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Why is contagion asymmetric during the European sovereign crisis?

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ABSTRACT

We use shocks to CDS spreads of peripheral countries to identify the effects of changes in the creditworthiness of these countries on stock returns of EU banks. We predict that large positive spread shocks should have a weaker impact in absolute value than large negative shocks because bank equity is an option on the bank's assets, policy reactions are asymmetric, and bank portfolios include bonds that benefit from a flight to safety. We find support for this prediction during the European crisis, so that contagion from pervasive creditworthiness shocks is asymmetric. This effect is important enough to make the portfolio contagion channel economically and statistically insignificant for adverse shocks.

1. Introduction

Throughout the acute phase of the European sovereign crisis, policymakers were very much concerned that shocks to the cost of borrowing of peripheral countries (the GIIPS countries, namely Greece, Ireland, Italy, Portugal, and Spain) could endanger other countries and the financial system of the European Union (EU) as a whole. There was little doubt for policymakers that, as put by Vitor Constâncio, the vice-president of the ECB at the time, "contagion phenomena play a crucial role in exacerbating the sovereign debt problems in the euro area." He went on to say that "Several of the ECB's interventions have been motivated by the need to address contagion".[1] A shock to the cost of borrowing of a peripheral country could impact the financial system through its effect on foreign banks. We call this transmission channel the bank contagion channel. In this paper, we predict that the bank contagion channel should be asymmetric, in that banks suffer less from adverse systemic shocks to peripheral countries than they gain from beneficial shocks to these countries, and find support for this prediction.

Transmission of sovereign shocks to banks in countries other than those suffering from the sovereign shock can take place through two distinct channels. First, an adverse sovereign shock can hurt foreign banks because such a shock can weaken the financial system. Hence, with this transmission channel, a bank is affected even if it is not directly exposed to the country experiencing a sovereign shock. We call this the *systemic risk channel*. Second, a sovereign shock can affect a foreign bank because of its exposure to the country suffering the shock. A bank can be exposed to a foreign country for a variety of reasons. For instance, it can have operations in that country or loans outstanding to corporations in that country. However, much

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[1] "Contagion and the European debt crisis," keynote lecture at the Bocconi University/Intesa Sanpaolo conference on "Bank Competitiveness in the Post-crisis World," Milan, October 2011.

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attention has been paid to the *portfolio channel*, which is the transmission of shocks due to the exposure of banks through sovereign bond holdings. During the period we consider, holding sovereign bonds from peripheral countries enables banks to hold bonds with high yields without having to use regulatory capital as the risk weights of these bonds were zero (Acharya and Steffen, 2015, Korte and Steffen, 2014). A bank that holds sovereign bonds from a country experiencing a decrease in its creditworthiness registers a loss on these bonds. In this paper, we investigate the asymmetry hypothesis for each of the two channels.

To investigate the portfolio channel, we have to measure the exposure of banks to the creditworthiness of peripheral countries through their bond holdings and we need to quantify shocks to the creditworthiness of these countries. To obtain data on bank bond holdings, we use evidence from the stress tests of EU banks starting in 2010. These stress tests provide data on EU banks' holdings of sovereign debt of European countries for five separate dates during our sample period from April 2010 to November 2012. To quantify a country's creditworthiness, we mostly use a country's five-year CDS spread. The advantage of using CDS spreads is that the data are easily comparable across countries. We show, however, that our key results are robust if we use bond returns.

We first demonstrate that banks are exposed to CDS spread changes during our sample period. We construct returns of bank sovereign bond portfolios and show that bank stock returns are correlated with returns on their GIIPS bond holdings. Further, we show that bank stock returns are correlated with CDS spread changes after accounting for banks' bond holdings. This evidence is consistent with the existence of both a portfolio and a systemic channel.

Having verified that there is a relation between CDS spread changes and bank stock returns in our sample period, we proceed to investigate how sovereign credit shocks affect bank returns more directly and whether they do so asymmetrically. There are at least three reasons why sovereign credit shocks should have asymmetric effects on banks (the asymmetry hypothesis). First, bank equity is an option on bank assets. Consequently, because of the convexity of the option function in the value of the underlying, a positive shock to assets has a larger impact than a negative shock of same absolute magnitude. Second, there are strong reasons for the markets to expect that there would be policy actions to offset the impact on banks of large adverse shocks to the creditworthiness of peripheral countries that could have systemic implications. The main reason for the markets to think so is that policymakers tend to intervene when the banking system is in danger. This asymmetric policy reaction to shocks makes bank equity values convex in the shocks. Third, banks hold portfolios of bonds that may benefit from a flight to safety in the event of large negative shocks to peripheral countries, creating a natural hedge against such shocks.

An important issue with assessing whether shocks to peripheral countries impact banks is to make sure that we are not simply measuring a correlation, but instead show that banks lose from adverse shocks and gain from beneficial shocks to peripheral countries. Our identification approach is to conduct an event study where we estimate bank stock-price reactions to large shocks to the creditworthiness of peripheral countries excluding the banks from countries where the shocks take place. Our identification approach assumes, over a short event window, that shocks to banks in countries not experiencing a creditworthiness shock are not causing the creditworthiness shock. For example, if French banks see their stock returns fall net of the market's return on a day that Italy experiences an adverse creditworthiness shock, it is implausible that the creditworthiness of Italy that day deteriorates because of the negative stock return of French banks. Though it is not conceptually impossible that a shock to banks in France and Germany could lead to an extreme spread change for the sovereign CDS of Italy, we are not aware of such a situation during our sample period. In contrast, the literature shows that shocks to banks in a country can cause shocks to that country's creditworthiness.

Because of the convexity of the valuation function of equity in the shocks we consider, we would not expect to find evidence of asymmetry for normal returns. This is because with convex functions, small changes have approximately a linear impact but large changes do not. Focusing on large shocks allows us to consider instances where we would expect to find contagion asymmetry. Consequently, to investigate the existence of an asymmetry, we focus on days with extreme positive or negative sovereign CDS spread changes, i.e., tail spread changes. We use CDS spread changes rather than returns because the impact of a 10% CDS spread increase is economically trivial if the CDS spread is small, but economically large if the spread is large. In contrast, a 100 basis point increase in the spread has roughly the same economic significance irrespective of the level of the spread. Our approach is similar to an event study where the event is a sharp change in the cost of borrowing of a sovereign. Such an approach has been used in the literature to study contagion from an unexpected deterioration in the credit of corporations (see Jorion and Zhang, 2007).

To identify whether the CDS spread change of a country on a given day is a tail spread change, we estimate the standard deviation of the CDS spread change over the previous 6 months. A positive tail spread change occurs when the CDS spread change is larger than two standard deviations. A negative tail spread change is a CDS spread change lower than minus two standard deviations. Using this approach, we find 101 positive tail spread changes and 161 negative spread changes between April 2010 (the first date for which we have holdings of sovereign bonds) and November 2012. The median tail spread change is 52 basis points for both spread increases and decreases. We estimate abnormal returns of banks on days of sovereign CDS tail spread changes. We define core countries on a given day to be those with CDS spreads below the median for EU countries for that day. We show that the abnormal returns of banks in core countries are significant on days of tail spread changes in peripheral countries. An alternative approach is to use yield changes instead of CDS spread changes. We use this approach as a robustness check and find that our results hold with that approach.

Having estimated abnormal returns on positive and negative tail spread change days, we investigate the role of the systemic risk channel and the bond portfolio channel in explaining these abnormal returns. We find evidence supporting the asymmetry hypothesis for shocks affecting each peripheral country (except for Greece), irrespective of a bank's portfolio holdings. When we measure tail days from CDS shocks taking place in any peripheral country, the average abnormal return on positive CDS tail days is −0.43% and the average abnormal return on negative CDS tail days is 0.72%. Though the coefficients are consistent with the existence of an asymmetry, the asymmetry is not significant; it is, however, significant if we exclude the days where Greece is the only country to experience a shock. Such a result makes sense in that policy actions mitigating systemic effects are unlikely to take place unless the shocks are important enough. Further evidence supporting this explanation is that the asymmetry increases with the ratio of the countries affected by shocks to the GDP of peripheral countries.

To investigate the bank portfolio channel, we estimate the change in the value of bonds held by banks, following Krishnamurthy et al. (2014) who estimate value changes resulting from changes in ECB policies. We find that, across peripheral countries experiencing a tail spread increase, the average loss on bonds from those countries held by banks in core countries ranges from −1.18% for Greece to −1.65% for Italy. However, tail spread increases for peripheral countries are at times accompanied by interest rate decreases for core countries because of a flight to quality. Since it is known from the literature that banks exhibit a high home-bias for sovereign bond holdings (Horvath et al., 2015), core country banks could have an increase in the value of their sovereign bond portfolios on tail days because of a flight to safety effect. We find that core country banks do not, on average, make significant losses on their aggregate sovereign portfolios on tail days. For instance, on average, the sovereign bond portfolio of core country banks experiences an insignificant increase of 0.04% on days that Italy has a tail spread increase. Hence, tail spread increases of peripheral country CDS are not sufficient to cause significant adverse changes in the value of sovereign bond portfolios of core banks. In contrast, banks from non-core countries other than the country having a tail spread increase make sizeable losses on their sovereign bond portfolios as well as on their holdings of bonds from the peripheral country. For instance, banks from non-core countries other than Italy make a loss corresponding to 5.66% of their market equity on days that Italy has a tail spread increase.

We then investigate how changes in the portfolio value of peripheral bonds translate into changes in the market value of the equity of banks. For negative value changes, we always find that a bond loss corresponding to 1% of the value of equity is associated with a shareholder wealth loss much smaller than 1%. Surprisingly, for our benchmark regression specification and many other specifications, we find that the bond portfolio channel is not significant for peripheral tail spread increases. In contrast, the channel is highly significant for bond portfolio value increases and the coefficient estimates are such that we cannot reject that shareholders capture all the bond portfolio value increases resulting from a positive shock. For positive value changes, we find a larger impact for banks from core countries than for banks from peripheral countries. These results are robust to alternative specifications of abnormal returns, of the identification of core countries, of the identification of tail change days, and of estimates of the bond holdings value changes.

After documenting the existence of the transmission channels and showing that they are asymmetric, we investigate explanations for the asymmetry as well as an additional prediction of the asymmetry hypothesis. We first examine the explanation for the asymmetry that focuses on the option properties of equity. We find that the term that captures the impact of convexity for changes in value of the assets is not significant. This suggests that the call option properties of equity cannot explain the asymmetry we document. We then investigate whether asymmetry in policy reactions can help explain our evidence of asymmetric contagion. We expect policy considerations to be relevant for shocks that involve large countries or a group of countries. The fact that we find that the asymmetry increases as the countries affected by shocks are more important as a fraction of the GDP of the Eurozone is evidence in support of the policy asymmetry explanation. More specifically, there is no asymmetry for idiosyncratic shocks to the smallest countries, but the asymmetry increases as the size of the affected countries increases.

