financial institutions' CDS returns that are in excess of analyst expectations can be seen as signals of contagion.

4.2: Return spillovers

Once we have established high co-movement in bank CDS returns, the next step is then to evaluate if contagion occurred. We measure the spillover effect using the variance decomposition approach of Diebold and Yilmaz (2012). We generate spillover measures using 200-day rolling samples and assess the variation over time via the corresponding time series of spillover indices. The model is estimated twice, for total and idiosyncratic CDS returns of the four portfolios built previously (US; Euro-Peripheral; Euro-Core and Non-Euro). Idiosyncratic returns are obtained from bank residuals, which are calculated once the PCA's common component is extracted from total returns.

At each window, the lag p of the GVAR model is determined using the likelihood ratio test, which confirms that p varies over time.[15] To choose the forecast horizon of ten days ($H = 10$) we compute at each window the *total return spillover* index for H varying from 1 to 16. The results show that the index is sensitive to the choice of the forecast horizon for low values of H, but in general it is stabilized for $H = 10$. This is the forecasting horizon commonly used in similar studies (see for example Diebold and Yilmaz (2012).

<Insert Figure 3 here>

Figures 3 to 5 present the evolution over time of the different return spillover measures, corresponding to total contagion, obtained using total CDS returns, (in blue in the Figures) and to the idiosyncratic contagion, computed using idiosyncratic returns (in grey in the Figures), due to bank specific factors. The difference between the two types of contagion can be interpreted as systematic contagion, linked to global or common factors.

The time dependent *total return spillover* index illustrated in Figure 3 reveals high levels of contagion across markets, especially after the onset of the global financial crisis on July 2007.[16] Prior to the credit crunch, the *total return spillover* index was in general quite low (around 15%) and it was mostly idiosyncratic in nature, probably reflecting the stable financial environment of that period. In July 2007, with the onset of the sub-prime crisis, total contagion started to increase: it climbed from 10% to 60% in the following months and it remained around 50% for the rest of the sample period. This indicates a high level of interconnectedness across bank CDS international markets.

Idiosyncratic contagion also increased (to 25%) in July 2007, but the peak only lasted a few days and then it decreased to previous levels. As the sub-prime crisis turned into the global financial crisis, affecting the world financial markets, we find strong evidence of systematic contagion across banking markets. For instance, only 14% of the total 64% of the spillover effects observed in March

[15] The Akaike information criterion does lead in some cases to higher values, but this criterion tends to overestimate the number of lags.
[16] See Appendix B for a timeline of key events in the global financial and eurozone crises.

2008 after the Bearn Stearns' bailout can be attributed to the idiosyncratic component, the remaining 50% is thus imputable to the systematic component.

During the European sovereign debt crisis (2009-2013) idiosyncratic contagion became more pronounced, increasing from 15% to 25% on average, although the systematic component remained high (25%) and equally important. At the height of the Greek crisis, the idiosyncratic spillover index increased to 35%, but the systematic component still played an important role (27% of the total 62%). Despite the fact that the increase in the overall spillover index was driven by a spike in the idiosyncratic component, the impact on the systematic component had a longer lasting effect as it took a longer time for the index to return to previous levels.

A similar pattern can be observed in the second half of 2011. During this period, the increasing concerns about the worsening of public finances in several eurozone countries, together with the perspective of a restructuring of Greek sovereign debt, heightened financial market tensions in the eurozone. This leads to an increase in the idiosyncratic component of 40% (the biggest increase over the whole sample period), whereas the systematic component remained at around 13%.

The policy measures conducted by the ECB in October 2011 and February 2012 appeared to have had a positive impact as it encouraged a more benign financial market sentiment in the first half of 2012.[17] The total return spillover index, our chosen measure of contagion, remained high fluctuating at around 50%. Interestingly, however, the idiosyncratic component declined significantly after December 2011, while the systematic component remained high.

A further significant increase in the idiosyncratic spillover effects occurred in the period September-December 2012 (over 30%), this time accompanied by a decrease in the systematic component, as the total spillover index did not change. One possible explanation is that markets worried about the fate of Spanish banks, as Spain's cost of borrowing shot up. Uncertainty on how to respond to Spanish problems unsettled the markets; however, similarly to previous idiosyncratic shocks, it triggered temporary increases in the idiosyncratic contagion index, while the systematic contagion index remained high for a longer period of time.

[17] The ECB decided to conduct refinancing operations that significantly extended the horizon at which credit institutions could obtain liquidity from the Eurosystem (for more details see Appendix B).

