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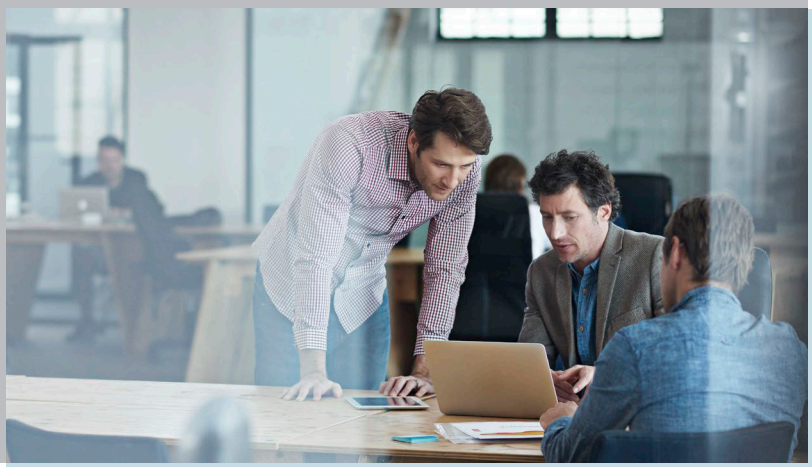
## Lender of Last Resort versus Buyer of Last Resort – Evidence from the European Sovereign Debt Crisis

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# Lender of Last Resort, Buyer of Last Resort, and a Fear of Fire Sales in the Sovereign Bond Market[☆]

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**Abstract**

We document the mechanism through which the risk of fire sales in the sovereign bond market contributed to the effectiveness of two major central bank interventions designed to restore financial stability during the European sovereign debt crisis. As a *lender of last resort*, the European Central Bank (ECB) improved the collateral value of sovereign bonds of peripheral countries. An elevated concentration of these bonds in the portfolios of domestic banks increased fire-sale risk, making both banks and sovereign bonds riskier. In contrast, the ECB's announcement of being a potential *buyer of last resort* attracted new investors and reduced fire-sale risk.

*Keywords:* Bank–sovereign nexus, ECB, financial stability, unconventional monetary policy.
*JEL:* G01, G21, G28

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## 1. Introduction

Unconventional monetary policies have been adopted by central banks across the world to restore the stability of their financial sectors during a crisis. Traditionally, to restore financial stability, central banks have acted as lenders of last resort, providing liquidity to the banks in order to prevent fire sales and inefficient runs. Alternatively, central banks have acted as buyers of last resort, purchasing, or announcing the commitment to purchase, assets from the market, restoring asset prices, and improving the financial health of banks holding the assets.

Given the effect of central bank policies on the expected returns of banks' assets, the policies will likely affect investment strategies and trigger portfolio rebalancing by banks. The portfolio reallocation of large banks can in turn affect the liquidity of assets and the probability of future fire sales. The model of Diamond and Rajan (2011) shows that a "fear of fire sales" emerges when illiquid assets are held by insolvent banks conditional on a future liquidity shock. The uncertainty about future liquidity induces the insolvent banks to hold on to the illiquid assets due to risk-shifting incentives, while potential liquid buyers do not buy the illiquid assets anticipating higher expected returns in a fire sale. Therefore, the market for the illiquid assets freezes up when the assets are held by banks that, given their liability structure, would become insolvent in the event of a future liquidity shock. In addition, given limited liability and risk-shifting incentives, the insolvent banks will load up even more on the illiquid assets if they had cash to invest.

In this paper, we bring the theoretical predictions of Diamond and Rajan (2011) to the sovereign bond market during the European sovereign debt crisis. Sovereign bonds may become illiquid due to market segmentation, where several sets of investors value the bonds differently due to their differing incentives for holding them.[1] In a sovereign debt crisis, large domestic banks become dominant holders of sovereign bonds due to gambling for resurrection or risk-shifting incentives (Acharya and Tuckman, 2014; Drechsler et al., 2016) or moral suasion (De Marco and Macchiavelli, 2016; Ongena et al., 2016). A fragile liability structure and a high correlation between the value of the domestic bank's portfolio and the value of the sovereign bond make domestic banks candidates

[1] For example, Pelizzon et al. (2016) document a spike in the bid-ask spread of Italian bonds (€4.48 per €100 of face value) on November 9, 2011.

to become insolvent conditional on a future liquidity shock. The concentration of illiquid sovereign bonds in the hands of insolvent domestic banks will increase the risk of fire sales. Moreover, the mere existence of limited liability of the insolvent bank will exacerbate the risk-shifting problem in the presence of a fear of fire sales, as in the model of Diamond and Rajan (2011).

We use the European sovereign debt crisis and two unprecedented policies of the European Central Bank (ECB) as a laboratory to study a fear of fire sales in the sovereign bond market. After investors "ran" from European banks by massively withdrawing short-term funding in the summer of 2011,[2] the ECB reacted with a series of non-standard policies. As a lender of last resort (LOLR), the ECB provided banks with funding liquidity in exchange for eligible collateral in its three-year long-term refinancing operation (LTRO) in December 2011 and February 2012. As a buyer of last resort (BOLR), the ECB announced the commitment to purchase government bonds in its Outright Monetary Transactions (OMT) program in July and September 2012.

Interestingly, the different interventions of the ECB led to changes in the concentration of sovereign bonds in the hands of domestic banks. We show the evolution of eurozone sovereign debt concentration in Figure 1, together with the evolution of eurozone banks' access to unsecured funding from U.S. money market funds (MMFs).[3] After eurozone banks lost 77% of their unsecured funding from U.S. MMFs in 2011, the sovereign debt concentration in eurozone domestic banks increased by 3.2 percentage points between December 2011 and September 2012. While becoming increasingly reliant on ECB funding through the LTROs, eurozone domestic banks held 22% of all issued sovereign bonds of their country. After the announcement of the OMT program, sovereign debt concentration started to decrease while eurozone banks were recovering access to private funding.

This paper uses the variation in sovereign debt concentration over time to shed light on an important channel of the bank–sovereign nexus—the fire-sale risk channel—when sovereign debt concentration in the domestic banking sector increases. Using data on sovereign bond holdings

[2]In particular, U.S. money market funds (MMFs) were the first group of investors to withdraw from banks in the eurozone; U.S. prime MMFs holdings of eurozone banks fell from 30% of their assets in May 2011 to 11% by December 2011 (Investment Company Institute, 2013).

[3]Data on sovereign debt concentration are from the Bruegel database of sovereign bond holdings developed in Merler and Pisani-Ferry (2012). Data on access to unsecured funding from U.S. MMFs are from the iMoneyNet database.

disclosed by the European Banking Authority, we observe that the trend in eurozone sovereign debt concentration following the LTRO liquidity injections is driven by the domestic banks of the peripheral countries of Greece, Ireland, Italy, Portugal and Spain (GIIPS). In particular, Italian and Spanish banks in our sample increased their domestic sovereign bond holdings by €49 billion in the time period between the announcements of the LTRO and OMT programs, increasing the domestic share in their sovereign bond portfolios from 79% to 83%. In contrast, non-GIIPS eurozone banks' balance sheets were stronger and they further reduced their GIIPS sovereign bond exposures.[4] Sovereign risk in the eurozone thus became more concentrated in the portfolios of peripheral banks.

With the entrenchment of risky sovereign bonds in the portfolios of banks dependent on public funding, our prediction for a fire-sale risk channel entails that the risk of fire sales of sovereign bonds rises with the probability of future insolvency of domestic banks. Therefore sovereign bonds become riskier when their concentration in domestic banks increases and when the solvency condition of domestic banks deteriorate. We document this prediction using Granger causality tests on five-year sovereign credit default swap (CDS) prices and five-year bank CDS prices. While the bank–sovereign relationship is highly endogenous, Granger causality tests should help indicate the relative importance of each direction in the nexus, i.e., sovereign risk predicting bank risk or bank risk predicting sovereign risk, during different sample periods.[5] These tests do not prevent both directions of contagion in the bank–sovereign nexus to be economically and statistically significant at the same time. However, we find that domestic bank risk predicts home sovereign risk in the period following the LTROs and before the OMT program announcement. In contrast, in the periods preceding the LTROs and after the OMT program announcement, we find the opposite effect: sovereign risk predicts domestic bank risk.

Importantly, we find that the influence of bank risk on sovereign risk in the post-LTRO period is related to the importance of sovereign bond holdings in the portfolios of GIIPS banks, disentangling the fire-sale risk channel from other channels (e.g., a government guarantee channel) not related to

[4] Acharya and Steffen (2015) identify the risk-shifting or "carry trade" incentives of under-capitalized GIIPS banks as the primary motive for sovereign bond purchases.