Our paper contributes to a growing literature on the impact of shocks to the cost of borrowing of sovereigns on banks. None of these papers examines the asymmetry hypothesis we test and none of these papers shows that the portfolio holdings channel is not economically significant for adverse shocks during the European crisis. Among contributions to that literature, Bolton and Jeanne (2011) model contagion through sovereign bond holdings. Angeloni and Wolff (2012) find that banks' market performance in July-October 2011 is impacted by Greek debt holdings and in October-December 2011 by Italian and Irish sovereign exposures. Constâncio (2012) shows that the CDS premiums of French banks are increasingly explained by sovereign CDS during 2011. Lahmann (2012) finds evidence in favour of increasing interdependence between sovereign CDS and the CDS of banks located in other countries. Alter and Schuler (2012) show that European government CDS premiums are an important determinant of banks' CDS in the period 2007–2010. Acharya et al. (2014) provide empirical evidence for the two-way feedback between sovereigns and banks. They find that the bank-sovereign CDS relationship is stronger for less well-capitalized banks, banks with more short-term debt, and banks located in countries with higher credit risk. Acharya and Steffen (2015) examine the incentives of banks to hold bonds from peripheral countries. They use the correlation between government bond returns and banks' stock returns to estimate the exposure of various European banks to sovereign debt and show that such exposure is consistent with the exposure disclosed through the stress tests. Barth et al. (2012) study the links between bank and sovereign risk globally. Gross and Kok (2013) explore feedback effects between sovereign CDS and bank CDS using a global VAR Model and show that there is contagion from sovereign CDS to bank CDS during the height of the European sovereign crisis. Krishnamurthy et al. (2014) investigate the impact of ECB policies designed to reduce the bond yields of peripheral countries. Finally, Fratzscher and Rieth (2015) provide evidence that, from 2003 to 2013, shocks to sovereign risk affect bank risk and vice versa, and they conclude that sovereign shocks have a bigger impact than bank shocks.

The paper proceeds as follows. We present our exposure data in Section 2. In Section 3, we show that bank returns are related to country CDS spread changes during the period 2010–2012. In Section 4, we introduce CDS tail events and study bank stock abnormal returns on CDS tail event days. In Section 5, we investigate the exposure transmission channel and the determinants of bank stock abnormal returns on tail event days. We conclude in Section 6.

2. Bank exposures to sovereigns

We use banks for which we have bond holdings data available so that we can investigate the portfolio contagion channel. Our bond holdings data is from the disclosures required as part of the stress tests of EU banks. In 2010, a stress test exercise was conducted by the Committee of the European Banking Supervisors. Subsequent stress tests of EU banks in our sample period were the responsibility of the European Banking Authority (EBA). The 2010 and 2011 exercises cover around 90 banks representing 65% of the EU market in terms of total assets and at least 50% in each member state. Further data on holdings of sovereign bonds are made available through the 2011 and 2012 Recapitalization Exercises. Sixty-one of the reporting banks are listed in stock markets across Europe at the time they participate in the stress tests. The sample changes over time as banks appear or disappear.[2]

The data include both the gross direct long exposure to central and local governments as well as the net direct positions (equal to the gross long positions of the banks in the trading and banking books offset by short cash positions in the trading book with matching maturities). We use the net exposures in the results we report. The results are similar if we use gross positions. Each bank discloses information about holdings of sovereign bonds issues by Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lichtenstein, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom. Detailed information about holdings of bonds of different maturities (three months, one year, two, three, five, ten and fifteen years) are released for holdings dated December 2010, September 2011, December 2011, and June 2012. The March 2010 holdings are available only for the aggregate amount and not for the different maturities. The release dates for the first three disclosures are respectively July 23, 2010, July 15, 2011, and December 8, 2011. The December 2011 and June 2012 data were jointly released on October 3, 2012. We only include the banks for which stock returns from Datastream are available.

To estimate daily value changes of bank portfolios, for each day in our sample starting on January 1, 2011, we assume that holdings of bonds for each maturity are equal to the most recent information, except that before the first release with maturity information, we assume that the maturities are those of the first release. Obviously, it would be better to have daily holdings of bonds of banks. However, such holdings are not generally available for the period we study and, as a result, the literature uses the stress test holdings. We believe that if our holdings are erroneous because of between period changes in holdings, this would weaken our results but not bias them. Importantly, however, the holdings we use are the ones the market knew and hence are the ones the market should take into account when reacting to events.

We compute the daily value changes assuming that the bonds held by each bank have a duration equal to their time to maturity since we do not have information about the specific bonds held. We use the standard duration approximation for a bond's rate of return, so that the bond value change equals the modified duration times the change in the interest rate times the bond position. For a bond denominated in a currency other than the euro, we add the percentage rate of change of the currency because all the holdings are expressed in euros. We then multiply the rate of return and the nominal holdings of bonds of that maturity and then sum across the seven available maturities in order to obtain the portfolio value change associated with the movement of interest rates on that day. We use term structure data for each country from Datastream, as well as the relevant exchange rates.

When assessing the exposure of a bank with respect to a specific peripheral country, we follow two alternative approaches. In the first, which we call the "balance sheet date approach", we assume that a bank has the exposure starting on the date of the balance sheet that is reported with the stress test. In the second, denoted "the disclosure date approach", we assume the initial exposure date is the date that the stress test results are made public. With the disclosure approach, we use exposures reported on the first stress test disclosure on July 26, 2010, and then change the exposures sequentially on the first trading day after each one of the subsequent stress test disclosures. With the balance sheet approach, we use exposures reported with the first stress test starting on April 1, 2010 since the exposures correspond to bank balance sheets for the end of March. We then change the exposures sequentially on the balance sheet dates that correspond to stress test disclosures. Most of the results we report use the balance sheet approach. The benefit from doing so is that it allows our sample to start on April 1, 2010, instead of July 26, 2010. However, we find that our results hold irrespective of the approach we use and report results using both approaches for our most critical results.

In Table 1, we provide summary statistics for the banks in our sample and their exposures. We average across quarter ends for each bank and then average across banks. For all bank characteristics, we distinguish between banks in core countries and banks in non-core countries. We first provide data on tangible equity. We see that the average ratio of tangible

[2] Datastream stops reporting prices for Landesbank Berlin on July 31, 2012, ITT Hellenic on August 30, 2012, Agricultural Bank of Greece on July 26, 2012, Banco Guipuzcoano on November 12, 2010, Caja de Ahorros del Mediterraneo on December 8, 2011, Banco Pastor on February 27, 2012, Irish Life and Permanent on June 11, 2012. Bankia enters the sample on July 21, 2011. We drop the Austrian bank Oestern Volksbanken as its stock trades extremely infrequently.

Table 1
Summary statistics on bank characteristics. The table reports summary statistics about bank characteristics for the 60 listed banks in the stress tests included in our sample from April 2010 to November 2012. Equity is the percentage ratio between tangible equity (equity minus intangible assets minus other intangibles) and assets, Market value of equity is the percentage ratio between market capitalization and total assets minus book value plus market value of equity, Fragility is defined as one hundred minus the percentage ratio between customer deposits and the sum of total deposits and short-term funding. Log assets is the log of total assets in units of billion euros, Market capitalization is stock market capitalization in units of billion euros, Book-to-market is the ratio between book values and market values, Total exposure to peripherals over total assets is the percentage ratio between the total holdings of sovereign bonds issued by peripherals and total assets, Total exposure to peripherals over market capitalization is the percentage ratio between the total holdings of sovereign bonds issued by peripherals and market capitalization lagged five days, Gain on holdings of peripherals is the percentage gain on holdings of bonds issued by peripherals over the market capitalization lagged five days. Peripheral countries include Greece, Ireland, Italy, Portugal and Spain. Core (non-core) countries on a given day are the countries whose CDS spread is below (above) the median CDS spread across all the countries in our sample. The statistics for Equity, Market value of equity, Fragility, Log assets, Market capitalization, Book-to-market value, Total exposure to peripherals over total assets and Total exposure to peripherals over market capitalization are derived from a cross-bank average of summary statistics computed for each bank from end-of-quarter observations between the first quarter of 2010 and the third quarter of 2012. The statistics for Gain on holdings of peripherals over market capitalization are derived from a cross-bank average of summary statistics computed for each bank from daily observations between the end of the first quarter 2010 and the end of the third quarter 2012, assuming that the exposure of banks to the sovereigns of all countries in 2010 is equal to the exposure measured by stress tests as of the beginning of 2011. The sample excludes banks when they have a negative book value, and therefore Dexia is in the sample until 30 December 2011, National Bank of Greece until 30 December 2011, Eurobank Ergasias until 29 June 2012, Bank of Piraeus until 30 December 2011. The coefficients for the mean are in bold whenever it is possible to reject the hypothesis that the means for core and non-core countries are equal. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	Mean	Median	Standard deviation	Minimum	Maximum
Equity	5.799	5.871	0.710	4.715	6.737
Equity of banks in core countries	4.742	4.748	0.293	4.338	5.193
Equity of banks in non-core countries	**6.304*****	6.402	0.923	5.087	7.303
Market value of equity	4.010	3.925	1.170	2.414	5.897
Market value of equity of banks in core countries	3.371	3.260	0.734	2.435	4.515
Market value of equity of banks in non-core countries	**4.199*****	4.119	1.397	2.674	6.184
Fragility	29.292	28.769	6.072	20.685	38.210
Fragility of banks in core countries	31.509	31.281	6.556	23.033	40.965
Fragility of banks in non-core countries	**28.987***	28.555	6.838	21.382	37.066
Log assets	5.025	5.027	0.070	4.914	5.120
Log assets of banks in core countries	5.825	5.823	0.087	5.688	5.935
Log assets of banks in non-core countries	**4.865*****	4.868	0.067	4.784	4.941
Market capitalization	12.567	12.520	2.972	8.138	17.159
Market capitalization of banks in core countries	19.207	18.774	4.252	13.024	24.952
Market capitalization of banks in non-core countries	**13.649*****	13.656	2.419	11.062	16.804
Book-to-market value	3.765	2.423	3.334	1.473	11.979
Book-to-market value of banks in core countries	2.071	2.007	0.622	1.331	3.046
Book-to-market value of banks in non-core countries	**4.315****	2.559	4.803	1.615	14.698
Total exposure to peripherals over total assets	4.628	4.744	0.710	3.783	5.591
Total exposure to peripherals over total assets, banks in core countries	0.555	0.575	0.196	0.291	0.790
Total exposure to peripherals over total assets, banks in non-core countries	**6.738*****	6.825	1.131	5.527	7.946
Total exposure to peripherals over market capitalization	331.490	212.643	277.412	134.950	896.272
Total exposure to peripherals over market capitalization, banks in core countries	31.507	30.994	11.971	17.529	52.469
Total exposure to peripherals over market capitalization, banks in non-core countries	**479.539*****	303.403	425.310	191.731	1353.791
Gain on holdings of peripherals, all banks	−0.633	−0.174	11.481	−90.790	100.907
Gain on holdings of peripherals, banks in core countries	−0.018	−0.015	0.377	−1.865	3.468
Gain on holdings of peripherals, banks in non-core countries	−0.831	−0.263	18.008	−130.826	189.532

equity to assets of core country banks is significantly lower than the average of tangible equity to assets for non-core country banks. We next show results for the ratio of market value of equity to the market value of assets, where the market value of assets is computed as the book value of assets minus book equity plus the market value of equity. Perhaps not surprisingly, the market value equity ratio is lower than the tangible equity ratio, but again banks in non-core countries have a higher ratio than banks in core countries. We borrow a measure of fragility from Demirguc-Kunt and Huizinga (2010) which is one minus the difference between the ratio of customer deposits to total deposits and the ratio of short-term funding. As a bank has more customer deposits, fragility falls. We show the fragility measure in percent. Banks in core countries are more fragile than banks in non-core countries. As to the log of assets, not surprisingly, the banks in core countries are larger than banks in non-core countries. The same is true when we look at the market capitalization of banks. We then report the book-to-market ratio. This ratio is 2.071 on average for banks in core countries, but 4.315 for banks in non-core countries.