4.3:Net Directional Spillovers and Net Pairwise Return Spillovers

The next step of the analysis is to account to directional information. To this end, we compute the *net directional return spillover* index, which is presented in Figure 4. The *net directional return spillover* index will enable us to identify the net transmitters and receivers of contagion. In addition we compute the *net pairwise return spillovers* effects between two markets and time evolution pairwise relationships are summarized in the three sub-periods: the pre-crisis period (January 2004 – June 2007), the global financial crisis period (July 2007 – September 2009) and the eurozone sovereign debt crisis period (October 2009 – March 2013), as shown in Figure 5.[18]

<Insert Figure 4 here>

<Insert Figure 5 here>

Looking at Figure 4 and Figure 5, we can see that the idiosyncratic component of contagion observed during the first part of the sample period (January 2004 – July 2007) appears to have been present in all portfolios, which indicates that all banks in all countries were both at the giving and receiving ends of the net transmissions, with similar magnitudes. Nevertheless, the most interesting part of the *net directional return spillover* index plot concerns the recent financial crises.

Banks in the US were the only ones that remained positive, in net systematic terms, throughout the various stages of the crises, especially during the global financial crisis (2007-2009). In July 2007 the net return spillovers from US banks were as high as 140% (of which 130% systematic and 10% idiosyncratic). Systematic contagion was mostly transmitted to banks located in Euro-Peripheral countries (76%) and to banks in Non-Euro countries (57%). After this extraordinary impact, systematic contagion declined significantly. Surprisingly, the impact of the sub-prime crisis from US banks was limited for Euro-Core banks (7%), which were not affected by the global financial crisis until the end of January 2008. The Bear Stearns and Lehman Brothers episodes impacted

[18] To summarize the main results, Figure 5 shows only the overall net pairwise return spillovers relationships. Graphs relating to the time evolution of *net pairwise return* indices are not presented to conserve space but are available upon request.

systematically (both around 30%) in all other zones. In summary, US banks were a natural net systematic return spillover transmitter during the global financial crisis, while banks in the three other markets/portfolios were net systematic return spillover receivers.

During this period, we find limited amount of idiosyncratic contagion. There were some isolated significant events linked to specific domestic episodes in some countries, but in general net spillover measures were low. Banks in Euro-Peripheral countries became net transmitters during the first days of the global financial crisis (July 2007). The index was over 30% and it was transmitted to all other markets, with a bigger impact on banks Non-Euro countries (around 20%).

Moving on to the period of the European sovereign debt crisis, banks in the Euro-Peripheral countries were the natural net idiosyncratic transmitter (to all other countries), mostly since May 2010 (following the Greek bailout) and with a bigger impact during the second half of 2011. However, the impact of the Greek bailout seems to be stronger for banks in Non-Euro countries while banks in Euro-Core countries were less affected. Banks in the US barely felt it.

Looking at the whole picture, banks in Euro-Peripheral countries did not have a net systematic transmitter role during the European debt sovereign crisis. It was banks in Euro-Core countries that were the unique net systematic transmitter. The spillovers mostly affected banks in Euro-Peripheral countries, with even a bigger impact than the idiosyncratic spillover they received in the opposite direction, especially after 2012.

Finally, note that banks Euro-Peripheral countries started to receive both types of contagion from Non-Euro and Euro-Core zones in 2013. The Cyprus debt crisis on March 19, 2013 caused a significant increase in both spillover total indices. Following the Cyprus crisis, the index decreased again, signaling that the immediate risk of the Eurozone breakup seemed to have been averted and confidence was slowly recovering.

5. Conclusion

This paper provides an evaluation of contagion among banks and banking sectors in different countries and regions during a period of prolonged financial distress. Increased integration in global financial markets strengthened the linkages between banks in different countries. This increased interdependence ultimately resulted in the sub-prime crisis - a problem in a sector of the US financial market - becoming a global financial crisis. Despite a growing literature, the transmission mechanisms of contagion are still not fully understood. Banks are likely to remain vulnerable to episodes of instability and continued stress in the markets.

We find supporting evidence of contagion in banking markets, firstly indicated by an increase in co-movement in CDS returns. This marked increase in commonality should be considered an early warning, alerting authorities to intervene. Contagion came in different waves, from July 2007 onwards, with the financial and eurozone crises being distinct episodes. Indeed, while during the financial crisis contagion was systematic in nature, during the Eurozone crisis the idiosyncratic part played a more dominant role. The examination of net directional return spillover measures enabled us to identify group of banks in countries that can be seen as net transmitters and receivers of contagion. US banks appear to be net transmitters, particularly during the 2007-2009 period. During the Eurozone crisis, banks in "Eurozone peripheral" countries were net transmitters in terms of idiosyncratic spillovers although Eurozone troubles are barely affecting US banks. Differences in vulnerability to contagion within the European Union and even within the Eurozone are remarkable, with the Eurozone periphery more exposed to systematic contagion.

The results of our analysis have a number of implications for regulators and policymakers as they provide an insight into bank specific and country/region specific vulnerabilities and how these vulnerabilities are transmitted. The historical and current level of spillovers represent crucial information to understand the dynamics of international risk transmission and can assist the formulation of effective and co-ordinated policy initiatives.