[5] Other papers evaluating risk contagion using Granger causality tests include Kodres and Pritsker (2002), Longstaff (2010), and Billio et al. (2012).

banks' sovereign bond holdings. We show in Figure 2 that banks that exert the highest pressure on sovereign bond prices during the post-LTRO period experienced the largest outflows of non-deposit liabilities before the LTRO liquidity injections, while the banks with the largest funding outflows are also the dominant holders of sovereign bonds of their country. These observations are consistent with the existence of a fire-sale risk channel affecting both the riskiness of banks and GIIPS sovereign bonds following the LTRO liquidity injections.

We then analyze a more conventional channel of the bank–sovereign nexus related to banks' sovereign bond holdings, where bank risk increases with the riskiness of its sovereign bond holdings. We investigate this "holdings channel" linking the influence of sovereign risk on bank risk to banks' sovereign bond holdings. This channel does not affect GIIPS banks differently, and appears significant only before the LTRO liquidity injections and after the OMT program announcement. Additional evidence for the holdings channel is obtained by studying the effect of sovereign bond exposures on abnormal bank performance around the announcement of ECB interventions. This analysis shows a reduction of CDS spreads and an increase in equity value of banks holding *short-term* GIIPS sovereign bonds (with a maturity between one and three years) around the announcement of the three-year LTROs. This analysis suggests that the LTRO announcement improved the collateral value of short-term sovereign bonds,[6] especially in countries where banks were most dependent on ECB funding.[7]

In summary, the increasing concentration of sovereign bonds in the portfolios of domestic banks relying on LTRO liquidity injections contributed to increase fire-sale risk in the sovereign bond market. In contrast and without purchasing any asset under the program, the ECB's announcement of being a potential BOLR to the sovereign bond markets under the OMT program mitigated the fire-sale risk channel and led to a permanent stabilization of bank risk. In further tests, we find

[6]Crosignani et al. (2017) document that Portuguese banks, to receive a secured loan of a given maturity at the ECB, prefer to hold sovereign bonds of a shorter maturity as collateral, since the banks are reluctant to remain exposed to (or to sell) the collateral once the loan matures. The LTRO announcement facilitated the extension of the maturity of existing secured loans from the ECB of up to three years to banks through its previous operations (including its one-year LTRO). This maturity extension improved the collateral value of sovereign bonds of a maturity between one and three years.

[7]In contrast, and similarly to Krishnamurthy et al. (2018), the abnormal performance of banks around the OMT program announcement does not appear to be specifically related to banks' sovereign bond holdings.

that the OMT program attracted new investors (eurozone banks as well as non-bank institutional investors) to the sovereign bond market, as the announcement plausibly led to a change in investors' expectations about the risk of future fire sales in the sovereign bond market.

While the ECB LTROs might have helped banks that would become insolvent without ECB funding support to increase their exposure to liquidity risk (Drechsler et al., 2016), it is not our ambition to explain why banks increased their holdings of sovereign bonds. Instead, we use this increase in sovereign debt concentration in domestic banks to study a fire-sale risk channel in the sovereign bond market. The analysis of central bank interventions and their effects on the bank–sovereign nexus is, by its very nature, highly endogenous. In addition, we have to rely on a small sample of large banks susceptible to affect fire-sale risk. Our research setting relies on hypotheses developed from the theoretical framework of Diamond and Rajan (2011) to describe a fire-sale risk channel in the sovereign bond market. We provide suggestive empirical evidence of a fire-sale risk channel with a series of analyses and tests from multiple data sources, taking advantage of the variation in sovereign debt concentration over time and the presence of large European banks operating in a fragmented sovereign bond market. To the best of our knowledge, this is the first paper that documents the presence and the importance of a fire-sale risk channel in the sovereign bond market and the consequence of LOLR and BOLR interventions regarding this channel.[8]

The rest of the paper proceeds as follows. In Section 2, we describe the institutional background and the conceptual framework. We present the data used in our analyses, as well as descriptive statistics, in Section 3. We investigate the fire-sale risk channel in Section 4. In Section 5, we investigate alternative channels of the bank–sovereign nexus. We relate our paper to the literature in Section 6 and we conclude in Section 7.

## 2. Institutional background and conceptual framework

Since 2010, the ECB has implemented a series of unconventional policy measures in an attempt to provide support for a "dysfunctional market" and repair the monetary policy transmission mech-

[8] While Greenwood et al. (2015) highlight the relevance of the fire-sale risk channel in the sovereign bond market simulating the effect of a sovereign stress scenario on bank contagion, we show evidence of the effect of the fire-sale risk channel on realized bank risk and sovereign risk following two major interventions of the ECB.

anism. We focus on two unprecedented measures introduced by the ECB—its three-year LTROs and its OMT program—after the peak of the European sovereign debt crisis in the summer of 2011. These measures were unprecedented by their scale and scope (€1 trillion liquidity injected to banks in the LTROs and unlimited bond buying program under fiscal constraints for countries entering the OMT program). In addition, the sequence of two successive intervention announcements after massive funds withdrawals from short-term investors gives us a unique laboratory to study LOLR and BOLR theory predictions and their effects on fire-sale risk.

### *2.1. LTROs*

The intention of the ECB to conduct longer term LTROs was first discussed by Mario Draghi before a plenary of the European Parliament on December 1, 2011. He explained that "*options include three-year ECB loans to banks and broadening the pool of assets that can be provided as collateral*."[9] The ECB announced that it would conduct three-year LTRO liquidity injections on December 8, 2011. In this announcement, the ECB stated it would conduct two three-year LTRO allotments on December 21, 2011 (LTRO 1) and February 29, 2012 (LTRO 2). The ECB allotted €489 billion to 523 banks in LTRO 1, and €530 billion to 800 banks in LTRO 2. The banks had to post collateral in exchange for funding under the LTRO programs and the interest on the funds was tied to the ECB policy rate.

The ECB switched to full allotment in its regular main refinancing operations (MROs) in October 2008, for which banks paid the same interest rate as for the LTROs. Rolling over weekly MROs is thus similar to borrowing under the LTROs. The latter, however, removes the uncertainty that the ECB switches back to fixed quantity allotment in its MROs. In LTRO 1, banks were also allowed to shift all of the outstanding amounts received in the one-year LTRO allotted on October 6, 2011 into the first three-year LTRO allotted on December 21, 2011. Most banks rolled their central bank funding over into longer maturity and, effectively, about €0.5 trillion of net liquidity was injected into the eurozone banks by the two three-year LTRO liquidity injections.

[9]"Draghi hints at eurozone aid plan" (*Financial Times*, December 1, 2011).

*2.2. OMT program*

In response to the worsening of the sovereign debt crisis, Mario Draghi declared on July 26, 2012, during a conference in London: "*Within our mandate, the ECB is ready to do whatever it takes to preserve the euro. And believe me, it will be enough.*" Mario Draghi focused his speech on financial fragmentation as the main short-term challenge for restoring the transmission of ECB monetary policy. On August 2, 2012, the ECB announced outright purchases of sovereign debt in secondary bond markets. On September 6, 2012, the ECB introduced and announced the key parameters of the OMT program. Under the program, the ECB could purchase unlimited amounts of eurozone government bonds with maturities of one to three years, provided that the country the ECB would buy bonds from met key conditions. First, the country had to receive financial support from the European Stability Mechanism (ESM). The government had to comply with the reform efforts required by the respective ESM program. Moreover, the OMT program could only be activated if the country had regained complete access to private lending markets. Finally, the country's government bond yields had to be higher than what could be justified by the fundamental economic data.

As of the end of 2015, the OMT program had not been activated (i.e., the ECB did not purchase any sovereign bonds under the program), yet the OMT program could be qualified as an unprecedented BOLR measure of the ECB. The OMT program differed from other asset purchase programs that have been implemented before.[10] While "promises" of fiscal and structural reforms were almost sufficient to benefit from ECB purchases in the Securities Markets Program (SMP), the introductory statement about the OMT details of Mario Draghi establishes strict and effective conditionality for countries to enter the OMT program. In addition, the ECB would improve transparency and publish the OMT holdings, the duration, the issuer, and the market value. The duration of purchased assets is also different and the ECB did not make itself a senior claimant under the OMT program. If the ECB purchased sovereign bonds under the OMT program, it would absorb the liquidity by

[10]The ECB implemented other BOLR actions in the previous months: the Securities Markets Program was announced in May 2010, and its extension to buy sovereign bonds of Italy and Spain in August 2011. Under the SMP program, the ECB holdings of GIIPS sovereign bonds amounted to €218 billion in December 2012 (including €103 billion of Italian sovereign bonds and €44 billion of Spanish sovereign bonds). The Securities Markets Program program was terminated with the announcement of the OMT program details in September 2012.

auctioning off an equal amount of one-week deposits at the ECB. Finally, although no clear limits to ECB holdings were announced under the SMP, the ECB stated that unlimited amounts of sovereign bonds could be purchased under the OMT program in order to reach its objectives.