Table 1 shows that sovereign bond exposures to peripheral countries differ sharply between banks in core countries and banks in non-core countries. Using exposures scaled by assets, the average exposure to sovereign bonds of peripheral countries of banks from core countries is 0.555%. The range of that average exposure over time is rather small as the maximum is 0.790%. In contrast, banks from non-core countries have an average exposure of 6.738% with a maximum of 7.946%. The exposures are naturally much larger relative to the market value of equity. The exposures as a fraction of the market capitalization for banks in core countries average 31.507% with a range from 17.529% to 52.469%. Looking at the average exposure of banks from non-core countries scaled by the market value of equity, we find that it is extremely large (479.539%). The last three rows provide statistics for the gain on holdings of sovereign bonds from peripheral countries normalized by the market value of equity. We find that the average daily gain on holdings of bonds of peripheral countries for core banks is −0.018%; in contrast, it is −0.831% for banks in non-core countries. The standard deviation of the gain is especially large for banks in non-core countries, so that the average for banks in non-core countries is not significantly different from the average for banks in core countries.

In Table 2, we provide summary measures of exposures using the data for March 2010 and for September 2011. The reason we use September 2011 and not June 2012 for the comparison is that the third stress test is the last one with disclosure of sovereign holdings of Greek banks. In panel A, we normalize exposure by the market value of equity estimated five days before the release date using Datastream. We show the information for banks from each peripheral country as well as for banks from core countries. Only one panel has information about derivatives because that information is not disclosed in the first stress test.

The table shows that banks from peripheral countries have large exposures to bonds from their own country, exhibiting a strong home bias. In March 2010, banks from each peripheral country have exposure to the sovereign bonds from their country that are a multiple of the market value of their equity. The highest exposure is for Irish banks. The Irish bank exposures are so large mostly because of the extremely low value of their equity at that time. The banks from peripheral countries also have material exposures to other peripheral countries. For instance, Irish banks have an exposure to Italy, Portugal, and Spain that is a multiple of their market equity value. Portuguese banks have an exposure to Greece and Italy that is respectively 39.14% and 21.99% of their market value. Nevertheless, many of the off-diagonal elements are close to zero. When we look at core banks, their average exposure to all peripheral countries scaled by the market value of equity amounts to 31.28%. Their highest exposure is to Italy and amounts to 18.45% of their equity. Turning to September 2011, we see that exposures are higher except for the Irish banks. The reason the exposures of Irish banks are lower is that their equity is higher as a result of a bailout and a recapitalization. Though the data for September 2011 includes derivatives exposures, in most cases this exposure is trivial and on net it increases exposure to peripheral countries rather than decreasing it.

Panel B of Table 2 reports exposures measured relative to book tangible equity instead of market value of equity. We see that exposures measured this way are smaller than in Panel A, and especially so for September 2011. For peripheral countries, all banks except Irish banks have exposures that exceed their tangible equity in March 2010. When we turn to September 2011, all exposure averages of banks from peripheral countries exceed 100% of tangible equity. Yet, from March 2010 to September 2011, the exposure of banks from core countries relative to tangible equity falls almost by half. As a result, in September 2011, banks from core countries have aggregate average exposure of 17.03% of tangible equity and their largest exposure is to Italy for 9.19% of their tangible equity. In contrast, the exposure of core country banks is 45.18% when measured as a percentage of the market value of their equity.

3. Bank stock returns and sovereign CDS spread changes

In this section, we show that bank returns are related to the CDS spread changes of peripheral countries. The CDS spread is the insurance premium an investor has to pay to buy insurance on a bond, so that an increase in the CDS spread means that the bond's credit risk is higher. To estimate a sovereign's cost of debt, we use its CDS spread from Markit for the five-year maturity CDS contract. The CDS spread is the annual premium paid by the protection buyer to receive protection against a default of the underlying name. This data is widely used by practitioners and academics. Note, however, that Markit has no CDS data for Greece after February 28, 2012.

It is useful to note that, compared to most CDS, the CDS of the peripheral countries are highly traded during our sample period. A study of CDS non-dealer volume from July 2010 to the end of 2014 shows that Brazil is the only CDS name that is more actively traded than Italy or Spain.[3] The least traded CDS name among the peripheral countries is Ireland, which is the 71st most traded CDS name over that period. Another recent study states that "sovereign CDS are the most heavily traded single-name CDS contracts (...) and consequently, CDS spreads (prices) are deemed efficient, real-time metrics, for gauging the credit health of a country." (Augustin et al., 2016).

Statistics for the equally-weighted bank stock returns and CDS spread changes for the countries in our sample are reported in Table 1 in the internet appendix. Our sample period is from April 2010 to November 2012 for all the results that do not use Greek CDS data. We stop our sample in November 2012, which is the month when the restrictions on short selling and naked credit default swap positions came into effect in Europe.[4] By the end of our sample period, the most acute part of the crisis is over. For the results that use Greek CDS data, our sample period stops at the end of February 2012 because there is no data after that date. Not surprisingly, there is considerable variation across countries in both bank returns and in CDS spread changes. During our sample period, the average daily CDS spread change across sample countries is 0.25 basis points when we exclude Greece but is 2.12 when we include Greece. Our results hold when we exclude Greece. After Greece, Cyprus is the country with the average highest spread change, followed in order by Portugal, Spain, Slovenia and Italy.

To assess the relation between CDS spread changes and bank returns, we first estimate in Table 3 the following regression using daily data:

3 See Donald R. van Deventer's Blog, Sovereign credit default swaps and the European commission short sale ban, 2010–2014, Kamakura Corporation.

4 See http://www.esma.europa.eu/page/Short-selling.

Table 2
Exposures to Peripheral Bonds. The table reports the across-bank average of the net holdings of bonds issued by a particular peripheral country as a percentage of market capitalization lagged five days (Panel A) and as a percentage of tangible equity (Panel B) for banks from each peripheral country and from core countries. Tangible equity is the percentage ratio between equity minus intangible assets minus other intangibles and assets. On a given day, a core country has its CDS premium below the median CDS premium for our sample of countries. The table also reports the exposure through derivatives as a percentage of market capitalization lagged five days (Panel A) and as a percentage of tangible equity (Panel B). Each Panel reports the data for two different dates, using data released on July 23, 2010 that refer to the balance sheet at the end of March 2010 and data released on October 3, 2012 that refer to the balance sheet at the end of September 2011.

Panel A. Normalization by market capitalization

		Net holdings of bonds issued by:					
Disclosures for balance sheets as of the end of March 2010:	Number of banks	Greece	Ireland	Italy	Portugal	Spain	Total
Greek banks	6	365.36	0.00	0.49	0.00	0.00	365.85
Irish banks	3	43.97	4478.65	720.73	275.63	419.35	5938.34
Italian banks	5	1.62	0.14	214.20	0.39	1.89	218.24
Portuguese banks	3	39.14	9.54	21.99	324.34	2.96	397.97
Spanish banks	8	2.26	0.72	4.80	4.41	339.90	352.08
Core banks	21	4.99	1.90	18.45	1.15	4.80	31.28

		Net holdings of bonds issued by:						Exposure through derivatives towards:					
Disclosures for balance sheets as of the end of September 2011:	Number of banks	Greece	Ireland	Italy	Portugal	Spain	Total	Greece	Ireland	Italy	Portugal	Spain	Total
Greek banks	6	1362.80	0.11	1.76	0.00	0.00	1364.68	12.29	0.00	0.00	0.00	0.00	12.29
Irish banks	3	0.09	109.97	2.53	0.55	0.76	89.67	0.00	0.11	0.00	0.00	0.00	0.11
Italian banks	5	2.96	0.23	509.91	1.19	5.26	519.56	−0.13	0.00	1.62	−0.04	−0.05	1.38
Portuguese banks	3	54.03	21.16	55.37	516.81	3.11	650.48	0.00	0.00	0.00	0.96	0.00	0.96
Spanish banks	7	0.88	2.30	6.96	5.89	995.47	1011.50	0.00	0.00	2.34	0.00	0.01	2.35
Core banks	23	5.89	2.42	27.15	2.19	7.52	45.18	0.00	−0.02	0.09	0.02	−0.02	0.07

Panel B. Normalization by tangible equity

		Net holdings of bonds issued by:					
Disclosures for balance sheets as of the end of March 2010:	Number of banks	Greece	Ireland	Italy	Portugal	Spain	Total
Greek banks	6	324.62	0.00	0.31	0.00	0.00	324.93
Irish banks	3	0.19	29.60	3.43	1.22	1.85	36.29
Italian banks	5	1.43	0.16	165.81	0.31	1.37	169.08
Portuguese banks	3	13.34	6.93	16.66	91.13	0.31	128.37
Spanish banks	8	0.69	0.07	4.41	3.89	125.49	134.56
Core banks	21	5.88	1.79	19.69	0.93	4.72	33.03

		Net holdings of bonds issued by:						Exposure through derivatives towards:					
Disclosures for balance sheets as of the end of September 2011:	Number of banks	Greece	Ireland	Italy	Portugal	Spain	Total	Greece	Ireland	Italy	Portugal	Spain	Total
Greek banks	6	391.82	0.04	0.17	0.00	0.00	392.06	1.83	0.38	0.00	0.00	0.00	2.21
Irish banks	3	0.32	96.84	6.69	1.95	2.69	108.48	−0.04	−0.00	0.00	0.00	0.00	−0.04
Italian banks	5	1.10	0.11	193.72	0.50	2.02	197.45	0.00	0.00	0.65	−0.01	−0.02	0.62
Portuguese banks	3	11.87	6.18	16.87	118.31	0.30	153.54	0.00	0.00	0.00	0.09	0.00	0.09
Spanish banks	7	0.56	0.11	3.41	3.86	141.33	149.28	−0.03	−0.03	1.86	−0.01	0.00	1.79
Core banks	23	2.97	0.80	9.19	0.85	3.21	17.03	0.00	0.00	0.20	0.03	−0.02	0.21

$$BPR(t) = a + b_1 Stoxx(t) + b_2 CDSP(t) + b_3 PGAIN(t) + \varepsilon(t) \quad (1)$$

where BPR(t) is the return of an equally-weighted bank portfolio for t, Stoxx(t) is an equally-weighted portfolio of the sectors of the Stoxx index excluding banks, insurance companies and financial institutions, CDSP(t) is an equally-weighted index of CDS spread changes of peripheral countries, and PGAIN(t) is the simple average percentage gain on the holdings of peripheral sovereign bonds of banks divided by the market capitalization lagged five days. We estimate the regression separately for banks from core countries and banks from non-core countries. For the regression using banks from core countries, Model 1 in the Table, the CDS index has a negative coefficient of −0.076 and is significant at the 10% level. With this estimate, a spread change of 100 basis points for the CDS index translates into a lower return of the bank index of 0.076%. When we estimate the same relation for non-core countries, Model 2, the coefficient on the CDS index is −0.136, which is significant at the 10% level and is almost twice the coefficient of the index for banks from core countries but is not significantly different from that coefficient. The non-core countries are also significantly less exposed to the index of non-financial firms.