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Appendix A. Estimation of banks' CDS returns

Following Berndt and Obreja (Berndt and Obreja, 2010) daily CDS return is given by

$$r_{CDS,t} = -\Delta CDS_t(T) \times A_t(T) = -\Delta CDS_t(T)\,\frac{1}{4}\sum_{j=1}^{4T} \delta\left(t, \frac{j}{4}\right) q\left(t, \frac{j}{4}\right) \qquad \text{(A.1)}$$

where $\Delta CDS_t(T)$ is the daily change in the CDS spreads with T maturity and $A_t(T)$ is the value of a defaultable quarterly annuity over the next T years. We denote the risk-free discount factor for day t and s years out as $\delta(t, s)$ and it is fitted from Datastream Euro and US zero curves. Assuming a constant risk-neutral default intensity λ for each bank, the risk-neutral survival probability of the bank over the next s years can be written as $q(t, s) = e^{-\lambda(t-s)}$. As a consequence, λ can be computed directly from observed CDS spreads by $\lambda = 4log\left(1 + \frac{CDS}{4L}\right)$, which can be used to calculate the annuity and hence the CDS return. L denotes the risk-neutral expected fraction of notional lost in the event of default. It is fixed at 60%.

Appendix B. Timeline of the crises with key events.

Date	Key Events
July 18, 2007	Bear Stearns disclosed that High-Grade Structured Credit and Enhanced Leveraged Funds had lost nearly all of their value amid a rapid decline in the market for subprime mortgages. US subprime crisis starts.
July 19, 2007	Dow Jones Industrial Average Index (DJIA) closes above 14,000 for the first time in its history.
July 26, 2007	Wall Street lost 2.26%, the London Stock Exchange, 3.15%, the Frankfurt Stock Exchange, 2.39%, the Paris Bourse 2.78%.
August 7, 2007	Numerous quantitative long/short equity hedge funds suddenly began experiencing unprecedented losses as a result of what is believed to be liquidations by some managers eager to access cash during the liquidity crisis. This is often considered the starting date of the worldwide "credit crunch".
August 9, 2007	French investment bank BNP Paribas suspends three investment funds that invested in subprime mortgage debt, due to a "complete evaporation of liquidity" in the market. This announcement compels the intervention of the European Central Bank (ECB), pumping €95bn into the European banking market.
August 10, 2007	Central banks coordinate efforts to increase liquidity for first time since the aftermath of the September 11, 2001 terrorist attacks. The Federal Reserve (FED) injects a combined $43bn, the ECB $214.6bn, and the Bank of Japan $8.4bn.
August 16, 2007	Countrywide Financial Corporation, the biggest U.S. mortgage lender, narrowly avoids bankruptcy by taking out an emergency loan of $11bn from a group of banks.
August 17, 2007	FED cuts the discount rate by half a percent to 5.75% from 6.25% while leaving the federal fund rate unchanged in an attempt to stabilize financial markets.
January 24, 2008	The National Association of Realtors (NAR) announces that 2007 had the largest drop in existing home sales in 25 years, and "the first price decline in many years and possibly going back to the Great Depression". Stock market downturn.
March 10, 2008	DJIA at the lowest level since October 2006, falling more than 20% from its peak just five months prior.
March 16, 2008	Bear Stearns is acquired for $2 a share by JP Morgan in a fire sale avoiding bankruptcy. The deal is backed by the FED, providing up to $30bn to cover possible Bear Stearn losses.
September 7, 2008	FED takeover of Fannie Mae and Freddie Mac, which at that point owned or guaranteed about half of the U.S.'s $12 trillion mortgage market, effectively nationalizing them.
September 15, 2008	Merrill Lynch is sold to Bank of America amidst fears of a liquidity crisis and Lehman Brothers collapse.
September 16, 2008	Moody's and Standard and Poor's downgrade ratings on AIG's credit on concerns over continuing losses to mortgage-backed securities, sending the company into fears of insolvency.
September 17, 2008	FED lends $85bn to AIG to avoid bankruptcy.
September 19, 2008	Paulson financial rescue plan ($700bn emergency bailout through the purchase of toxic assets) is unveiled after a volatile week in stock and debt markets.