The OMT has been challenged in German constitutional court hearings in June 2013 as a measure outside the legal framework provided by the Maastricht treaty. However, it received a favorable ruling by the European Court of Justice in June 2015, rejecting the challenge of the German constitutional courts. In June 2016, these courts decided that the policy decision on the OMT does not "manifestly" exceed the competences attributed to the ECB and, importantly, does not constitute a threat to the German Bundestag's right to decide on the budget.

### *2.3. Conceptual framework*

The predictions we test in this paper are centered around two propositions from the model of Diamond and Rajan (2011). In the context of our paper, the first proposition implies that if a domestic bank would become insolvent conditional on a liquidity shock at a future date, the bank has no incentives to sell the sovereign bonds today, even if by doing so the bank could remain solvent. By selling assets now, the banker would make a transfer to depositors or tax payers (through the government insurance fund and implicit government guarantees) in the state of the liquidity shock. In addition, weak domestic banks will want to use any cash to increase their exposure to the illiquid sovereign bond in order to "double-up" their bets.

While we do not document the effect of a fear of fire sales on bank lending (Proposition 2 in Diamond and Rajan, 2011), we provide empirical support for the third proposition. The third proposition indicates a positive relationship between a bank's exposure to the aggregate liquidity shock and its impact on asset prices, for the subsample of banks that would become insolvent conditional on the liquidity shock. In the model, risk is endogenous in that price risk of the illiquid asset is a function of the liability structure of the domestic bank, and therefore the exposure of the bank to the aggregate liquidity shock. Consequently, the model predicts a reinforcement of the bank–sovereign nexus from the fire-sale risk channel. The uncertainty about future liquidity should generate a high correlation between sovereign bond risk and the solvency risk of domestic banks holding the bonds.

In light of these predictions, the LOLR intervention could produce contrasting effects on financial stability. According to the classical LOLR theory (Bagehot, 1873), the LOLR provides banks with liquidity, which stops bank runs by allowing banks to continue financing existing assets. Banks thus do not need to sell assets at fire-sale prices and can continue lending, avoiding a credit crunch. However, the fraction of risky sovereign bonds held by weak banks may even increase if banks can use the public funds to increase their exposure to risky sovereign bonds because of, for example, gambling incentives of under-capitalized banks (Acharya and Tuckman, 2014; Drechsler et al., 2016; Crosignani, 2017) or moral suasion (De Marco and Macchiavelli, 2016; Ongena et al., 2016), especially once risky sovereign bonds are eligible collateral at the central bank at attractive haircuts (Drechsler et al., 2016; Hoshi and Kashyap, 2015; Nyborg, 2017).

Because sovereign bonds are also used as collateral in central bank operations, it is crucial to disentangle the effect holding sovereign bonds on banks' balance sheet versus the effect of banks' response to the intervention in their investment decisions. While the LOLR intervention might temporarily increase the collateral value of sovereign bonds allowing banks to raise funding against this collateral (a "*holdings channel*"). An increase in sovereign debt concentration in the portfolios of risky banks could aggravate bank risk and sovereign risk due to the risk of fire sales if there is uncertainty about future funding liquidity (a "*fire-sale risk channel*").

In contrast, purchasing assets directly from the market does not segment the market preferentially towards banks. To unfreeze asset and credit markets, Diamond and Rajan (2011) and Acharya and Tuckman (2014) show that the central bank could implement an intervention that moves the risky assets from weaker banks into safer hands. The credibility of asset purchases in future periods of stress can attract even non-bank financial firms to the market, allowing banks to deleverage by selling the risky assets and reducing the risk of fire sales. In the context of the European sovereign debt crisis, this would imply taking on some of the risks associated with sovereign debt holdings and providing liquidity to the markets at large, in turn weakening the domestic bank–sovereign nexus and the risk of fire sales. By doing so, the asset purchases by the central bank could result in restoring financial stability in a sustainable manner.

## 3. Data and descriptive statistics

### *3.1. Data and sample*

In this section, we discuss the data sources we used in our analyses. We use equity, five-year and three-year prices of CDS contracts on unsecured senior corporate bonds of European banks. In addition, we collected euro-denominated government bond yields and government bond CDS spreads of European countries. All asset prices are collected from Bloomberg between January 2010 and August 2014. We also collected accounting information on European banks (banks' assets, capitalization, etc.) from SNL, and data on their sovereign bond holdings as disclosed by the European Banking Authority (EBA) in its stress tests, capital exercises, and transparency exercises on eight different dates from March 2010 until December 2013. The sample of banks for which we have sovereign bond holdings in September 2011 (before the LTRO announcement) and June 2012 (before Draghi's speech) is limited to 65 and 62 banks, respectively. For the analysis of equity prices, our sample is further restricted to the 33 European public banks participating in all EBA exercises. In our analysis of bank CDS prices, we focus on the 28 European banks participating in all EBA exercises, and for which we find sufficiently liquid CDS prices during our sample period.

We complete our information on bank risk with data on banks' access to short-term wholesale funding. We use monthly information on U.S. MMF investments at European banks collected from the regulatory reports (Form N-MFP) of U.S. MMFs available from the iMoneyNet database from November 2010 until August 2014.[11] We find 63 European banks that received funding from U.S. MMFs during that period. The 63 banks cover 15 European countries; ten are countries in the eurozone (including three GIIPS countries). We provide the list of definitions of the main variables used in our analyses in Table A.1 in the Appendix, the list of banks with access to U.S. MMFs in Table A.2, as well as descriptive statistics of bank characteristics, banks' sovereign bond holdings, and equity and CDS prices for GIIPS banks and non-GIIPS banks in Table A.3.

[11] As a consequence of the 2007–2009 global financial crisis, the U.S. Securities and Exchange Commission (SEC) approved changes to Rule 2a-7 of the Investment Company Act of 1940 in 2010 and took other actions to strengthen the regulatory framework that governs MMFs. Following the revised SEC rules, U.S. MMFs have to report monthly mark-to-market net asset value (NAV) per share of their portfolios on Form N-MFP, which is then published by the SEC.

### *3.2. Bank and sovereign risk following LOLR and BOLR*

In this section, we describe the post-intervention trends in bank equity, bank CDS prices and sovereign CDS prices in Subsection 3.2.1, and bank access to funding in Subsection 3.2.2.

#### *3.2.1. Bank risk and sovereign risk*

In Figure 3, we examine the evolution of average bank equity prices in Panel A, and the evolution of average bank CDS prices in Panel B from October 2010 until June 2013.

While the pre-intervention trend is characterized by falling stock prices and increasing CDS spreads, we observe a temporary fall in CDS prices and a stabilization of stock prices following the first LTRO liquidity injection. However, the trend is reversed and the situation of the banking sector worsened after the second LTRO liquidity injection. We document this reversal in Table 1 (Panel A), where the average five-year CDS spread of GIIPS banks decreases following LTRO 1 (-20%), and increases between LTRO 2 and Draghi's speech (25%).[12] Similarly, the average equity prices of GIIPS banks (Panel B) increase by 15% after LTRO 1, but decrease by 60% after LTRO 2. We find an even more pronounced reversal of the trend of CDS spreads for Italian and Spanish banks following LTRO 2.[13]

Only the BOLR intervention is followed by a permanent stabilization of bank risk; the average equity return is 36% for GIIPS banks and 41% for non-GIIPS eurozone banks between Draghi's speech (July 2012) and December 2012. The reduction of five-year CDS prices during the same period is 27% and 45% for GIIPS and non-GIIPS eurozone banks, respectively.

Similarly, as shown in Figure 4, GIIPS *sovereign* bond CDS prices decreased by about 59% after Mario Draghi's speech during the July 2012 to December 2012 period. It was not only the GIIPS countries that saw a decrease in risk after the announcement of the ECB acting as a BOLR, the average CDS spreads of non-GIIPS eurozone countries and non-eurozone countries also decrease by

[12]Note that Greek banks are excluded from GIIPS banks, and Dexia is excluded from non-GIIPS eurozone banks. Greek banks had their own interventions, and were treated separately in the 2011/2012 EBA Capital exercise in order not to conflict with pre-agreed arrangements under the EU/IMF program. Dexia was bailed out and restructured in October 2011.