Table 3
Portfolio exposures to the market, to peripheral CDS returns and to the gain on holdings of peripheral sovereign bonds. The table reports regressions of geographical portfolios on the market and CDS returns, using daily data for the period April 2010-February 2012. A country is core (non-core) on day t if its CDS spread is below (above) the median CDS spread across the countries included in the dataset on the same day. Core is the percentage excess return of an equally-weighted portfolio of stress test banks belonging to core countries; Non-core is the percentage excess return of an equally weighted portfolio of stress test banks belonging to non-core countries; Gain on holdings of peripherals is the across bank simple average percentage gain on the holdings of peripheral sovereign bonds divided by the market capitalization lagged five days. Benchmark is the percentage excess return of an equally-weighted portfolio of the sectors of the Stoxx index excluding banks, insurance companies and financial institutions; Periphery delta CDS is an equally-weighted portfolio of first difference in CDS of Greece, Ireland, Italy, Portugal and Spain. P-values derived from robust standard errors in parentheses. The estimated coefficient is in bold whenever we can reject the null hypothesis that its value for the portfolio of non-core banks is equal to the value of the corresponding coefficient for the portfolio of core banks. *, **, and *** next to a coefficient in bold represent rejection of the null hypothesis at 10%, 5%, 1% levels, respectively.

	1 Core	2 Non-core	3 Core	4 Non-core	5 Core	6 Non-core	7 Core	8 Non-core
Constant	−0.057	**−0.199****	−0.027	**−0.164****	.-0.063	**−0.194*****	−0.128	−0.204
	(0.229)	(0.008)	(0.562)	(0.023)	(0.170)	(0.011)	(0.020)	(0.018)
Benchmark	1.370	**1.129*****	1.314	**1.055*****	1.370	**1.129*****	1.316	**1.060*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Periphery delta CDS	−0.076	−0.136	−0.043	−0.070				
	(0.093)	(0.094)	(0.314)	(0.456)				
Periphery delta CDS on days when delta CDS is positive					−0.067	−0.144	−0.045	−0.095
					(0.064)	(0.141)	(0.227)	(0.409)
Periphery delta CDS on days when delta CDS is negative					−0.098	−0.117	−0.045	−0.010
					(0.465)	(0.407)	(0.698)	(0.930)
P-value for test of equality of coefficients on periphery CDS on positive and negative tail days					0.828	0.875	0.996	0.613
Gain on holdings of peripherals			1.171	**0.065*****				
			(0.000)	(0.000)				
Gain on holdings of peripherals on days when gain is positive							1.767	**0.077*****
							(0.000)	(0.000)
Gain on holdings of peripherals on days when gain is negative							0.625	**0.052*****
							(0.261)	(0.000)
P-value for test of equality of coefficients on gains on positive and negative gain days							0.051	0.248
Number of observations	499	499	499	499	499	499	499	499
Adjusted- R^2	0.733	0.418	0.759	0.478	0.733	0.418	0.763	0.480

Models 3 and 4 in Table 3 add the portfolio gain to the explanatory variables. The first regression uses the equally-weighted index of banks in core countries. The coefficient on gain is 1.171 and is significant at the 1% level. The interpretation of the coefficient is that a 1% average change in the value of the peripheral holdings of core banks normalized by the market value of equity is associated with a 1.171% return on the index. The second regression uses the equally-weighted index of banks in non-core countries. The coefficient on gain, though significant, is only 0.065. Hence, while there is a relation between bank returns and portfolio returns on peripheral bonds for core banks, there is no evidence supportive of such a relation for non-core banks.

In the next four regressions of Table 3, we allow the coefficients on CDS spread changes on the percentage gain on the holdings of peripheral sovereign bonds of banks to differ, respectively, depending on the sign of the CDS index spread change and the gain on the holdings of peripheral sovereign bonds. We therefore estimate:

$$\mathrm{BPR}(t) = a + b_1\mathrm{Stoxx}(t) + b_2\mathrm{CDSP}(t)^+ + b_3\mathrm{CDSP}(t)^- + b_4\mathrm{PGAIN}(t)^+ + b_5\mathrm{PGAIN}^- + \varepsilon(t) \quad (2)$$

where a positive sign superscript denotes a positive change and a minus sign a negative spread change.

Models 5 and 6 show estimates of Eq. (2) without the portfolio gain variables. We find that the coefficient b_2 is significantly negative for core countries but not for non-core countries. The coefficient b_3 is significant neither for core countries nor for non-core countries. There is no evidence that the coefficients are significantly different. Models 7 and 8 add the portfolio gain variables. We find that the coefficient on days of portfolio value increases is larger for core countries than the coefficient on days of portfolio decreases, so that there is evidence of a contagion asymmetry even with daily returns. Note that the coefficient for portfolio value decreases should be positive, as the coefficient is multiplied by a negative return, so that bank returns are lower when the portfolio gain is negative. There is no evidence of asymmetry for non-core countries. However, all portfolio gain coefficients are positive and significant.

Having established that bank returns are related to CDS spread changes for our sample of banks, we investigate whether the results of Table 3 hold at the country level. We report the results in Table 2 of the Internet Appendix. Looking at individual countries allows us to consider three different groups of banks: the banks from the peripheral country considered, the other banks from non-core countries, and the banks from core countries. We find that for each country except Greece all three groups of banks have returns that are negatively correlated to the CDS spread change of the country. In general, the domestic banks have the largest coefficient on the CDS spread change, followed by the non-core banks and then by the core banks. For each peripheral country except Greece, the coefficients are significantly different in absolute value for banks from core countries in comparison to non-core banks.

We also estimated the models of Table 3 and of Table 2 of the Internet Appendix using CDS spread changes divided by the CDS spread. As we discussed in the introduction, such an approach is questionable in that a spread change of 100% for a country with a very low spread change may represent a spread change that is not material in comparison to a doubling of the spread for a country that already has a sizeable spread. We found that the inferences we draw from the tables in the text are similar if we use relative spread changes.

4. Peripheral country CDS tail shocks and bank stock returns

In Section 2, we showed that bank returns are related to CDS spread changes of peripheral countries during our sample period. This is true for banks from both core countries and non-core countries. Though the regressions show the existence of a correlation, they do not show causation. The correlation could result from common shocks. Alternatively, the sovereign shocks could result from bank shocks. In this section and the next, we use large unexpected CDS shocks to examine whether these shocks impact bank returns and do so asymmetrically.

Large unexpected sovereign one-day CDS shocks can be viewed as exogenous for banks from countries that do not experience a large unexpected shock on the same day. This is because there is little or no chance that a bank in a country not suffering from a CDS shock would be responsible for a CDS shock in a peripheral country. To provide an example, a shock in the Greek sovereign CDS is exogenous to a German bank because there is no serious concern that a German bank would have caused a shock to the Greek Sovereign CDS. To obtain further reassurance that we should not be concerned that sovereign CDS shocks are caused by banks in countries not experiencing the shocks, we examine headlines in the Financial Times for our whole sample period. We find no instance where the CDS shock of a country occurs because on the same day there is a shock to a bank outside that country. We use an event-study design, so that we examine the abnormal returns of banks on days of large sovereign shocks. We define abnormal returns as returns not explained by the benchmark index that we use in the regressions of the previous section. Since the markets for sovereign CDS as well as the markets for bank stocks for our sample are fairly liquid during our sample period, we estimate the same-day impact. In the language of event studies, we use one day as our event window. However, as we show later, our results hold equally well when we use a three-day window.

Table 4 shows the distribution of tail spread changes across countries from April 2010 to November 2012. There are many more tail spread increases, 161, than there are decreases, 101. A day with at least one tail spread change is more likely to have multiple tail spread changes than just one. We see that our sample has 34 days where only one country has an extreme positive tail spread change and 53 days where only one country has a negative tail spread change. Greece is the country with the most tail spread changes without other countries having tail spread changes. More than 50% of the tail spread changes of Greece occur in isolation, while the analogous percentage for other countries is always below 30%. Greece is also the country with the most tail spread changes. We show that our results hold when the days where only Greece has a tail spread shock are dropped from the sample. Simultaneous tail spread changes complicate our analysis in that the relevant bond value changes when more than one country has a tail spread change are the bond value changes of positions in bonds from all countries that have such a spread change on the same day.

Table 4

Frequency of CDS tail first differences. The table reports the number of times a peripheral country has a negative CDS tail first difference in Panel A and a positive CDS tail first difference in Panel B conditional on how many other peripheral countries have a CDS tail first difference. Tail CDS first difference are changes in CDS outside the interval delimited by plus or minus twice the rolling standard deviation (computed over the previous 60 trading days). Except for Greece, the sample includes all tail days from April 2010 to November 2012. For Greece, the sample stops in February 2012.

Country	Greece	Ireland	Italy	Portugal	Spain	Total number of tail first differences conditional on the number of countries with tail first differences reported in the rows
Panel A. Negative tail CDS first differences						
Number of other peripheral countries with simultaneous tail CDS first differences						
0	17	3	4	5	5	34
1	5	4	6	2	6	24
2	3	5	3	3	6	19
3	2	3	2	1	1	9
4	3	3	3	3	3	15
Total number of tail first differences	30	18	18	14	29	101
Panel B: positive tail CDS first differences						
Number of other peripheral countries with simultaneous tail CDS first differences						
0	29	8	6	6	4	53
1	3	0	5	6	6	20
2	8	8	8	11	8	43
3	1	2	1	0	1	5
4	8	8	8	8	8	40
Total number of tail first differences	49	26	28	31	27	161

Table 5 summarizes the data for our CDS tail (spread change) days. We first show statistics for CDS spread changes on positive tail days. We find that the CDS spread of core countries increases on those days, but by a very small amount compared to the extremely large increase of the CDS spread of the countries experiencing a positive tail spread change. The non-core countries that are not peripheral countries with a tail spread change have larger spread changes than the core countries. The results for CDS spread changes on negative tail days are similar to those for positive tail days, but with the opposite sign. As we see from the data, the distribution of spread changes for countries with tail events is highly skewed. For instance, for countries having a positive CDS tail spread change, the average change is 413 basis points, but the median is only 52 basis points.

We next report statistics for the value change of portfolio holdings of peripheral bonds as a fraction of the market value of equity. Considering days of positive tail spread changes, the loss for core countries is 0.24% on average. Non-core countries without tail spread changes experience much larger changes, as they average −3.667%. However, these losses pale in comparison to the losses of countries with tail spread changes, which average −20.865%. Turning to the tail days with decreases in CDS spreads, we see a similar ranking of magnitudes in absolute value.