September 25, 2008	Washington Mutual is seized by the Federal Deposit Insurance and its banking assets are sold to JP Morgan for $1.9bn.
September 30, 2008	US Treasury changes tax law to allow a bank acquiring another to write off all of the acquired bank's losses for tax purposes.
January 18, 2009	The Danish Parliament agreed to a financial package worth $17.6bn. In response, markets panicked yet again. Start of the Eurozone debt crisis.
February 27, 2009	The two-month period from January 1-February 27 represented the worst start to a year in the history of the S&P 500 with a drop in value of 18.62%.
March 2, 2009	DJIA dropped more than 50% from its October 2007 peak. The decline has been compared to that of the 1929 Great Depression, which was 53% between September 1929 and March 1931.
March 6, 2009	The Bank of England announced up to 150bn pounds of quantitative easing, increasing the risk of inflation.
March 9, 2009	DJIA had fallen to 6440, a percentage decline exceeding the pace of the market's fall during the Great Depression and a level which the index had last seen in 1996.
March 10, 2009	A countertrend bear market rally began, taking the DJIA up to 8500 by May 6, 2009. Financial stocks were up more than 150% during this rally.
June 22, 2009	The World Bank projected that the global production for 2009 would fall by 2.9%, the first decline since the second world war.
April 32, 2010	The Greek government requested an initial loan of €45bn from the European Union (EU) and International Monetary Fund (IMF), to cover its financial needs for the remaining part of 2010. A few days later Standard & Poor's slashed Greece's sovereign debt rating to BB+ in which case investors were liable to lose 30–50% of their money. Stock markets worldwide and the euro currency declined in response to the downgrade.
May 2, 2010	The first Greek bailout (€110bn) resulted in a payout of €20.1bn from IMF, €52.9bn from Greek Loan Facility (GLF) and €34.6 bn from the European Financial Stability Facility (EFSF), during May 2010 until December 2011. Credit rating agencies immediately downgraded Greek governmental bonds to an even lower junk status.
May 3, 2010	Announcement of the ECB that it will still accept as collateral all outstanding and new debt instruments issued or guaranteed by the Greek government, regardless of the nation's credit rating, in order to maintain banks' liquidity.
May 8, 2010	Leaders of the eurozone countries resolved to take drastic actions to protect the euro from further market turmoil after approving $110bn bailout plan for Greece.
July 21, 2011	EU emergency measures continued and Euro countries leaders approved a second rescue package. Eurozone leaders agreed to extend Greek (as well as Irish and Portuguese) loan repayment periods extended from seven to 15 years and the interest rate was lowered to 3.5%. They also approved the construction of a new €109bn support package provided by the newly created European Financial Stability Facility.
October 27, 2011	The Troika, a tripartite committee formed by the European Commission (EC), the ECB and the IMF, offered Greece a second bailout loan worth €172.6bn, but with the activation being conditional on implementation of further austerity measures and a debt restructure agreement.
Dec 2011	The Greek prime minister George Papandreou first answered that call by announcing a referendum on the new bailout plan, but had to back down amidst strong pressure from EU partners, who threatened to withhold an overdue €6bn loan payment that Greece needed by mid-December.

February 12, 2012	The Greek parliament approved the new austerity package.
February 21, 2012	The Troika agreed to provide a second bailout package €172.6bn (€28bn from IMF and €144.6bn from EFSF).
March 2012	The Greek government defaulted on its debt, which was the largest default in history by a government, about twice as big as Russia's 1918 default. This counted as a "credit event" and holders of credit default swaps were paid accordingly.
May 15, 2012	The crisis and impossibility to form a new government after elections and the possible victory by the anti-austerity axis led to speculations that Greece would have to leave the Eurozone. This phase became known as "Grexit" and influenced the behaviour of international markets. The Greek centre-right's narrow victory in the 17 June election gave hope that Greece would honour its obligations and remain in the eurozone.
June 9, 2012	Spain's 10-year bonds reached the 7% level and the country faced difficulty in accessing bond markets. This is seen as a worsening of the eurozone troubles.
June 25, 2012	The Cypriot Government requested a bailout from the EFSF or the ESM, citing difficulties in supporting its banking sector from the exposure to the Greek debt haircut.
September 2012	The ECB removed some of the pressure on Spain when it announced its "unlimited bond-buying plan", to be initiated conditional upon Spain signing a new sovereign bailout package with EFSF/ESM (European Stability Mechanism).
November 28, 2012	Spain's €100bn support package earmarked for recapitalisation of the financial sector. The first ESM recapitalisation tranche of €39.47bn approved and transferred to the bank recapitalisation fund (FROB) on 11 December 2012. A second tranche of €1.86n for was approved by the Commission on 20 December. This tranche aimed to recapitalise "category 2" banks and was finally transferred by ESM on 5 February 2013. "Category 3" banks were also subject for a possible third tranche in June 2013, in case they failed to acquire sufficient additional capital funding from private markets.
March 19, 2013	The final package for the Cyprus debt crisis amounted to a €10bn support package, financed partly by IMF (€1bn) and ESM (€9bn), because it was possible to reach a fund saving agreement with the Cypriot authorities, featuring a direct closure of the most troubled Laiki Bank and a forced bail-in recapitalisation plan for Bank of Cyprus.

Table 1
List of European and US Banks

Banks are assigned to countries based on the Datastream classification. Obs. refers to the available number of observations (CDS spread) for each bank in the sample. Total assets (December 2012 data) are expressed in thousand euros. For non euro countries Datastream average exchange rate in December 2012 is used.