[13]We obtain similar trends in CDS and equity prices of non-GIIPS eurozone banks to the ones observed for GIIPS banks. Average equity prices of non-GIIPS eurozone banks decrease by 36% between LTRO 2 and Draghi's speech, and their average five-year CDS prices increase by 23% over the same period.

64% and 59%, respectively, from July 2012 until December 2012. In contrast, the LTRO liquidity injections in December 2011 and February 2012 are not followed by significant trends in eurozone sovereign yields or CDS prices. The average five-year CDS spread of Italian and Spanish bonds even increases by 48% between the LTRO 2 allotment in February 2012 and Draghi's speech in July 2012.

*3.2.2. Banks' access to funding*

Ivashina, Scharfstein, and Stein (2015) indicate that U.S. prime MMFs sharply reduced their funding to eurozone banks due to concerns about the credit quality of these banks, in particular after Moody's put the French banks BNP Paribas, Credit Agricole and Societe Generale on notice for possible downgrades on June 15, 2011. Money market investors were also withdrawing their funds from U.S. MMFs, in particular MMFs exposed to eurozone banks (Chernenko and Sunderam, 2014).

In Figure 5, we illustrate the "run" of U.S. MMFs on unsecured funds—composed of certificates of deposits and financial commercial papers—from eurozone banks starting in April 2011.[14] While non-eurozone banks were able to maintain their unsecured funding, U.S. MMFs reduced the principal amount invested at eurozone banks by $119 billion from May 2011 until August 2011. In particular, GIIPS banks completely lost access to unsecured funding via U.S. MMFs following the deterioration of the sovereign bond yields of Italy and Spain in the first half of 2012.

In Panel C of Table 1, we observe similar trends as we observed for bank CDS and equity prices. Private short-term funding temporarily returns to non-GIIPS eurozone banks after LTRO 1; U.S. MMFs invest an additional $14 billion (+19%) in unsecured securities at non-GIIPS eurozone banks between LTRO 1 and LTRO 2 (December 2011 to February 2012).[15] The trend in funding flows is

[14]"US money market funds warm to eurozone" (*Financial Times*, February 28, 2013). Even though the fraction of U.S. MMFs principal amount invested at a European bank relative to the bank liabilities is small (see Table A.3), it appears that the run of U.S. MMFs was instrumental in precipitating funding liquidity problems at European banks. The U.S. MMF flows to European banks predict other short-term funding flows from other investors. In particular, the one-month lagged U.S. MMF unsecured funding flows are correlated with the flows in all debt securities with residual maturity of one year invested at the 28 largest banks in the European Union.

[15]Banco Santander is the only GIIPS bank that kept access to unsecured funding at the time of the LTRO 1 allotment. The bank loses access after the LTRO 2 allotment, and is the only GIIPS bank to recover access to U.S. MMFs during our sample period.

reversed after LTRO 2, where all banks (non-GIIPS eurozone and non-eurozone banks) experience a further loss in unsecured funding. Eurozone and non-eurozone banks lost $19 billion (-21%) and $28 billion (-19%) in unsecured funding, respectively, between February 2012 (LTRO 2 allotment) and July 2012.

In contrast, we observe a permanent reversal of U.S. MMF flows to non-GIIPS eurozone banks starting in July 2012, following Mario Draghi's speech. Between July and December 2012, U.S. MMFs invested $61 billion unsecured at non-GIIPS eurozone banks (and an additional $1 billion at Banco Santander), increasing the unsecured principal amount invested at eurozone banks by 89%.

Overall, our descriptive results show an increase in sovereign and financial sector credit risk following the LOLR intervention (LTRO liquidity injections). The OMT, however, i.e., the BOLR intervention, is followed by a permanent stabilization of bank and sovereign risk, as indicated by lower sovereign and bank CDS spread, higher equity prices and increased access to short-term U.S. MMF funding. In Section 4, we investigate the role of a fire-sale risk channel in explaining this contrasting effect of LOLR and BOLR interventions.

## 4. Fire-sale risk in the sovereign bond market

The fire-sale risk channel we document in this paper provides empirical support for two propositions of the model of Diamond and Rajan (2011). First, the LOLR intervention gives the possibility for domestic banks that would become insolvent conditional on a future liquidity shock to increase their exposure to sovereign bonds, increasing the sovereign debt concentration in domestic banking sectors. Liquid buyers in turn do not buy the sovereign bonds as they wait to buy the bonds at fire sale prices in the future. We examine the evolution of sovereign bond holdings of European banks in Subsection 4.1, and the exposure of non-bank financial institutions to sovereign debt in Subsection 4.2.

Second, the extent banks are exposed to the aggregate liquidity shock is positively correlated with their ask price to sell sovereign bonds. The impact of domestic banks on sovereign bond prices will therefore increase with the risk of the domestic bank and the importance of sovereign bonds on their balance sheets. We investigate the consequences of the variation in sovereign debt

concentration on contagion between sovereign risk and bank risk in Subsection 4.3. Finally, we document a fire-sale risk channel by linking the influence of bank risk on sovereign risk to banks' holdings of sovereign bonds in Subsection 4.4.

### *4.1. Sovereign bond holdings of banks*

As Figure 1 indicates, sovereign debt concentration in eurozone domestic banks increased after the LTRO liquidity injections. The fraction of eurozone sovereign debt held by domestic banks increased from 18.5% to 21.7% between December 2011 and June 2012, and stayed constant from June 2012 until December 2012. The data are from the Bruegel database of sovereign bond holdings developed in Merler and Pisani-Ferry (2012), which provides sectoral holdings of sovereign debt for France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal and Spain. In the rest of the paper we use sovereign bond holdings data available at the bank level from the EBA.

We show the evolution of the sovereign bond holdings of European banks reporting in all EBA exercises following ECB interventions in Table 2. In Panel A of Table 2, we report the aggregate change (in € billion) in the domestic sovereign exposure (home exposure) of GIIPS banks and banks in large countries of the European Union (Italy, Spain, France, Germany, and the UK), as well as the aggregate change in the GIIPS sovereign exposure of non-GIIPS eurozone banks and non-eurozone European banks. Between the LTROs and the OMT program (between December 2011 and June 2012), the home exposure of GIIPS banks increased by €55 billion while non-GIIPS banks (eurozone and non-eurozone) decreased their exposure to GIIPS sovereign debt by €15 billion. In particular, Italian and Spanish banks increase their home exposure by €36 billion and €13 billion, respectively, following the LTRO liquidity injections.

The trend is different following the OMT program announcement (between June 2012 and December 2012), where almost all banks increase their exposure to GIIPS sovereign debt. During this period (including Draghi's speech and the announcement of the OMT program), GIIPS banks increase their home exposure by €12 billion. More importantly, non-GIIPS eurozone banks start buying GIIPS sovereign bonds again; their exposure to GIIPS sovereign debt increases by €4 billion following the announcement of the OMT program. Similarly, in Figure 6, we find that French banks only increase their exposure to Italian and Spanish official sectors after the OMT program

announcement, while Italy and Spain were increasing their home exposure after both LTRO liquidity injections and OMT program announcements.

As a measure of the concentration of sovereign debt in domestic banks, we use the ratio of a country's sovereign bonds held by domestic banks to the total outstanding amount of sovereign debt of that country. We report the change in this concentration measure over several periods in Panel B of Table 2, and find that the increase in domestic bond holdings of Italian and Spanish banks during the post-LTRO period translates into a higher concentration of Italian and Spanish sovereign debt in their domestic banking sectors (1.9 and 1.2 percentage point, respectively). In the post-OMT period, the increase in Italian debt concentration is less important (0.8 percentage point) than in the post-LTRO period, and the concentration of Spanish debt in domestic banks even decreases by 1.3 percentage point.

In Panels C and D of Table 2, we split the evolution of banks' sovereign exposures by maturity of their sovereign bond holdings. Panel C shows the evolution of sovereign bond holdings of short maturity (between one and three years), while Panel D shows the evolution of long-term bond holdings (maturity above three years). Purchases by GIIPS banks of GIIPS sovereign bonds were concentrated in the one- to three-year maturities following the LTRO liquidity injections, which is precisely the maturity of LTROs, suggesting that GIIPS banks used the bonds as collateral in the LTRO liquidity injections. In contrast, GIIPS banks and non-GIIPS banks buy more long-term GIIPS sovereign bonds than short-term bonds after the announcement of the OMT program, even though the OMT program also targeted the short-term sovereign bonds.