In the remainder of Table 5 we show estimates of banks' abnormal returns on tail days. We see that the abnormal returns for banks from core countries and from non-core countries that are not experiencing a tail event are similar. Perhaps not surprisingly, the abnormal returns of banks in countries experiencing tail events are much larger in absolute value. It is also

Table 5

Summary statistics. The table reports summary statistics about country CDS first differences, portfolio gains and abnormal returns for the 60 listed banks in the stress tests included in our sample of tail days from April 2010 to November 2012, except for Greece where the sample stops in February 2012. Core (non-core) countries on a given day are those whose CDS spread is below (above) the cross-country median CDS spread. Non-core/non-tail countries on a given day are non-core countries whose CDS first difference in absolute value is below its rolling six-month standard deviation. Tail countries on a given day are peripheral countries (Greece, Ireland, Italy, Portugal, and Spain) whose CDS first difference in absolute value is above its rolling six-month standard deviation. Positive (negative) tail days are days when the first CDS difference of a peripheral country is above (below) twice its rolling standard deviation. Gain on holdings of peripherals is the across-bank average percentage gain on holdings of bonds issued by peripherals over the market capitalization lagged five days. Average abnormal stock returns is the across-bank average abnormal return. For a given bank on a given day t, the abnormal return is obtained from a market model estimated over [t-65, t-5]. P-values from robust standard errors in parentheses. The coefficients are in bold whenever it is possible to reject the hypothesis that the absolute values of the means of non-core/non-tail countries and core countries for positive tail days and negative tail days are equal, and similarly for the hypothesis that the absolute values of the means of tail countries and core countries for positive and negative tail days are equal. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels.

	Bank location	Mean	Median	Standard deviation	Minimum	Maximum
First CDS difference on positive tail days	*core*	0.020 (0.000)	0.019	0.029	−0.075	0.100
	non-core/non-tail	**0.067**** (0.001)	0.085	0.1921	−1.297	0.433
	tail	**4.131***** (0.001)	0.516	11.188	0.116	90.258
First CDS difference on negative tail days	*core*	−0.018 (0.000)	−0.017	0.035	−0.136	0.054
	non-core/non-tail	−**0.060**** (0.003)	−0.071	0.165	−0.544	0.625
	tail	−**3.333***** (0.001)	−0.522	7.642	−42.251	−0.107
Gain on holdings of peripherals on positive tail days	*core*	−0.243 (0.000)	−0.168	0.332	−1.634	0.542
	non-core/non-tail	−**3.667***** (0.001)	−1.848	10.268	−70.553	20.182
	tail	−**20.865***** (0.000)	−8.172	45.943	−329.23	111.89
Gain on holdings of peripherals on negative tail days	*core*	0.182 (0.000)	0.144	0.390	−1.034	1.733
	non-core/non-tail	**3.889***** (0.003)	1.212	10.511	−13.922	57.005
	tail	**12.934**** (0.044)	6.174	49.698	−110.740	232.894
Abnormal bank stock returns on positive tail days	*core*	−0.469 (0.000)	−0.441	1.056	−3.394	2.887
	non-core/non-tail	−0.310 (0.045)	−0.503	1.489	−3.355	4.595
	tail	−**1.282*** (0.000)	−1.435	4.326	−14.738	17.890
Abnormal bank stock returns on negative tail days	*core*	0.761 (0.000)	0.600	1.516	−2.822	6.222
	non-core/non-tail	0.805 (0.001)	0.692	1.866	−2.898	5.638
	tail	**2.083***** (0.000)	2.044	3.207	−5.038	14.584

noteworthy that the means and medians are fairly close in all cases. Importantly, we see that for all types of countries, the abnormal returns on positive tail days are smaller in absolute value than the abnormal returns on negative tail days. This evidence is supportive of the asymmetry hypothesis.

In Table 6, we document CDS spread changes, bank stock abnormal returns, and portfolio gains for the days that individual peripheral countries have negative and positive tail spread changes. We show results for the days of tail spread changes, but our results are robust to event windows that include the following day or the two following days. We distinguish between days where there is at least one tail spread change (multiple tail days) in panel A and days where there is only one tail spread change in panel B (single tail days). For example, the row for Greek positive tail events in Panel A includes all days where the Greek CDS spread has a positive tail spread change regardless of what happens to the spread change of other peripherals. In contrast, the same row in Panel B includes only days where Greece is alone in having a positive tail spread change. For CDS, the estimates are obtained from a regression of all tail spread change days of the peripheral country on a constant and indicator variables for positive and negative tail days of the same country. We proceed in the same way for portfolio gains. For stock returns, we estimate the same regression but add the benchmark index return.

Turning first to panel A, we see that there is a very large difference in average CDS tail spread changes on Greek tail days and on other countries' tail days. Specifically, the average tail spread change on Greek tail days is more than ten times the average tail spread change on other countries' tail days whether we consider positive or negative spread changes. The negative and positive tail CDS spread changes are similar in absolute value. For instance, when Italy has a tail day, the average positive tail spread change for CDS of countries having a tail day is 32 basis points and the average negative tail spread change is −34 basis points. For no country there is a significant difference between the absolute value of the CDS spread changes between positive and negative tail days.

On days when a peripheral country has a tail spread change, core countries' CDS changes are of the order of a tenth of the country experiencing the tail spread change. This does not happen on days when Greece has a tail spread change, when the core country spread changes are tiny compared to the changes in the CDS spread of countries having a tail event. In the case of Greek tail days, the core country CDS spread change is 2 basis points whereas the average for the countries having a tail spread change is 868 basis points. All core CDS spread changes are significantly different from zero except for Greece negative tail days.

We now turn to abnormal returns for banks in all countries that do not have a tail spread change on days when at least one peripheral country has a tail day. We find that all average abnormal returns are significantly different from zero. They also have the expected sign, in that the average abnormal return is negative on positive tail days and positive on a negative tail days. Lastly, the average abnormal return is larger in absolute value for decreases, rather than for increases, in CDS spreads. The difference in absolute value of average abnormal returns between decreases in spreads and increases in spreads is positive for all countries, but it is not statistically significant on Greek tail days. The magnitude of the difference is economically significant, in that the average abnormal return for negative spread changes is at least 50% higher in absolute value than the average abnormal return for positive spread changes. This evidence is strongly supportive of the asymmetry hypothesis. When we look separately at banks from core countries and banks from non-core countries that are not experiencing tail spread changes, the asymmetry is present but is not always significant. When we turn to banks from countries experiencing the CDS tail spread change, the magnitude of the abnormal returns is larger, but the asymmetry is never significant.

The last six columns of Panel A of Table 6 show the changes in value of banks' sovereign bond portfolios and of the holdings of bonds from the country experiencing a tail day, expressed as a percentage of the market value of the equity of banks. To understand how these estimates are obtained, consider the estimate for the gain for the portfolio of sovereign debt of banks in core countries when Greece has a positive CDS tail spread change. This estimate is equal to −0.049%. It is obtained by averaging the change in value of the portfolio of sovereign debt of core banks expressed as a percentage of the market value of equity five days before the tail day across all core banks in the sample on that day. Hence, on average, a positive tail spread change for Greece reduces the value of the portfolio of sovereign debt of core banks by an insignificant five basis points of the market value of equity. It turns out that there is no peripheral country for which core banks experience a significant aggregate portfolio loss if that country has a tail day. When we turn to negative tail spread changes, there is no peripheral country for which core banks experience a significant portfolio gain when there is a negative tail day. In other words, the portfolios of sovereign bonds held by core banks are such that changes in value of their holdings of bonds from peripheral countries experiencing positive tail days are not big enough to cause significant losses in their portfolios of sovereign bonds. Such a result is explained by the fact that core banks predominantly hold bonds from their own country. Their own country bonds at times increase in value because of a flight to safety effect or are unaffected by the fact that a peripheral country has a tail spread increase.

The next column provides estimates of the percentage portfolio gain for banks in non-core countries, excluding banks from the country having a tail event. We immediately see that the percentage change in the value of the sovereign bond portfolio of these banks is much larger and is almost always significantly different from zero. There are two reasons for this. First, the market value of the equity of these banks is lower, so that the same value loss represents a greater percentage. Second, there is transmission of such shocks among non-core countries.

In the last column for percentage portfolio gain, we show that the percentage gain or loss is even larger for banks in the country or countries where the tail event takes place. The estimates are particularly large for Greece and Ireland. The reason

Table 6

First CDS spread differences, bank abnormal returns and gain on holdings of sovereign bonds on CDS tail event days. A CDS is in the positive tail when the absolute value of its first difference is larger than twice the rolling standard deviation, computed over the previous sixty trading days. In the various columns, we estimate regressions on an indicator variable that is equal to one when the first difference of the CDS of the country specified in the first column is in the positive tail and an indicator variable that is equal to one when the first difference of the CDS is in the negative tail. Except for Greece, the sample includes all tail days from April 2010 to November 2012. For Greece, the sample of tail days stops in February 2012. A country is defined as a core (non-core) country on a day when its CDS spread is below (above) the median CDS spread across the countries in our sample, as a non-core/non-tail country when its CDS spread is above the median CDS spread across the countries in our sample and its first CDS spread difference is not in the tail on a given day, and as a tail country when it is a peripheral country (Greece, Ireland, Italy, Portugal, Spain) and its first CDS spread difference is in the tail on a given day. The different dependent variables are described as follows: CDS spread difference is the first difference of the CDS spread, Abnormal return is the across-bank average of abnormal returns, where for each bank the abnormal return is obtained from a market model estimated over the period [t-65,t-5], Aggregate gain for a bank is the average percentage gain on its holdings of sovereign bonds issued by all European countries divided by the five day lagged of the market value of its equity, Gain on holdings of peripherals for a bank is the percentage gain on its holdings of sovereign bonds issued by peripheral countries divided by the five day lagged market value of its equity. Gain is computed for each bank on the basis of the actual exposure to sovereign bonds of different buckets, available from January 2011, back to April 2010 assuming that the exposure was the same as on January 2011. In panel A we condition on at least the CDS of one peripheral country being in the tail. In panel B we condition on the CDS of a peripheral country being in the tail when the CDS of no other peripheral is in the tail on the same day. *, **, and *** indicate rejection of the null hypothesis that each abnormal return is equal to zero at the 10%, 5%, and 1% levels, respectively. We also report the p-value of the test that the coefficient for the positive tail dummy is equal to minus the coefficient for the negative tail dummy, and. *, **, and *** indicate rejection of the null hypothesis that the absolute value of the two abnormal returns are equal at the 10%, 5%, and 1% levels, respectively.