Country	Bank Name	Obs.	Total Assets
Euro-Peripheral (20)			
Greece (4)	National Bank of Greece	915	104,798
	Alpha Bank	2,407	58,357
	EFG Eurobank Ergasias	1,935	67,653
	Piraeus Bank	927	70,406
Italy (7)	Unicredito Italiano	2,407	926,827
	Intesa San paolo	2,407	673,475
	Banca Monte Paschi Siena	2,407	197,081
	Unione di Banche Italiane (Ubi Banca)	2,364	132,433
	Banco Popolare	2,402	131,921
	Banco Popolare Milano	2,407	52,475
	Banca Italease	1,516	10,531
Portugal (3)	Banco Espirito Santo	2,407	83,690
	Banco Comercial Português	2,407	89,744
	Banco Português de Investimento	2,407	44,564
Spain (6)	Banco Santander	2,407	1,269,628
	Banco Bilbao Vizcaya Argentaria	2,407	637,785
	Banco Popular Español	2,407	157,618
	Banco de Sabadell	1,496	161,547
	Bankinter	2,004	58,165
	Banco Pastor	2,263	31,135
Euro-Core (16)			
Austria (2)	Erste Group Bank	2,407	213,824
	Raiffeisen Zentralbank	2,407	145,955
Belgium (2)	KBC Bank	2,405	224,824
	Dexia	2,407	357,210
France (5)	BNP Paribas	2,407	1,907,290
	Société Générale	2,407	1,250,696
	Crédit Agricole	2,406	1,842,361
	Natixis	2,407	528,370
	BPCE SA	1,904	1,147,521
Germany (4)	Deutsche Bank	2,407	2,012,329
	Commerzbank	2,407	635,878
	Deutsche Postbank	2,380	193,822
	HSH Nordbank	2,407	130,606
Netherlands (3)	ING Bank NV	2,407	836,068
	Rabobank	2,407	752,410
	ABN AMRO Bank	2,407	394,404

Table 1 ***(continued)***
List of European and US Banks

Country	Bank Name	Obs.	Total Assets
Non-Euro (14)			
Denmark (1)	Danske Bank	2,394	466,708
Norway (1)	DNB NOR ASA	1,274	273,743
Sweden (4)	Nordea Bank	2,407	677,309
	Svenska Handelsbanken	2,407	276,972
	Skandinaviska Enskilda Banken	2,407	285,047
	Swedbank	2,294	214,572
Switzerland (1)	Credit Suisse Group	2,407	752,006
UK (7)	HSBC Holdings PLC	2,407	3,318,590
	Lloyds Banking Group	2,407	1,139,523
	Standard Chartered	2,050	784,517
	Alliance and Leicester PLC	2,090	92,739
	Barclays	2,407	1,837,366
	Royal Bank of Scotland Group	2,407	1,617,422
	HBOS	2,407	717,455
US (5)	Bank of America corporation	2,407	1,673,231
	JP Morgan Chase & Co.	2,407	1,786,754
	US Bancorp	1,314	268,001
	Wells Fargo & Co.	2,406	1,077,720
	Citigroup Inc	2,407	1,412,247

Table 2
Descriptive statistics of European and US bank CDS spread and return series

This table contains descriptive statistics (minimum, maximum and mean) for the daily 5-year CDS spreads (Panel A) and returns (Panel B). The banks of the sample are summarized in equally weighted portfolios sorted by geographic zone using average CDS data of each zone's countries. CDS spreads are reported in basis points and CDS returns in percentage form. Results are shown for the complete period, from January 2004 to March 2013, and for three sub-periods: January 2004 to June 2007 (Pre-Crisis), July 2007 to September 2009 (Global Financial Crisis) and October 2009 to March 2013 (European Sovereign Debt Crisis). The lack of statistics for Norway in the first sub-period is due to the lack of data for the Norwegian bank until May 2008.