Overall, the results of this section show a distinctive pattern in the evolution of GIIPS sovereign bond holdings following the LOLR and BOLR interventions. Following the LTRO liquidity injections (ECB acting as LOLR), we observe a rotation of GIIPS sovereign bonds from non-GIIPS banks to GIIPS banks (i.e., an increase in home bias and an increase in sovereign debt concentration in the portfolios of domestic banks). Because the risk of GIIPS sovereign bonds is not reduced following the LTRO interventions, we observe a rotation of risky assets from low-risk to high-risk banks. The LTRO liquidity provided by the ECB might have helped risky banks to increase their exposure to risky illiquid assets—as suggested by theory (Diamond and Rajan, 2011; Acharya and Tuckman,

2014), and consistent with Drechsler et al. (2016).[16] After the OMT program announcement, non-GIIPS banks invest again in both short-term and long-term GIIPS sovereign bonds.

*4.2. Do non-bank investors increase their holdings of sovereign bonds after OMT?*

We provide additional evidence of new investors (non-bank financial institutions) coming back to the peripheral eurozone sovereign bond market following the OMT program announcement. Unfortunately, micro level data of sovereign bond holdings of non-bank financial institutions is scarce. We thus follow an approach used in Acharya and Steffen (2015) and estimate investors' sovereign bond exposures using multifactor models in which the sensitivities of stock returns to sovereign bond yields measure investors' exposure to sovereign debt. More precisely, the investors' exposure to sovereign debt estimated with such approach capture the exposure as perceived by the market. We estimate the following model:

$$\begin{aligned} r_{it} &= \alpha + \alpha_{LTRO} d_{LTRO} + \alpha_{OMT} d_{OMT} + \varphi r_{it-1} + \beta r_{mt} + \beta_{Germany} dy_{Germamy,t} \\ &\quad + \beta_{GIIPS} dy_{GIIPS,t} + \beta_{GIIPS,LTRO} \left( dy_{GIIPS,t} * d_{LTRO} \right) + \beta_{GIIPS,OMT} \left( dy_{GIIPS,t} * d_{OMT} \right) + \epsilon_{it} \end{aligned} \tag{1}$$

where $r_{it}$ is the daily return on an equity index for different financial institution groups, $dy_{Germany,t}$ is the daily change in the yield of five-year German bonds, $dy_{GIIPS,t}$ is the daily change in average yield of five-year GIIPS bonds, $r_{mt}$ is the market return, $d_{LTRO}$ and $d_{OMT}$ are dummy variables equal to one during the post-LTRO allotment period (12-08-2011–7-25-2012), and during the post-OMT program period (7-26-2012–6-25-2013), respectively. We use the HFRX Global Hedge Fund Index and the Stoxx Europe 600 Insurance Index as indices for non-bank financial institutions. Since we have yield changes as independent variables, a negative factor loading indicates a long exposure. We report the results in Table 3.

The estimation sample starts at the beginning of the sovereign debt crisis (June 2011) and ends at the end of the post-OMT period (December 2012). We find that insurance companies had a short exposure in German bonds during our sample period, while hedge funds maintained a long exposure

[16] Evidence of Italian and Spanish banks loading up more on the three-year LTRO liquidity compared to other eurozone banks can be found in the BIS Quarterly Review of March 2012 (Graph 3, p. 4).

in those bonds. The regression of Equation (1) is specified such that the parameter $\beta_{GIIPS}$ captures the exposure to GIIPS bonds during the sovereign debt crisis, and the parameter $\beta_{GIIPS,LTRO}$ (resp. $\beta_{GIIPS,OMT}$) captures a variation in GIIPS exposure in the post-LTRO allotment (resp. post-OMT program) period compared to the sovereign debt crisis period. During the summer of 2011, we find that insurance companies have a significant long exposure to GIIPS sovereign debt.[17]

We do not find any significant change in the GIIPS exposure in the post-LTRO allotment period. However, we find a significant increase in the GIIPS exposure of hedge funds in the post-OMT period. While hedge funds had a short exposure during the sovereign debt crisis, they significantly invest in GIIPS bonds in the post-OMT period and turn their GIIPS exposure into a long exposure.

Following the OMT program announcement (ECB acting as BOLR), hedge funds increased their exposure to GIIPS sovereign debt. The entry of new investors contributed to a reduction in GIIPS sovereign debt concentration in domestic banks, and potentially mitigated concerns related to fire-sale risk.[18]

### *4.3. Bank risk and sovereign risk contagion*

In this section, we investigate the consequences of sovereign debt concentration on contagion between sovereign risk and bank risk. In the bank–sovereign nexus, we expect risk contagion in both directions, i.e., sovereign risk influencing domestic bank risk and bank risk influencing home sovereign risk. First, sovereign risk influences bank risk because of (i) banks' holdings of domestic sovereign bonds, (ii) uncertainty about the capacity of the government to provide guarantees to the banking sector (including deposit insurance), (iii) moral suasion, for example, when a large fraction of bank equity shares is held by the government, and possibly (iv) riskier loans in a weaker economy under fiscal constraints. Second, bank risk influences sovereign risk due to (i) government guarantees increasing sovereign default risk, (ii) the performance of bank equity shares held by the government, (iii) a weaker economy due to impaired lending to firms, and (iv) fire-sale risk when

[17] Acharya and Steffen (2015) link those factor loadings to actual holdings of banks in sovereign bonds and show that they adequately reflect banks' exposure to sovereign debt.

[18] Additional evidence of a reduction in financial fragmentation (or an increase in financial integration) following the OMT program announcement can be found in the ECB report on "Financial Integration in Europe," April 2014 (Chart 2, p. 9).

sovereign bonds are concentrated in risky banks. With the latter channel at work, we expect an increase in sovereign risk when the risk of dominant holders of sovereign bonds (domestic banks) increases.

To understand the directionality in the bank–sovereign nexus, we perform Granger causality tests of five-year bank CDS and five-year sovereign CDS returns. While we expect the bank–sovereign relationship to be highly endogenous, Granger causality tests performed in both directions—sovereign risk predicting bank risk and bank risk predicting sovereign risk—should help to indicate the relative importance of each direction in the nexus during different sample periods.

We report the results of Granger causality tests for large countries of the European Union (Italy, Spain, France, Germany, and the UK) in Table 4. The table reports the estimation results of the following joint bivariate regression:

$$\begin{aligned} \triangle bank_{jt} &= \alpha_{1j} + \varphi_{1j} \triangle bank_{jt-1} + \beta_{1j} \triangle svg_{jt-1} + \epsilon_{jt} \\ \triangle svg_{jt} &= \alpha_{2j} + \varphi_{2j} \triangle svg_{jt-1} + \beta_{2j} \triangle bank_{jt-1} + \xi_{jt} \end{aligned} \tag{2}$$

where $\triangle bank_{jt}$ is the daily percentage change on average five-year bank CDS prices of country $j$, and $\triangle svg_{jt}$ is the daily percentage change in the five-year sovereign CDS price of country $j$. We repeat these regressions for three sample periods; the crisis period (6-01-2011–12-07-2011), the post-LTRO period (12-09-2011–7-25-2012), and the post-OMT period (7-27-2012–12-31-2012). The estimated parameters corresponding to the first line of Equation (2) are reported in Panel A of Table 4. In this joint regression, the parameter $\beta_{1j}$ (resp. $\beta_{2j}$) indicate the percentage change in the average domestic bank (resp. sovereign) CDS spread following a 1% change in the sovereign (resp. average domestic bank) CDS spread of their country the previous day. We find that *sovereign risk predicts bank risk* in Spain, Italy, and Germany during the crisis period, and in Spain, Italy, and France in the post-OMT period. Importantly, we do not find this direction of the bank–sovereign nexus to be significant at the 10% level for any country in the post-LTRO period.

In contrast, the results of the second line of Equation (2) reported in Panel B of Table 4, show that *bank risk predicts sovereign risk* in Italy, Germany, France, and the UK in the post-LTRO period, while this direction of the bank–sovereign nexus is less important or not significant in the

crisis and post-OMT periods. This reversal in the prevalence of bank–sovereign nexus directions obtained from the Granger causality tests in the post-LTRO period versus other periods indicates a greater influence of domestic banking sector risk on sovereign risk during the post-LTRO period. This greater influence of bank risk on sovereign risk is consistent with the hypothesis of a fire-sale risk channel during the period following the LTRO liquidity injections.