		CDS spread difference in countries defined as:			Abnormal return of banks located in countriesdefined as:				Aggregate gain of banks located in countries defined as:			Gain on holdings of peripherals for banks located in countries defined as:		
		Core	Non-core	Tail	Core and non-core/non-tail	Core	Non-core/ non-tail	Tail	Core	Non-core/ non-tail	Tail	Core	Non-core/ non-tail	Tail
Panel A. Sample includes only days when at least one peripheral CDS is in either the positive or the negative tail														
Greek CDS	*positive tail*	0.018***	1.053***	8.678***	−0.377**	−0.408**	−0.431*	−0.861	−0.049	−4.368***	−12.886***	−1.181***	−3.795***	−26.003***
	negative tail	−0.008	−0985***	−8.215***	0.657*	0.620*	0.742**	2.282***	1.120	3.638	15.030***	0.926**	2.209**	13.757
	p-value	0.326	0.832	0.875	0.480	0.607	0.450	0.199	0.631	0.769	0.739	0.602	0.347	0.361
Irish CDS	*positive tail*	0.028***	0.296***	0.421***	−0.888***	−0.705***	−1.276***	−2.050***	0.054	−4.543***	−27.821**	−1.029***	−3.657*	−32.243***
	negative tail	−0.034***	−0.367***	−0.467***	1.599***	1.375***	1.938***	2.878***	−0.088	3.442***	21.284***	1.012**	3.497***	24.744**
	p-value	0.481	0.582	0.540	0.059	0.086	0.145	0.260	0.801	0.571	0.664	0.972	0.942	0.624
Italian CDS	*positive tail*	0.042***	0.388***	0.320***	−0.810***	−0.916***	−0.728*	−1.504***	0.042	−5.664***	−14.352***	−1.653***	−7.432***	−19.963***
	negative tail	−0.040***	−0.317**	−0.343***	1.703***	1.523***	2.036***	2.794***	−0.032	7.902**	11.606***	1.326***	5.975***	15.298***
	p-value	0.865	0.650	0.590	0.041	0.162	0.030	0.039	0.954	0.457	0.577	0.554	0.550	0.432
Portuguese CDS	*positive tail*	0.027***	0.361**	0.655***	−0.646***	−0.636***	−0.838**	−1.312**	0.056	−5.169***	−14.803***	−1.293***	−3.471*	−21.437***
	negative tail	−0.032***	−0.403**	−0.889***	1.620***	1.752***	1.471**	2.040***	0.097	8.246**	18.025***	1.345**	3.211**	21.433***
	p-value	0.682	0.828	0.043**	0.081	0.028	0.381	0.415	0.363	0.412	0.603	0.933	0.913	0.999
Spanish CDS	*positive tail*	0.037***	0.346***	0.298***	−0.675***	−0.773***	−0.628	−1.868***	0.090	−5.507***	−10.863***	−1.304***	−6.198***	−16.364***
	negative tail	−0.034***	−0.340***	−0.354***	1.603***	1.331***	2.025***	2.930***	−0.002	6.344***	8.152***	1.057***	4.533***	11.984***
	p-value	0.684	0.958	0.107	0.018	0.120	0.019	0.059	0.584	0.768	0.483	0.600	0.483	0.384
Panel B. Sample includes only days when one peripheral CDS is in either the positive or the negative tail														
Greek CDS	*positive tail*	0.004	1.333***	11.881***	0.041	0.009	0.079	−0.713	−0.074	−2.842***	−8.202**	−0.480***	−0.999***	−23.513**
	negative tail	0.011*	−1.261***	−11.520***	0.292	−0.228	−0.280	1.006*	0.111	−0.844	8.961	−0.009	−0.273	3.297
	p-value	0.105	0.885	0.936	0.491	0.561	0.637	0.856	0.855	0.022	0.934	0.222	0.191	0.354

Irish CDS	*positive tail*	0.007	0.089***	0.357***	−0.549*	−0.070	−1.034**	−2.910***	0.088	−0.852**	−59.107	−0.062**	−0.043**	−59.295
	negative tail	0.004	−0.092***	−0.488***	0.444	0.670	0.306	5.650	−0.154*	−0.301	80.468	0.064	0.055	81.548
	p-value	0.123	0.903	0.293	0.849	0.378	0.219	0.520	0.557	0.084	0.796	0.959	0.792	0.790
Italian CDS	*positive tail*	0.044***	0.208***	0.277***	−0.891**	−0.839**	−1.020**	−1.487**	0.257	−0.319	−4.684	−0.909	−6.355	−4.654
	negative tail	−0.036	0.259	−0.343***	0.371	0.858	−0.003	0.758	−0.448**	2.834	−0.207	−0.002	1.080***	−0.181
	p-value	0.852	0.213	0.535	0.437	0.985	0.089	0.449	0.501	0.630	0.174	0.142	0.263	0.175
Portuguese CDS	*positive tail*	0.013	−0.109	0.711***	0.085	−0.045	0.196	−0.923	−0.049	−3.815	−11.646*	−0.126**	−0.081**	−9.663*
	negative tail	−0.034***	0.021	−0.902***	0.464	0.909	0.119	0.308	0.251	8.464*	8.575**	0.131**	0.079***	6.921**
	p-value	0.137	0.713	0.410	0.546	0.298	0.826	0.515	0.308	0.376	0.662	0.946	0.953	0.645
Spanish CDS	*positive tail*	0.024***	0.146***	0.248***	0.178	0.116	0.312	−0.422	0.167	−1.248	−0.632**	−0.042**	−0.083**	−0.669**
	negative tail	−0.026***	−0.150	−0.295***	0.754	0.237	1.441	0.847	0.079	1.908	3.391	0.136	0.137	6.439*
	p-value	0.928	0.967	0.173	0.363	0.612	0.298	0.723	0.588	0.894	0.279	0.287	0.556	0.133

for this is that the banks in these countries have little equity but these countries experience some extremely large changes in CDS spreads.

The last three columns provide estimates of the portfolio gain or loss on holdings of peripheral bonds. In contrast to the results for the portfolio as a whole, we see that banks in core countries have significant losses for positive tail events and significant gains for negative tail events in all peripheral countries. Not surprisingly, the absolute magnitude of the portfolio gain is larger for non-core countries without a tail event and is extremely large for banks in the countries experiencing a tail event.

Panel B, which excludes all cases where multiple peripheral countries have tail events, has much weaker results. Note, however, that the CDS spread changes of the country experiencing the tail event are similar to those of Panel A. Consequently, the weaker results are not due to the smaller spread changes for the country having the tail event. Abnormal stock returns on single tail days are mostly insignificant. The changes in value of the bond portfolios on such days are somewhat smaller in absolute value than in multiple tail days and they are less often significant.

The results of Table 6 show that there is an abnormal return asymmetry in the response of banks to peripheral spread shocks. It also finds that this asymmetry cannot be explained by an asymmetry in bond portfolio returns in response to peripheral shocks. Differences across countries and across panels in Table 8 show that the asymmetry results are stronger when multiple countries experience adverse shocks.

To further explore the relation between bank returns on tail days and the number of countries with tail spread changes, we estimate the following regression for days with tail shocks:

$$\mathrm{BPAR}(t) = c + b_1\#\mathrm{POSTS}(t) + b_2\#\mathrm{NEGST}(t) + \varepsilon(t) \tag{3}$$

where BPAR(t) is the abnormal return on a portfolio of bank stocks on day t, #POSTS(t) is the number of countries experiencing a positive tail shock on day t, and #NEGST(t) is the number of countries experiencing a negative tail shock on day t, and t is the subset of dates including only tail days. The first three regressions, see Table 7, show results for the portfolio that includes all banks. Model 1 shows that the abnormal return increases with the number of countries with negative tail spread changes and falls with the number of countries with positive tail spread changes. There is a strong asymmetry in that the coefficient on negative tail days is more than twice the size in absolute value of the coefficient on positive tail days. The difference in the slopes is significant at the 1% level. We add squared terms for the number of countries experiencing tail spread changes to regression (3) in Model 2. We see that no coefficient is significant in that regression, which is likely due to

Table 7

Banks abnormal returns and pervasiveness of shocks. The dependent variable is the abnormal return of bank portfolios. The independent variables are, respectively, the number of peripheral countries with positive tail spread shocks on that day, the square of that number, the number of peripheral countries having negative tail spread shocks on that day, and the square of that number. The column on Banks located in all countries reports results of regressions of abnormal returns of an equally weighted portfolio of stress test banks located in all countries; the column on Banks located in core countries reports the results of regressions of abnormal returns of an equally weighted portfolio of stress test banks located in core countries, the third column on Banks located in non-core/non-tail countries reports results of regressions of an equally weighted portfolio of stress test banks located in non-core countries excluding the banks located in a peripheral country with a tail CDS realization on a given day, the fourth column of Banks located in peripheral countries with tail outcome reports results of regression of abnormal returns of an equally weighted portfolio of stress test banks located in the peripheral country with a tail outcome on a given day. On a given day a country is defined as a core (non-core) country if its CDS spread is below (above) the median CDS spread across the countries considered in the sample. The regression is run only on days of tail returns over the sample period April 2010-November 2012. P-values obtained from robust standard errors in parentheses. A coefficient is in bold whenever we can reject the hypothesis that the absolute value of the coefficient of the negative indicator is different from the coefficient of the positive indicator. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	Banks located in:											
	All countries			Core countries			Non-core/non-tail countries			Peripheral countries in tails		
	1	2	3	1	2	3	1	2	3	1	2	3
Constant	−0.149	0.047	−0.032	−0.175	0.787**	−0.102	−0.119	−0.571	0.034	−0.192	−0.841	0.019
Number of positive tail spread shocks	−0.254	−0.281		−0.185	−0.981		−0.234	0.526		−0.475	−0.232	
	(0.001)	(0.440)		(0.019)	(0.002)		(0.077)	(0.373)		(0.007)	(0.809)	
Number of negative tail spread shocks	**0.701*****	0.206		**0.580****	**−0.834*****		**0.700****	0.774*		**1.125***	2.527	
	(0.005)	(0.580)		(0.000)	(0.011)		(0.000)	(0.157)		(0.000)	(0.021)	
Number of positive tail spread shocks squared		−0.013	−0.075		0.122	−0.053		−0.165	−0.080		−0.000	−0.113
		(0.845)	(0.000)		(0.028)	(0.000)		(0.128)	(0.001)		(0.999)	(0.000)
Number of negative tail spread shocks squared		0.128	**0.188*****		**0.317*****	**0.169*****		0.032	**0.186*****		−0.351	**0.242****
		(0.073)	(0.000)		(0.000)	(0.000)		(0.738)	(0.000)		(0.084)	(0.000)
Number of observations	163	163	163	163	163	1363	163	163	163	163	163	163
Adjusted- R^2	0.399	0.417	0.402	0.353	0.434	0.402	0.248	0.274	0.265	0.152	0.167	0.099

Table 8
Tail regressions. The regressions are estimated using tail days (defined as days when the absolute value of the first difference in a CDS spread is above twice its rolling six month standard deviation). The dependent variable in the regressions is the abnormal stock return, obtained as a residual from a market model estimated over the previous sixty days where the market is represented by the equally-weighted average of the sectors of the Stoxx index (excluding banks, insurance companies and financial institutions). The sample period is April 2010-November 2012 and includes stress test banks that are publicly traded and report sovereign bond holdings. Model 2 excludes all event days where only Greece has a spread shock. The bank variables are winsorized at the 1% and 99% levels and are expressed in percentage terms. For each bank, gain on holdings of tail peripherals (non-tail peripherals, core countries) is the gain on holdings of sovereign bonds issued by countries in the tail (not in the tail, core) normalized by the market capitalization of the bank five days before. Gain is computed daily using data on holdings of bonds with maturities 0.25, 1, 2, 3, 5, 10 and 15 years, estimating the return at each maturity using the first difference in the specific yield and the modified duration approximation and using the balance sheet date approach. Market value of equity is the ratio between market capitalization and assets minus book value plus market capitalization. For each bank, Delta is the value of the cumulative normal distribution evaluated at the sum of the market equity over liabilities ratio plus half the standard deviation, and Gamma is the normal density function evaluated at the sum of the market equity over liabilities ratio plus half the standard deviation divided by the product of the stock price and volatility. Size is the sum of the GDP of the tail peripherals divided by the GDP of the five peripherals. Model 2 is estimated excluding days where only Greece has a tail event. Standard errors are obtained by clustering at the event level. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. P-values for the test of equality of the absolute values of the coefficients for positive and negative tail days are in parentheses.