Panel A

	CDS spreads											
	Jan2004-Mar2013			Pre-Crisis Jan2004-Jun2007			Global Financial Crisis Jul2007-Sep2009			European Sovereign Debt Crisis Oct2009-Mar2013		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Euro-Peripheral	12.91	1,625.26	277.91	12.91	31.02	19.46	19.58	216.25	100.70	113.47	1,625.26	652.67
Greece	15.00	4,190.93	491.38	15.00	41.00	25.66	21.59	172.55	34.61	147.00	4,190.93	1,255.79
Italy	9.07	694.93	157.47	9.07	36.87	20.60	21.83	379.23	144.21	67.72	694.93	303.69
Portugal	10.50	1,483.58	273.57	10.50	31.39	16.75	17.63	171.09	86.56	79.30	1,483.58	653.04
Spain	10.38	769.58	189.22	10.38	23.19	14.81	17.08	309.62	137.43	121.75	769.58	398.16
Euro-Core	10.13	384.93	110.31	10.13	35.10	15.68	24.37	274.42	119.84	98.31	384.93	199.27
Austria	3.83	510.25	123.24	3.83	117.83	26.05	74.15	510.25	170.10	123.05	364.59	190.60
Belgium	5.50	709.49	175.81	5.50	13.40	9.75	10.60	395.70	172.89	136.14	709.49	344.68
France	5.18	356.17	89.69	5.18	58.23	14.96	9.92	156.01	78.85	60.32	356.17	171.87
Germany	10.22	276.11	87.01	10.22	37.10	19.09	16.25	182.29	99.02	88.95	276.11	147.53
Netherlands	3.83	254.40	75.77	3.83	14.53	8.54	6.83	172.73	78.35	64.07	254.40	141.68
Non-Euro	7.50	245.60	75.42	7.50	18.70	12.80	11.19	227.82	91.65	63.79	245.60	127.86
Denmark	1.00	344.80	83.59	1.00	21.00	8.80	4.10	225.00	81.76	60.56	344.80	158.91
Norway	37.50	212.00	100.46	-	-	-	37.50	188.11	103.21	49.54	212.00	99.35
Sweden	9.63	242.38	68.69	9.63	25.43	15.93	13.17	242.38	88.46	67.00	216.96	108.92
Switzerland	9.20	262.88	74.68	9.20	25.50	16.25	17.50	262.88	99.82	52.80	213.45	117.14
UK	4.37	285.29	88.50	4.37	20.40	10.11	9.97	230.15	107.52	77.90	285.29	154.98
US	8.13	337.73	86.39	8.13	30.93	17.67	14.53	337.73	123.78	74.15	262.02	131.25

Table 2 *(continued)*
Descriptive statistics of European and US bank CDS spread and return series

Panel B

	CDS returns											
	Jan2004-Mar2013			Pre-Crisis Jan2004-Jun2007			Global Financial Crisis Jul2007-Sep2009			European Sovereign Debt Crisis Oct2009-Mar2013		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Euro-Peripheral	-529.32	1,113.66	-0.38	-20.17	24.82	0.04	-119.99	49.87	-0.56	-529.32	1,113.66	-0.69
Greece	-1,679.64	4,246.79	0.12	-46.03	66.70	0.06	-429.05	38.91	-0.75	-1,679.64	4,246.79	0.75
Italy	-207.26	290.88	-0.58	-28.04	18.66	0.06	-145.56	168.71	-0.23	-207.26	290.88	-1.46
Portugal	-312.20	527.90	-0.52	-26.66	26.85	0.03	-143.22	97.19	-0.56	-312.20	527.90	-1.05
Spain	-199.67	305.07	-0.54	-35.43	34.18	0.02	-147.80	134.64	-0.69	-199.67	305.07	-1.01
Euro-Core	-136.94	162.02	-0.22	-71.55	49.50	0.04	-136.94	105.44	-0.53	-120.39	162.02	-0.29
Austria	-345.24	289.12	-0.14	-345.24	224.47	-0.07	-246.66	289.12	-0.31	-150.47	210.10	-0.11
Belgium	-366.81	246.17	-0.40	-11.74	11.46	0.00	-366.81	246.17	-0.95	-220.90	204.95	-0.44
France	-179.67	222.69	-0.22	-179.67	153.02	0.10	-114.20	80.18	-0.40	-159.43	222.69	-0.44
Germany	-168.58	116.51	-0.12	-77.69	94.34	0.12	-111.95	107.78	-0.59	-168.58	116.51	-0.05
Netherlands	-146.38	115.22	-0.24	-9.33	9.49	0.02	-146.38	115.22	-0.40	-71.83	113.77	-0.40
Non-Euro	-96.17	102.68	-0.15	-16.88	14.75	0.02	-96.17	83.68	-0.41	-81.73	102.68	-0.15
Denmark	-392.76	209.57	-0.21	-64.29	36.70	0.01	-392.76	209.57	-0.43	-167.62	150.21	-0.27
Norway	-202.99	157.05	-0.10	-	-	-	-202.99	157.05	-0.01	-126.47	112.43	-0.13
Sweden	-188.22	100.05	-0.12	-24.14	21.53	0.04	-188.22	69.78	-0.46	-73.63	100.05	-0.06
Switzerland	-167.31	195.38	-0.13	-24.68	21.98	-0.01	-167.31	195.38	-0.35	-142.30	186.97	-0.10
UK	-191.07	227.54	-0.16	-43.43	45.80	0.03	-191.07	227.54	-0.45	-103.86	182.30	-0.17
US	-178.96	230.81	-0.13	-19.23	14.69	0.02	-178.96	230.81	-0.85	-168.85	118.20	0.20

Figure 1

Time evolution of CDS spread and returns series

Panel A: Daily time series of CDS spreads (in basis points); Panel B: and CDS returns. Panel A and Panel B report the CDS spreads and returns for the four equally weighted portfolios, sorted by the geographical area where banks are headquartered. The sample period is January 2004 to March 2013. The scaling in Euro-Peripheral is from 0 to 1,800 (Panel A) and from -8 to 12 (Panel B); in the others is from 0 to 400 (Panel A) and from -3 to 3 (Panel B).