The results we find in Table 4 are confirmed when we let the lag length in the bivariate regressions be selected based on goodness-of-fit criteria. The optimal lag length is found using the software Autometrics.[19] We report the results of the first lag $\beta_{1j}$ and $\beta_{2j}$ parameters in Table B.1 in Appendix B using this procedure. The first lag is only reported when it appears in the lag selection by Autometrics. The lag length and lag selection is different for each country. The results using the Autometrics procedure reflect the same conclusions and generally show greater t-statistics in absolute value than in the simple one-lag Granger causality tests.

### *4.4. Bank contagion and sovereign bond holdings*

To relate the contagion between bank risk and sovereign risk to banks' sovereign bond holdings, we consider Granger causality regressions at the bank level, controlling for common factors capturing volatility cycles, credit cycles, and interest rate policy. This allows us to collect a cross-section of $\beta_1$ and $\beta_2$ estimated parameters, respectively measuring the influence of sovereign risk on bank risk and the influence of bank risk on sovereign risk. These estimates are obtained from the following joint bivariate regressions:

$$\begin{aligned} \triangle bank_{it} &= \alpha_{1i} + \varphi_{1i}\triangle bank_{it-1} + \beta_{1i}\triangle svg_{it-1} + \gamma_{1i}'\mathbf{x}_{t-1} + \epsilon_{it} \\ \triangle svg_{it} &= \alpha_{2i} + \varphi_{2i}\triangle svg_{it-1} + \beta_{2i}\triangle bank_{it-1} + \gamma_{2i}'\mathbf{z}_{t-1} + \xi_{it} \end{aligned} \tag{3}$$

where $\triangle bank_{it}$ is the daily percentage change in the five-year CDS price of bank $i$, and $\triangle svg_{jt}$ is the daily percentage change in the five-year sovereign CDS price of the country where bank $i$'s headquarter is located. The regressions are augmented by a vector of common factors $\mathbf{x}_t$ including the return on the Markit iTraxx Europe Crossover index on the most liquid sub-investment grade

[19] The Autometrics procedure is available from the PcGive module of Oxmetrics version 7.

European corporate entities, the return on the Euro Stoxx 50 volatility index (Vstoxx), the ECB deposit rate level, and the eurozone sovereign bond term spread between the ten-year and the three-month yields, and $\mathbf{z}_t$ including the return on the Markit iTraxx SovX Western Europe index, the return on the Vstoxx index, the ECB deposit rate level, and the eurozone sovereign bond term spread.

We then collect the three cross-sections of $\beta_{1i\tau}$ and $\beta_{2i\tau}$ estimates in the crisis, post-LTRO and post-OMT periods, and use the estimates as dependent variables in the panel regressions explaining the influence of sovereign risk on bank risk and the influence of bank risk on sovereign risk. We first describe the regression linking sovereign bond holdings of banks to their influence on sovereign risk (we relegate the description of the counterpart regression explaining the influence of sovereign risk on bank risk in Subsection 5.1 devoted to alternative channels):

$$\hat{\beta}_{2i\tau} = \lambda_{1\tau} \frac{Home\,holdings_{i\tau}}{Assets_{i\tau}} * d_{GIIPS,i} * d_\tau + \lambda_{2\tau} \frac{Home\,holdings_{i\tau}}{Assets_{i\tau}} * d_\tau + \lambda_{3\tau} d_{GIIPS,i} * d_\tau + \lambda_\tau + \varsigma_{i\tau} \quad (4)$$

where $\hat{\beta}_{2i\tau}$ is the estimate capturing the influence of the risk of bank $i$ on home sovereign risk in period $\tau$, $\frac{Home\,holdings_{i\tau}}{Assets_{i\tau}}$ is the fraction of home sovereign bond holdings of a bank divided by the bank's total assets, $d_{GIIPS,i}$ is a dummy variable equal to one when bank $i$ is located in a GIIPS country, and $d_\tau$ is a dummy variable referring to the period (crisis, post-LTRO, post-OMT). All bank characteristics are measured prior to the sample period used to estimate the $\beta_{2i\tau}$ parameters. We report the results of this regression in Table 5.

In the first column of Table 5, we report the results of a regression where we impose the restriction $\lambda_{1\tau} = \lambda_{3\tau} = 0$. We do not find a significant effect of domestic banks holdings of sovereign bonds during the post-LTRO period in the restricted regression. Home holdings are even negatively associated with the bank influence on sovereign risk in the crisis period.

We report the results of the unrestricted regression of Equation (4) in the second column of Table 5. The parameter capturing the sensitivity of a GIIPS bank's influence on sovereign risk to its home exposure (measured by its home sovereign bond holdings as a fraction of its total assets) is $\lambda_1 + \lambda_2$. This parameter is close to zero for GIIPS banks during the crisis ($\hat{\lambda}_{1,crisis} + \hat{\lambda}_{2,crisis} \simeq 0$). During the post-LTRO period, when bank risk significantly predicts sovereign risk in some eurozone

countries, we find that the home exposure of a GIIPS bank increases the bank's influence on sovereign risk ($\hat{\lambda}_{1,LTRO} + \hat{\lambda}_{2,LTRO} > 0$). While this effect is not significantly different from zero for non-GIIPS banks, it is significant at the 1% level for GIIPS banks. For GIIPS banks, the sensitivity of sovereign CDS returns to a 1% change in the CDS spread of a domestic bank the previous day is 4.27 ($3.66 + 0.61$) percentage points larger when the share of home sovereign bonds in the bank portfolio increases by one percentage point. We find that the results reported in Table 5 hold when controlling for bank variables that could confound the effect of sovereign bond holdings on the bank's influence on sovereign risk. We detail such control variables in the section on alternative channels (Subsection 5.2).

GIIPS banks holding a large fraction of their balance sheets in home sovereign bonds exert higher pressure on sovereign risk during the post-LTRO period. We are therefore able to link bank risk pressure on home sovereign bonds to their sovereign bond portfolios. Importantly, we do not find a significant effect of the bank's home exposure on its influence on sovereign risk in the post-OMT period. GIIPS banks' influence on sovereign risk is related to their home sovereign bond holdings, and this effect is limited to the post-LTRO period. The results are consistent with the existence of a fire-sale risk channel for GIIPS banks and their home sovereign bonds in the period following the LTRO liquidity injections. This finding is also consistent with the increased concentration of GIIPS sovereign debt in the portfolios of GIIPS banks observed in Subsection 4.1 for the post-LTRO period, and a reduction of sovereign debt concentration in the post-OMT period.

## 5. Alternative channels of the bank–sovereign nexus

We study another channel of the bank–sovereign nexus related to domestic banks' holdings of sovereign bonds—the holding channel—in Subsection 5.1.[20] In Subsection 5.2 we assess the robustness of our results for the fire-sale risk channel and the holdings channel to alternative channels of the bank–sovereign nexus. We evaluate the joint effects of holdings and fire-sale risk channels on

[20] Alternatively, the Basel Committee on Banking Supervision (2011) defines four channels of transmission of sovereign risk to the banks: an asset holdings channel, a collateral channel, a rating channel, and a government guarantee channel (see also De Bruyckere et al., 2013). We focus on transmission channels specific to the sovereign bond holdings of banks.

bank realized performance following ECB interventions in Subsection 5.3.

### *5.1. Holdings channel*

To illustrate the holdings channel we first link the influence of sovereign risk on bank risk parameters to banks' sovereign bond holdings. This is the counterpart analysis of Subsection 4.4 for the holdings channel. We then analyze the effect of sovereign bond holdings of banks before banks have the opportunity to reallocate their sovereign bond portfolio; we estimate the effect of banks' sovereign bond holdings on abnormal bank performance around the different announcement dates of LOLR and BOLR policies.

#### *5.1.1. Sovereign contagion and sovereign bond holdings*

The estimated sovereign contagion parameters $\hat{\beta}_{1i\tau}$ capture the sensitivity of domestic banks' CDS spread returns to a 1% increase in the sovereign CDS spread of their country, and are estimated using the procedure described in Subsection 4.4. The regression linking sovereign contagion parameters to banks' sovereign bond holdings is given by:

$$\hat{\beta}_{1i\tau} = \delta_{1\tau}\frac{Home\,holdings_{i\tau}}{Assets_{i\tau}} * d_{GIIPS,i} * d_\tau + \delta_{2\tau}\frac{Home\,holdings_{i\tau}}{Assets_{i\tau}} * d_\tau + \delta_{3\tau} d_{GIIPS,i} * d_\tau + \delta_\tau + \eta_{i\tau} \quad (5)$$

where $\hat{\beta}_{1i\tau}$ is the estimate capturing the influence of sovereign risk on the risk of domestic bank $i$ in period $\tau$, the other elements of the regression are the same as described for Equation (4). We report the results of this regression in Table 6.