	1	2	3	4	5	6	7	8	9
Constant for positive tail days/100	−0.429***	−0.677***	−0.411***	−0.409***	−0.380**	−0.379*	−0.637	−0.188	−0.220
Constant for negative tail days/100	0.718***	1.129***	0.583***	0.587***	0.528**	0.353	0.363	−0.283	−0.276
	(0.267)	(0.052)	(0.488)	(0.483)	(0.550)	(0.943)	(0.846)	(0.139)	(0.124)
Gain on holdings of tail peripherals on positive tail days			0.086	0.086	0.065	0.152	0.080		0.058
Gain on holdings of tail peripherals on negative tail days			0.846***	0.846***	0.756***	1.160***	0.861***		0.495***
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)		(0.011)
Gain on holdings of non-tail peripherals on positive tail days				0.005					
Gain on holdings of non-tail peripherals on negative tail days				−0.005					
				(0.796)					
Gain on holdings of core countries on positive tail days					−0.236*				
Gain on holdings of core countries on negative tail days					−0.868**				
					(0.117)				
Market value of equity on positive tail days/100						−0.715			
Market value of equity on negative tail days/100						5.347			
						(0.134)			
Market value of equity × Gain on holdings of tail peripherals on positive tail days						2.501			
Market value of equity × Gain on holdings of tail peripherals on negative tail days						12.285			
						(0.290)			
Delta							0.006		
Gamma							−0.112**		
Size on positive tail days/100								−0.910**	−0.731*
Size on negative tail days/100								3.422***	3.140***
								(0.001)	(0.003)
Size × Gain on holdings of tail peripherals on positive tail days									0.084***
Size × Gain on holdings of tail peripherals on negative tail days									0.055
									(0.661)
Number of observations	5783	3690	5334	5334	5334	5334	5329	5783	5334
Adjusted-R^2	0.031	0.081	0.051	0.052	0.059	0.053	0.054	0.079	0.096

multicollinearity. When we use only the squared terms in Model 3, each is significant, but the explanatory power of the regression is almost unchanged from the regression with linear terms.

The next three models provide estimates using a portfolio of banks from core countries. The results are essentially the same as for the whole sample, except that the quadratic term for negative tail changes is significant and positive. Further, the explanatory power of the regression with only quadratic terms is higher than the explanatory power of the regression with only linear terms.

Turning to the non-core countries, the coefficient on positive tail spread changes is significant in Model 1 but the coefficient on negative tail spread changes is positive, significant, and more than three times the other coefficient. In Model 2, no coefficient is significant. Finally, in Model 3, both quadratic terms are significant, with a negative coefficient for positive spread changes and a positive coefficient for negative spread changes. The last three regression models are for the banks in the countries experiencing the tail spread changes. The results for Model 1 and Model 3 are similar to those for the sample as a whole, and the asymmetry is statistically significant in Model 1. For Model 2, no coefficient is significant.

The main results of this section are (a) the evidence of transmission of shocks to peripheral countries to banks in countries without shocks is much stronger for multiple tail days and (b) the impact of shocks to peripheral countries on banks from countries that are not subject to a shock is strongly asymmetric on multiple tail days. The evidence that banks are hurt less by spread increases than they benefit from spread decreases is supportive of the asymmetry hypothesis.

5. Sovereign tail risk events and the cross-section of bank returns

In this section, we estimate regressions to test the asymmetry hypothesis. The regressions have the following format:

$$AR_i(t) = a + b_1 IndPTS(t) + b_2 IndNTS(t) + b_3 GainPTS_i(t) + b_4 GainNTS_i(t) + \varepsilon(t) \quad (4)$$

where $AR_i(t)$ is the abnormal return on t of bank i, IndPTS(t) and IndNTS(t) are indicator variables for positive and negative tail spread shocks, respectively, $GainPTS_i(t)$ and $GainNTS_i(t)$ correspond to the portfolio gain of bank i for positive tail shocks and negative tail shocks, respectively. For each regression we estimate, the sample is composed of the stress test banks that are not located in the peripheral country or countries with a CDS tail change on that day. Systemic risk contagion occurs irrespective of bond holdings. Hence, if this is the only contagion channel, bond holdings should be irrelevant in explaining abnormal returns, but we should see negative abnormal returns for banks on positive tail days and positive abnormal returns on negative tail days. Alternatively, if only the bond portfolio contagion channel is relevant, the abnormal returns should be zero if exposure is zero. Since we can identify each channel, we can test for asymmetry for each channel.

The regressions are shown in Table 8. We cluster the standard errors by event day. We use any day on which there is at least one CDS tail spread change for a peripheral country. On multiple tail days the CDS spread change is the average CDS spread change across the countries having tail events. Model 1 regresses the abnormal returns of banks outside of the country or countries with tail spread changes on an indicator for positive spread changes and an indicator for negative spread changes. The coefficients on these indicator variables are significant at the 1% level. The coefficient on the indicator variable for positive spread changes is −0.429, so that a positive sovereign CDS spread change is associated on average with an abnormal return of −0.429%. The coefficient on the indicator variable for negative spread changes is 0.718%. The coefficient on the indicator variable for negative spread changes is 67% higher than the coefficient for the indicator variable for positive spread changes in absolute value. Though both coefficients are significant at the 1% level, the difference in the absolute value of the coefficients is not significant. We would not expect the impact of shocks to Greece to be very asymmetric because Greece is the smallest country, so that the markets probably did not expect policy actions to offset the impact of shocks to Greece. In Model 2, we remove the events where only Greece has a spread shock. When we do that, we find that the asymmetry is statistically significant at the 10% level. We keep the events where only Greece has a spread shock in the sample for the other regressions in Table 8.

In Model 3, we add the gain variables to Model 1. Consequently, Model 3 tests for a systemic channel and a portfolio channel. We call Model 3 our benchmark model. Adding the gain variables has no material impact on the coefficients of Model 1. The coefficient on the gain variable on days with positive tail spread changes is 0.086 and insignificant; in contrast, the coefficient on the gain variable on days with negative tail spread changes is 0.846 and significant at the 1% level. The absolute values of the coefficients are significantly different, so that banks gain more from spread decreases than they lose from spread increases. Though we do not report the results in the table, we test for whether the coefficients are significantly different from one. While the coefficient for positive tail spread changes is significantly different from one, the coefficient for negative tail spread changes is not. These results show that bond losses due to tail CDS spread increases are not associated with significant shareholder wealth losses, but bond gains due to tail CDS spread decreases translate into shareholder wealth gains such that shareholders appear to capture the whole gain on the bonds.

A concern with the results of Model 3 is that the gain variable could partly proxy for gains on other bonds. To check for this, we add gains on holdings of bonds from peripheral countries that do not experience a tail event in Model 4. We find that adding these gain variables does not affect inferences on the magnitude of the coefficients on the gains on the bonds from the countries experiencing the tail event. In Model 5, we add instead the gains on the bonds from core countries. Again, our estimates of the coefficients on the gain variables for bond holdings from the countries that experience a tail event are not materially affected. Surprisingly, however, the coefficient on gains on holdings of core countries on negative tail days is significantly negative. We find similar results using an alternative definition of core countries where core countries are those that have a CDS spread below the median at least 80% of the time. These results suggest that the flight to safety effect cannot by itself explain the asymmetry in the impact of tail shocks on stock prices.

We now turn to possible explanations for the asymmetry we document. If a bank is highly levered, we would expect gains and losses to be shared between shareholders and bondholders. It is furthermore likely that a highly levered bank would receive official support to potentially offset losses. In contrast, in the extreme case of an unlevered banks, shareholders bear all the gains and losses. It follows that we would expect less asymmetry for a bank with low leverage. In Model 6, we add a traditional measure of market leverage, the market value equity ratio defined earlier as the market value of equity divided by the book value of assets minus book value of equity plus the market value of equity, and interact that measure with all the variables in Model 3. None of the added variables is significant. Adding the leverage variables does not change our inferences about the asymmetry of the effect of tail shocks on bank stock returns. An important caveat is that the variation in leverage for our sample banks is rather limited so that we may have limited power in finding a leverage effect.

Model 7 shows results for an alternative approach to explore the impact of leverage. With this alternative, we explicitly take into account that equity is an option on a bank's assets. Instead of adding the gain variables as in Model 3, we multiply a bank's portfolio gain on peripheral bonds from tail countries by delta and then include gamma times the square of the gain variable. Delta and gamma are obtained from Merton's model for the value of equity. If the option properties of equity explain the asymmetry, we should expect that the coefficient on delta times the gain variable to be positive and the coefficient on gamma times the square of the gain variable to be positive as well. We find that the coefficient on delta times the gain is insignificant and the coefficient on gamma times the gain squared is negative. This evidence is not supportive of the hypothesis that the option properties of equity explain the asymmetry we document. Further, adding the option variable has no impact on our inferences about the asymmetry of the effect of tail shocks on bank stock returns. Though the coefficients on the indicator variables are not significant when we add the option variables, the estimates for these coefficients do not differ from the estimates in the benchmark regression (3).

An alternative explanation for the asymmetry is that the market believes that potentially systemic adverse shocks make it more likely that policy actions will protect large banks against systemic adverse shocks. With this explanation, we expect that the market takes into account that large adverse shocks that are more pervasive, because of either occurring in a larger country or affecting multiple countries, increase the likelihood of policy measures that will mitigate the impact of these adverse shocks on banks, so that the impact of these shocks would be discounted by the market. To test this hypothesis, we investigate the impact on the portfolio and systemic risk channels of the pervasiveness of shocks. We introduce a variable that we call Size. It is the ratio of the GDP of countries with a tail shock to the aggregate GDP of the peripheral countries. This variable goes from less than 0.05 to 1. In Model 8, we re-estimate Model 1, but add Size interacted with the indicator variables. We find that, while the indicator variables are not significant, there is a strong asymmetry in the indicator variables interacted with Size. This means that shocks to larger countries and more pervasive shocks are more asymmetric. Model 9 adds interactions with the gain variables to Model 8. We still find a strong asymmetry when the indicator variables are interacted with size, but we find so significant asymmetry when the gain variables are interacted with size.