Panel A **Panel B**

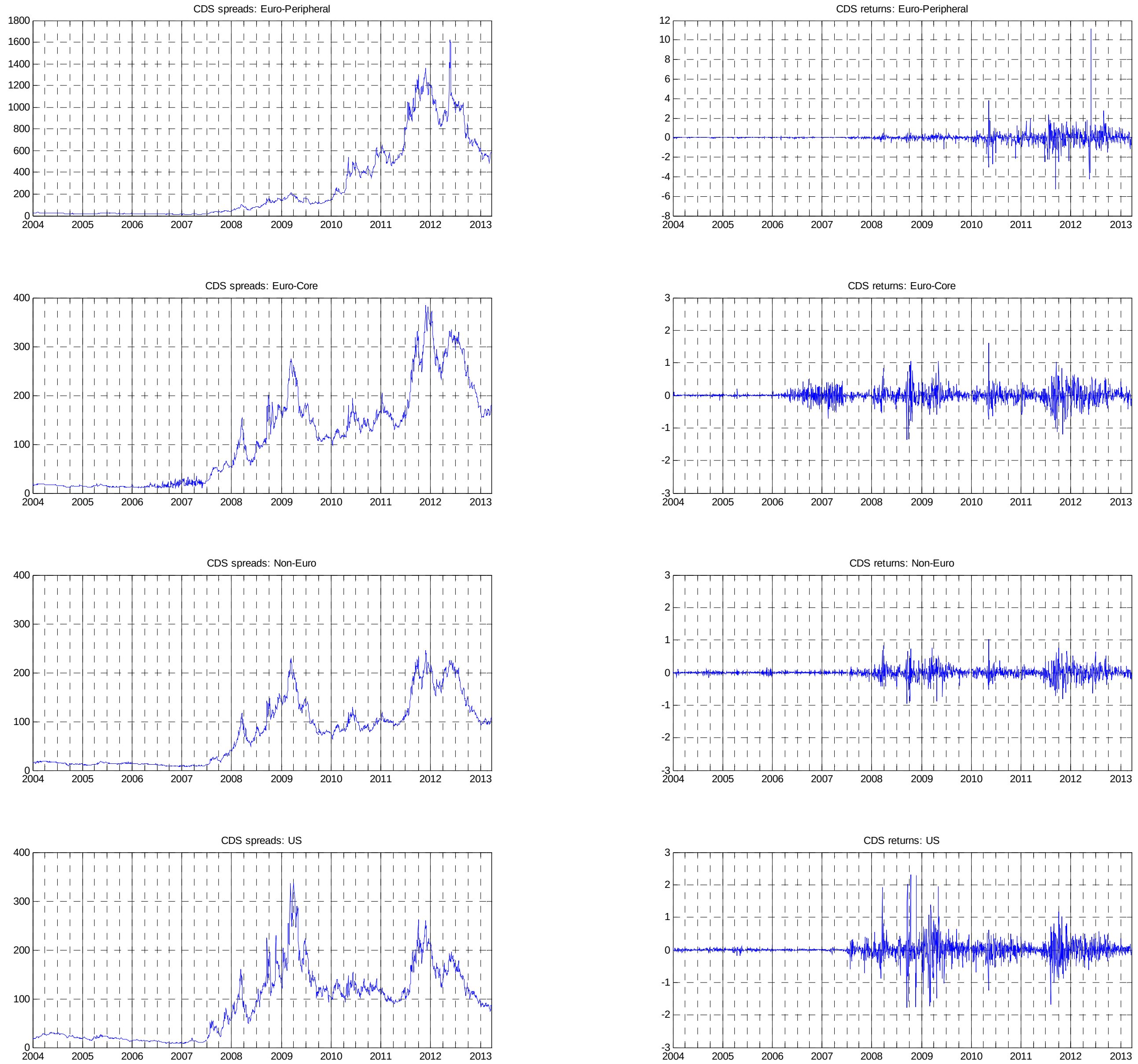


Figure 2
Principal Component Analysis

This figure reports the time evolution of the proportion of variance (in percentage) explained by the first four principal components of banks CDS returns series. The sample period is January 2004 to March 2013, but the figure starts on October 2004 since a 200-day rolling window is used to get the evolution over time.

Figure 3
Total return spillover index

This figure reports the time evolution of the *total return spillover* index for total contagion in blue, computed using total CDS returns, and idiosyncratic contagion in grey, computed using idiosyncratic returns. It measures on average the percentage of the forecast error variance in all the series that comes from contagion due to shocks. Returns of the four equally weighted portfolios sorted by geographical area where banks are headquartered are used. The sample period is January 2004 to March 2013, but the index starts on October 2004 since a 200-day rolling window is used to get the evolution over time.