As for Table 5, we first report the results of a restricted regression where $\delta_{1\tau} = \delta_{3\tau} = 0$ (no differential effect for GIIPS banks) in column (1). The column shows a significant correlation between banks' sovereign bond holdings and the extent to which bank risk is predicted by sovereign risk during the crisis period. In contrast, we do not find a significant effect of domestic banks' sovereign bond holdings on the influence of sovereign risk on bank risk during the post-LTRO period where the fire-sale risk channel appears to be prevalent.

As opposed to the fire-sale risk channel results in Table 5, the differential effect of GIIPS banks does not appear to be significant for the holdings channel (column (2)). GIIPS banks and other European banks are similarly exposed to the holdings channel. It does not mean that they are

exposed to the same risk, but they are similarly affected by the holdings channel when holding sovereign bonds of their country on their balance sheets. Importantly, unlike the results for the fire-sale risk channel (see Table 5), we do not find an effect of the home exposure of GIIPS banks explaining the influence of sovereign risk on domestic bank risk during the post-LTRO period ($\hat{\delta}_{1,LTRO}$ and $\hat{\delta}_{2,LTRO}$ are not significant).

*5.1.2. Effect of banks' sovereign bond holdings at the intervention announcement*

To quantify the announcement effects of LOLR and BOLR interventions on bank risk and profitability, we implement an event study analysis of five-year bank CDS spreads, three-year bank CDS spreads, and bank equity prices around ECB intervention dates. We calculate the cumulative abnormal CDS changes (resp. cumulative abnormal equity returns) of an equally weighted bank CDS (resp. bank equity) portfolio. The event window is two-days long, such that we are describing the abnormal performance of the banks between the closing price one day before and the closing price one day after the announcement date.[21] We report the results and details of our methodology in Appendix C. In Table C.1 (in Appendix C) we show the average cumulative abnormal CDS changes (Panel A) and the average cumulative abnormal equity returns (Panel B) of GIIPS, non-GIIPS eurozone, and non-eurozone European public banks.

We collect the cross section of bank CDS and equity cumulative abnormal changes and returns (CARs) around seven events: (1) the preliminary announcement of the three-year LTROs (12-01-2011), (2) the official announcement of the three-year LTROs (12-08-2011), (3) the allotment of the first LTRO liquidity injection (12-21-2011), (4) the allotment of the second LTRO liquidity injection (2-29-2012), (5) "Draghi's speech" (7-26-2012), (6) the preliminary OMT program announcement (8-02-2012), and (7) the announcement of the OMT program details (9-06-2012). We relate the abnormal performance of banks to their sovereign bond holdings in the rest of this section.

In Panel A of Table 7, we report the results of cross-sectional regressions of CDS CARs on bank characteristics, including their holdings of GIIPS and non-GIIPS eurozone sovereign bonds scaled

[21] We show the cumulative abnormal returns and changes (CARs) derived over alternative event window lengths in Appendix B.

by the banks' total assets:

$$CAR_i = \alpha + \beta_1 \frac{GIIPS\,1-3yr_i}{Assets_i} + \beta_2 \frac{GIIPS\,long_i}{Assets_i} + \beta_3 \frac{euro\,nonGIIPS_i}{Assets_i} + \delta' \mathbf{x}_i + \epsilon_i \qquad (6)$$

where $CAR_i$ is the two-day cumulative abnormal change in the five-year CDS spread of bank $i$ around a given announcement date, $GIIPS\,1-3yr_i$ is the GIIPS sovereign bond holdings of maturity between one and three years of bank $i$, $GIIPS\,long_i$ is the GIIPS sovereign bond holdings of maturity above three years of bank $i$, $euro\,nonGIIPS_i$ is the non-GIIPS eurozone sovereign bond holdings of bank $i$, and $Assets_i$ are the bank's total assets. We use a vector of bank-specific variables $\mathbf{x}_i$ to control for bank size (logarithm of their total assets), bank capitalization (ratio of Tier 1 common capital to total assets), bank credit risk (ratio risk-weighted assets to total assets), and the bank's total GIIPS exposure (including financial institutions, retail, corporate, and commercial real estate exposures) divided by the bank's total assets.[22] All bank characteristics are measured before the event window start date.

The table shows a beneficial effect for banks holding short-term bonds following LOLR announcements. When Mario Draghi announced the possibility to extend the one-year LTRO to three-year maturity loans on December 1, 2011, we observe a significant reduction of the two-day CDS CARs at banks holding GIIPS sovereign bonds with a maturity between one and three years (short-term sovereign bonds). The bank two-day CDS CAR around that date decreases by -7.51 bps for a bank holding one additional percentage point of its portfolio in short-term GIIPS sovereign bonds. This announcement implied the possibility that some sovereign bonds with maturity above one year, not accepted as collateral on private funding markets but eligible at the ECB, would be matching the maturity of LTRO loans. More banks would start using the GIIPS sovereign bonds of maturity between one and three years as collateral in LTROs as they do not need to remain exposed to the credit risk of those bonds after the loan matures (Crosignani et al., 2017). This haircut subsidy without additional credit risk, extended to sovereign bonds of maturity between one and three years,

[22]The bank's total GIIPS exposure divided by the bank's total assets will serve as a control variable for effects related to the asset side of the bank that are not specific to the bank sovereign bond holdings.

improved the collateral value of these bonds and reduced the default risk of banks holding them as it reduced the funding pressure of banks holding these assets.

In contrast, we do not observe any significant effect of holding short-term GIIPS sovereign bonds on the abnormal CDS performance of banks around the different BOLR announcements, although the ECB also targeted the sovereign bonds of maturity between one and three years in its OMT program.

In Panel B of Table 7, we show a similar analysis as in Panel A for abnormal bank profitability around announcement dates. We analyze bank *equity* CARs controlling for banks' sensitivity to the ECB interest rate policy in addition to controlling for bank size, capitalization level, credit risk, and total GIIPS exposure. As banks' profitability is tightly linked to the maturity mismatch between their assets and liabilities, we control for banks' sensitivity to the level and slope of the yield curve. Using this control allows us to derive the effects of other variables for banks that have the same sensitivity to interest rate policy, and therefore would be affected the same way by interventions affecting the yield curve.[23]

Using banks' holdings of sovereign bonds to explain the cross section of equity CARs, we find similar evidence showing preferences in favor of short-term sovereign bonds following LOLR announcements. The two-day equity CARs are in general larger for banks with a larger exposure to short-term GIIPS sovereign bonds following the different announcements related to the LTROs, but this effect is significant at the 1% level only around the second LTRO allotment date.[24] Around that date, the two-day equity CARs increase by 2.17% for a bank holding one additional percentage point of its portfolio in short-term GIIPS sovereign bonds.

[23] A measure of bank sensitivity to interest rate policy is obtained by regressing daily bank stock returns on the daily returns of the Euro Stoxx Index, the daily change in the interest rate of the ECB deposit facility, the daily change in the term spread between the ten-year and the three-month yields of eurozone sovereign bonds, and a constant. We run this regression for each bank during the crisis period (6-01-2011–12-07-2011), the post-LTRO period (12-08-2011–7-25-2012), and the post-OMT period (7-26-2012–12-31-2012), and collect the coefficient estimates capturing the bank exposure to interest rate level (interest rate exposure) and interest rate term spread (term spread exposure). For example, we expect the interest rate exposure estimate to be large for banks relying on short-term wholesale markets for funding, and the term spread exposure estimate to be large for banks with a more pronounced maturity mismatch between the asset and liability sides of their balance sheets. We then use these proxies of banks' exposure to interest rate policy as control variables in our cross-sectional regressions of equity CARs on bank characteristics.

[24] While the LTRO 1 allotment mainly resulted in rolling over existing MROs and one-year LTRO funding from the ECB, banks obtained additional net funding with the LTRO 2 allotment (Carpinelli and Crosignani, 2017).

Overall, the results of this section show a reduction in bank risk and an improvement in bank profitability for banks holding short-term GIIPS sovereign bonds around the LTROs announcement dates, while the effect of the announcement of the OMT program details does not appear to be specifically related to banks' sovereign bond holdings.