Though we do not tabulate the results, we investigate whether the impact of a tail shock on a bank's common stock depends on the bank's funding. We add the Demirguc-Kunt and Huizinga (2010) fragility measure, which increases as a bank relies less on customer deposits, and interact it with all the variables of Model 3. We find that the measure is never significant. It is plausible that on some tail days there is a macroeconomic policy announcement affecting both banks and borrowing costs of peripheral countries. To investigate whether days of macroeconomic policy announcements affect our results, we re-estimate Model 3 first excluding the days of macroeconomic LTRO (long term refinancing operations) policy announcements used by Acharya and Steffen (2015) in their event study and second excluding the days of macroeconomic policy announcements in Krishnamurthy et al. (2014). The regression estimates from these regressions lead to the same conclusions. We also investigate the role of the pervasiveness of a shock by restricting the sample to tail shocks that take place in only one country. The results are much weaker. We find no asymmetry.

In summary, Table 8 shows that there is both a systemic channel and a bond portfolio channel. With our results, a bank that has no exposure to bonds from peripheral countries is still affected by tail spread shocks in these countries. We also find that the impact of shocks is asymmetric in that bank shareholders gain more from negative spread shocks than they lose from positive spread shocks, but only when the shocks are pervasive.

We now turn to different specifications of two benchmark regression models of Table 8, which are Model 3 and Model 9 which takes into account the pervasiveness of the shocks. In Panel A of Table 9, we provide estimates of Model 3 using different samples, different definitions of the gain variables, and different specifications of tail events. We report as Model 1 in Panel A of Table 9 the estimates of Model 3 from Table 8 for comparison.

In Table 8, we use the exposures reported in the stress tests as of the balance sheet date of that exposure to estimate the gain variables. In Model 2 of Panel A of Table 9, we show estimates based on the gain variables computed from disclosed exposures. Using exposures at disclosure means that we have a shorter sample period but investors could have invested based on that information. We find that the results are similar to those of the benchmark model. In Model 3, we restrict the sample to banks in the Eurozone. The results are similar to the benchmark model except that the coefficient on the gain variable for negative tail change days is much smaller, though still significant at the 1% level.

So far, we have used changes in CDS to determine tail spread change days. In Model 4, we use instead changes in the five-year bond yield. We choose the five-year bond yield because the CDS we use have a five-year maturity. The estimates of Model 4 are similar to the estimates of Model 3.

The event window in the models estimated so far is a one-day event window. We now show results for a three-day event window. The estimates of Model 5 use a three-day window for the balance sheet announcement dates and show strong evidence of asymmetry for both transmission channels. In Model 6, we use a three-day window for the disclosure announcement date. Again, we find strong evidence of asymmetry for both channels.

The next two models we report use different approaches to determine tail event days. Model 7 uses estimates of volatility based on a three-month rather than a six-month moving average. Instead of using CDS spread changes, we use CDS returns in Model 8. These changes do not affect our inferences.

Table 9
Tail regressions robustness. The regressions are estimated using tail days (defined as days when the absolute value of the first difference in the CDS spread is above twice its rolling six month standard deviation). The dependent variable in the regressions is the abnormal stock return, obtained as residuals from a market model estimated over the previous sixty days where the market is represented by the equal average of the sectors of the Stoxx index (excluding banks, insurance companies and financial institutions). The sample period is April 2010-November 2012 and includes stress test banks that are publicly traded and report sovereign bond holdings. The bank variables are winsorized at the 1% and 99% levels and are expressed in percentage terms. Gain on holdings of tail peripherals is the gain on holdings of sovereign bonds issued by tail countries normalized by the market capitalization of the bank five days before. Gain is computed daily, using data on holdings of bonds with maturities 0.25, 1, 2, 3, 5, 10 and 15 years and estimating the return at each maturity using the first difference in the specific yield and the modified duration approximation. Exposure is the ratio between the most recent exposure to a tail peripheral country and market capitalization lagged five days. We use the balance sheet date approach except in Models 2 and 6 where we use the disclosure date approach. In Model 3 the sample is restricted to banks located in the euro-area; in Model 4 tail days are defined on the basis of the first difference in five-year bond yields rather than CDS spreads; in Models 5 and 6 the dependent variable is the three day abnormal return including [t-1,t + 1]; in Model 7 the rolling standard deviation used to define the tails is computed over the previous three months; in Model 8 the tails are defined using CDS returns rather than CDS spread first differences. Model 9 excludes days where only Greece has a tail event. Model 10 excludes days where only Greece, Ireland or Portugal has a tail event. In panel A the benchmark is Model 3 of Table 8, also reported as Model 1 in panel A. In panel B, the benchmark is Model 9 of Table 8, also reported as Model 1 of panel B. Standard errors are obtained by clustering at the event level. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. P-values for the test of equality of the absolute values of coefficients for positive and negative tail days are in parentheses.

	1	2	3	4	5	6	7	8	9	10
Panel A										
Constant for positive tail days/100	−0.411***	−0.411***	−0.512***	−0.538***	−0.689**	−0.657**	−0.482***	−0.336*	−0.632***	0.721***
Constant for negative tail days/100	0.583***	0.522**	0.745***	0.592***	1.618***	1.639***	0.586**	1.000***	1.117***	1.400***
	(0.488)	(0.674)	(0.459)	(0.819)	(0.042)	(0.048)	(0.706)	(0.066)	(0.097)	(0.079)
Gain on holdings of tail peripherals on positive tail days	0.086	0.070	0.034	0.047	0.135	0.105	0.178*	0.206*	0.173*	0.124
Gain on holdings of tail peripherals on negative tail days	0.846***	0.808***	0.218***	0.252***	1.044***	1.090***	0.972***	0.702***	0.839***	0.508***
	(0.000)	(0.002)	(0.012)	(0.010)	(0.006)	(0.012)	(0.001)	(0.021)	(0.000)	(0.002)
Number of observations	5334	4529	3763	5926	5460	4639	4532	3454	3435	2431
Adjusted-R^2	0.051	0.043	0.050	0.065	0.062	0.060	0.066	0.077	0.108	0.132
Panel B										
Constant for positive tail days/100	−0.220	−0.302	−0.375	−0.479***	−0.281	−0.506	−0.333**	−0.038	−0.511**	0.600*
Constant for negative tail days/100	−0.276	−0.258	−0.353	0.147	0.714	0.718	0.061	0.258	0.096	−0.784
	(0.124)	(0.091)	(0.056)	(0.316)	(0.459)	(0.735)	(0.386)	(0.612)	(0.318)	(0.102)
Gain on holdings of tail peripherals on positive tail days	0.058	0.042	0.036	0.043	0.093	0.072	0.141	0.141	0.138	0.129*
Gain on holdings of tail peripherals on negative tail days	0.495***	0.457***	0.116	0.226***	0.813***	0.841**	0.582***	0.420**	0.532**	0.432***
	(0.011)	(0.027)	(0.310)	(0.027)	(0.023)	(0.037)	(0.051)	(0.174)	(0.082)	(0.034)
Size on positive tail days/100	−0.731*	−0.523	−0.532	−0.212	−1.536*	−0.716	−0.543	−1.012*	−0.325	−0.224
Size on negative tail days/100	3.140***	3.057***	3.965***	1.580**	3.293***	3.623***	2.816***	3.267***	2.617***	3.914***
	(0.003)	(0.003)	(0.001)	(0.120)	(0.157)	(0.043)	(0.031)	(0.035)	(0.013)	(0.011)
Size × Gain on holdings of tail peripherals on positive tail days	0.084***	0.085***	0.023	−0.014	0.102***	0.106***	0.078***	0.074***	0.072**	0.066*
Size × Gain on holdings of tail peripherals on negative tail days	0.055	0.082	−0.012	0.053	−0.092	−0.112	0.053	0.035	0.033	−0.088
	(0.661)	(0.964)	(0.330)	(0.127)	(0.094)	(0.105)	(0.754)	(0.664)	(0.751)	(0.276)
Number of observations	5334	4529	3763	5926	5460	4639	4532	3454	3435	2431
Adjusted-R^2	0.096	0.085	0.092	0.079	0.082	0.078	0.066	0.123	0.135	0.166

In Model 9, we remove the days where only Greece has a tail spread change. Our inferences are again not affected. In model 10, we remove the days where only Greece, Ireland or Portugal has a tail spread change. The results are even stronger.

Panel B repeats all the robustness tests for Model 9 of Table 8, which is the model that allows for interactions with the size variable. In Table 8, we find that there is an asymmetry of the systemic risk transmission channel for more pervasive shocks. In Table 9, we find that this result holds for all of our robustness tests except Models 4 and 5 where tails are, respectively, estimated using bond returns and CDS returns. We also find that the asymmetry of the portfolio transmission channel holds for all of our robustness tests except Model 3 which is restricted to the Eurozone.

6. Conclusion

In this paper, we investigate the contagion of shocks to the creditworthiness of peripheral countries during the European crisis. We consider two contagion channels of sovereign shocks. The first channel is the impact of the shock to the financial system, which is independent of the exposure of a bank to the country affected by the shock. We call this the systemic risk channel. The second channel is the impact of the shock on bonds held by a bank. We call this channel the bond portfolio channel. Using banks that report results of stress tests between 2010 and 2012, we provide evidence that sovereign shocks impact banks through both channels.

We test the hypothesis that shocks to the creditworthiness of peripheral countries have an asymmetric impact on banks, so that for shocks of the same absolute size, positive shocks benefit banks more than negative shocks hurt them. There are three motivations for this hypothesis. First, if bank stocks are call options on the assets, bank stocks are convex functions of the value of the assets. Second, large pervasive adverse shocks increase the probability of policy decisions mitigating the impact of shocks on banks. Third, core country banks have a home bias in their holdings of sovereign bonds and at times core country sovereign bonds benefit from a flight to quality phenomenon which provides a hedge against losses from shocks to peripheral country bond holdings. We find little support for the explanation that relies on the option properties of bank equity. In contrast, there is support for the two other motivations for our asymmetry hypothesis. We find that small-country idiosyncratic shocks create no systemic contagion while pervasive shocks produce an asymmetric contagion as expected. Similarly, the portfolio transmission channel is asymmetric in that bank shareholders appear to receive the whole gain from peripheral sovereign bond price increases on tail spread change days but suffer no significant loss when the bond prices fall.[5] Further, core country banks do not experience aggregate portfolio losses on days of adverse tail shocks in peripheral countries.

Our evidence also shows that the portfolio channel is surprisingly weak for adverse shocks. The reason for this surprising result is in part that banks in core countries have a strong home bias and that the bonds from their home countries at times benefit from flight to safety effects. We find that losses on bonds from peripheral countries experiencing tail CDS spread increases are not associated with shareholder wealth decreases in our main specification and generally have a small economic impact, but in contrast shareholder wealth increases almost one for one with gains on bonds from peripheral countries experiencing tail spread decreases.

The results of this paper show that there is a strong asymmetry in the impact of shocks to sovereign credit spreads of peripheral countries on banks from other countries when shocks are pervasive, i.e, they affect larger countries or multiple countries. This asymmetry is consistent with markets believing that adverse effects of shocks to sovereign credit spreads from peripheral countries would bring about policy responses offsetting the impact of these shocks, which made it less risky to hold sovereign bonds from peripheral countries.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jimonfin.2019.102081.

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[5] Though we find that on average core banks were little affected by adverse shocks in sovereign credit spreads of peripheral countries, it is important to note that this does not imply that no bank was affected. Acharya and Steffen (2015) emphasize the case of Dexia, which had high holdings of bonds from peripheral countries and had to be bailed out as a result.

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