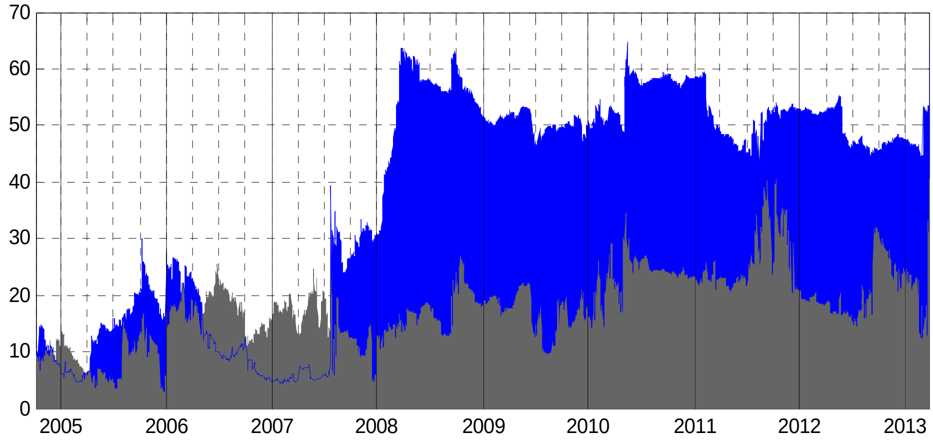
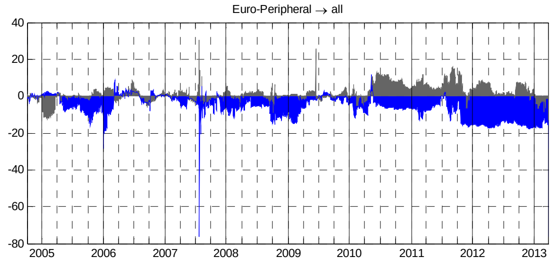


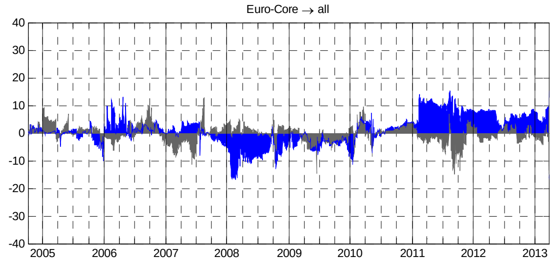
Figure 4
Net directional return spillover indices

This figure reports the time evolution of the *net directional return spillover* indices for total contagion in blue, computed using total CDS returns, and idiosyncratic contagion in grey, computed using idiosyncratic returns. They measure the spillover due to shocks (in percentage terms) transmitted by each portfolio to all others. Positive (negative) values indicate that the corresponding portfolio is in net terms a transmitter (receiver) of return spillover effects to all others. Returns of the four equally weighted portfolios sorted by geographical area where banks are headquartered are used. The sample period is January 2004 to March 2013, but the indices start on October 2004 since a 200-day rolling window is used to get the evolution over time.

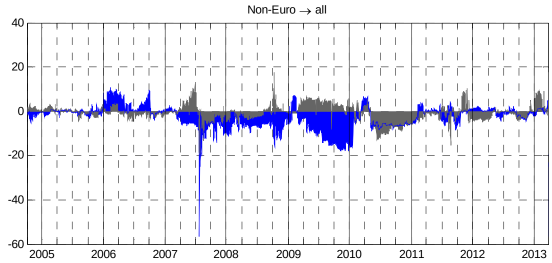
Panel A



Panel B



Panel C



Panel D

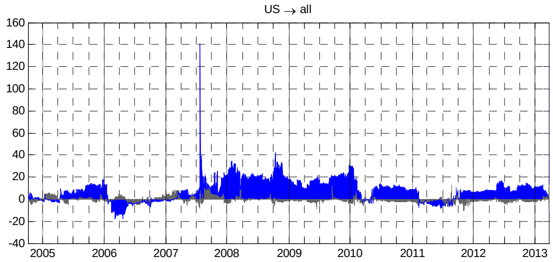


Figure 5

Net pairwise return spillover relationships

This figure reports the time evolution of the *net pairwise return spillover indices* relationships for total contagion in blue, computed using total CDS returns, and idiosyncratic contagion in grey, computed using idiosyncratic returns. They measure the net spillover due to shocks (in percentage terms) transmitted between each pair of portfolios. Returns of the four equally weighted portfolios sorted by geographical area where banks are headquartered are used. EP, EC, NE and US consists of Euro-Peripheral banks (Greece, Italy, Portugal and Spain), Euro-Core banks (Austria, Belgium, France Germany and Netherlands), Non-Euro (Denmark, Norway, Sweden, Switzerland and the UK) and US banks, respectively.The sample period is January 2004 to March 2013, but the time evolution pairwise relationships are summarized in three important sub-periods: the Pre-crisis period (January 2004 – June 2007), the Global financial crisis period (July 2007 – September 2009) and the Eurozone Sovereign debt crisis period (October 2009 – March 2013) .