*5.2. Alternative transmission channels not related to sovereign bond holdings*

As mentioned above, there are alternative hypotheses to an increase in fire-sale risk for GIIPS sovereign bonds that could explain the increase in banks' influence on sovereign risk in the post-LTRO period. First, an increase in sovereign default risk through the government guarantee channel (Acharya et al., 2014) is expected when the risk of large domestic banks with large deposits increases. In addition to controlling for the funding fragility of those banks with their unsecured funding flows, we also add a control for bank size in the regressions of Equation (4) using the logarithm of banks' total assets.

Second, sovereign default risk can also increase when the government directly holds equity shares in domestic banks. To account for increasing sovereign risk through government equity holdings, we add the fraction of a bank's equity shares held by the government to the bank's Tier 1 capital as a control variable in the regressions of Equation (4).

Third, a riskier domestic banking sector might lead to impaired lending to domestic firms and households. A real economic slowdown would in turn result in lower tax income for the government. We account for this effect by adding the fraction of the total home holdings of the bank (including non-sovereign exposures) to the bank's total assets as a control variable in the regressions of Equation (4).

Similarly, different channels can explain the transmission of sovereign risk to bank risk. The first channel is a home sovereign bond holdings channel for the bank, since bank risk also reflects the riskiness of its assets. Higher sovereign risk also leads to a deterioration of the quality of the government guarantee to domestic banks. This government guarantee channel describes the uncertainty about the capacity of the government to rescue its large domestic banks (Acharya et al., 2014; Bonfim and Santos, 2017). Governments holding a significant fraction of the equity shares of a bank can also influence bank management through a moral suasion channel (De Marco

and Macchiavelli, 2016; Ongena et al., 2016). Finally, lending to firms and households might become riskier in a country under fiscal constraints. We therefore consider the set of control variables for both Equation (4) and Equation (5) describing the two directions of contagion in the bank–sovereign nexus, and find in Table B.2 in Appendix B that our results of Tables 5 and 6 are robust to including these control variables capturing alternative transmission channels in the regressions.

*5.3. Summary of holdings and fire-sale risk channels effects*

In this section, we attempt to quantify the joint impact of holdings and fire-sale risk channels on banks' realized performance during the post-LTRO period (between LTRO 1 and Draghi's speech), and the post-OMT period (after Draghi's speech until the end of 2012). As measures of a bank's realized performance, we consider the change in its five-year CDS spread and its equity return. We regress banks' realized performance on bank characteristics that are measured before the period used to derive banks' realized performance starts. We detail the methodology used to derive the holdings and fire-sale risk effects on banks' realized performance in Appendix D.[25]

The effects of the holdings and fire-sale risk channels for the post-LTRO period, and the post-OMT period are summarized in Table 8. In this table, we report cross-sectional averages of the effects of the respective channel on five-year CDS spread changes (Panel A) and equity returns (Panel B), together with the cross-sectional average raw changes of bank CDS spreads and average raw bank equity returns.

In Panel A of Table 8, we find that, during the post-LTRO period, the average increase in CDS spreads of banks due to their long-term GIIPS sovereign bond holdings (+144 bps) is not offset by the average reduction in CDS spreads due to the beneficial effect of holding short-term GIIPS sovereign bonds on their balance sheets (-34 bps). In particular, GIIPS banks benefit from a reduction of risk of 104 bps on average due to their short-term home sovereign bond holdings that they could pledge as collateral at the ECB in exchange for funding in the LTROs.

The effect on realized performance due to short-term bond holdings can be further decomposed into holdings and fire-sale effects according to the methodology described in Appendix D. For

[25]The channel "effects" are obtained by multiplying the estimated parameters of the regression described in Appendix D to the corresponding regressor value for the bank.

eurozone non-GIIPS banks, the reduction in bank CDS spreads resulting from an improvement in the collateral value of short-term GIIPS bonds (-47 bps) during the post-LTRO period is dominated by an increase in CDS spread from a fire-sale risk effect affecting both short-term (+70 bps) and long-term GIIPS bonds (+69 bps).

After the OMT program announcement, we find a reversal of the fire-sale risk channel for short-term bonds reducing the risk of banks by 233 bps on average. Importantly, we find a reduction of bank risk of 48 bps on average due to banks' long-term GIIPS sovereign bond holdings, even though the OMT program did not target long-term bonds. For GIIPS banks, the average reduction in the bank CDS spread from holding long-term home sovereign bonds is 135 bps on average, while the average reduction is only 68 bps from short-term bond holdings.

We report the average channel effects on bank equity returns in Panel B of Table 8. Unlike our results on bank CDS spreads, we do not find the fire-sale risk channel to be significant in explaining bank equity returns for any of the periods we consider. We therefore only report the effects of the holdings channel. This channel confirms an improvement of the collateral value of GIIPS sovereign bonds with a maturity between one and three years during the post-LTRO period. The equity gains from holding short-term GIIPS sovereign bonds are 15% on average during that period. While positive equity returns are associated with short-term bonds in the post-LTRO period, we find a reduction in bank equity prices of 30% on average from holding GIIPS sovereign bonds with a maturity above three years.

We do not find any significant effect on bank profitability of holding short-term GIIPS sovereign bonds during the post-OMT period. In contrast, holding long-term bonds after the OMT program announcement is associated with bank equity returns of 6% on average. The results indicate that banks' equity performance after the OMT program is poorly explained by their sovereign bond holdings (as in Krishnamurthy et al., 2018), consistent with a broader impact of this program on all asset prices.

## 6. Related literature

Our paper relates to various strands of literature. First, it connects to the growing literature on the European sovereign debt crisis. Recent work investigates the real effects of unconventional monetary policy by the ECB (e.g., Acharya et al., 2016a,b; Carpinelli and Crosignani, 2017; Daetz et al., 2016), and the effects of these policies on sovereign risk (e.g., Eser and Schwaab, 2013; Szczerbowicz, 2015; Krishnamurthy et al., 2018). Pelizzon et al. (2016) show that the LTROs, by releasing funding pressure, weakened the sensitivity of the liquidity of Italian sovereign bonds to Italian sovereign credit risk. In particular, our fire-sale risk channel is related to the residual component of sovereign bond yields not explained by sovereign default risk or redenomination risk, and referred to as a *domestic segmentation channel* in Krishnamurthy et al. (2018). Other papers study the bank–sovereign nexus and possible spillovers between banks and sovereigns (e.g., De Bruyckere et al., 2013; Acharya et al., 2014; Gennaioli et al., 2014; Beltratti and Stultz, 2015; Bekooij et al., 2016; Farhi and Tirole, 2018; Kirschenmann et al., 2017). In contrast to these papers, we highlight the fire-sale risk channel in the sovereign bond market and the effect of ECB interventions on fire-sale risk.

Our paper contributes to the literature on fire sales, relying on the Schleifer and Vishny (1992) insight where a limited set of potential buyers for the bank's specialized assets have limited resources. Empirical evidence for fire sales in equity markets is provided by Coval and Stafford (2007), where the price pressure comes from open-end funds with concentrated positions in securities and subject to investors' withdrawals. Ellul et al. (2011) document a similar mechanism for the corporate bond market where the price pressure comes from insurance companies constrained by regulation. For the sovereign bond market, Greenwood et al. (2015) document the effect of fire sales on bank risk contagion. Their analysis reveals the importance of a fire-sale risk channel in the sovereign bond market by showing the effect of simulated fire sales in a sovereign stress scenario using data prior to the ECB interventions of our study. Our paper instead provides evidence on realized outcomes following the LOLR and BOLR interventions of the ECB, documenting the presence of a fire-sale

risk channel and its effects on realized bank risk and sovereign risk.[26]

Finally, our paper also relates to the literature on the role of central banks as LOLR (e.g., Calomiris and Kahn, 1991; Rochet and Vives, 2004; Freixas et al., 2004) and, in particular, during the recent European sovereign debt crisis (e.g., Garcia-Posada and Marchetti, 2016; Andrade et al., 2015; Crosignani et al., 2017; Alves et al., 2016; Drechsler et al., 2016; Garcia de Andoain et al., 2016). In particular, Drechsler et al. (2016) find evidence for a risk-taking channel of monetary policy in which under-capitalized banks take out more LOLR loans and further increase their exposure to risky sovereign debt. Alternatively, De Marco and Macchiavelli (2016) and Ongena et al. (2016) explain the increase in home bias by moral suasion and show that this effect remains after controlling for LTRO liquidity injections.

We contribute to this literature presenting the fire-sale risk channel through which increasing sovereign debt concentration in banks relying on public funds affects sovereign and bank risk. Our empirical results bring the theoretical predictions of Diamond and Rajan (2011) to the European sovereign bond market, where increasing concentration of risky sovereign bonds in the portfolios of risky banks reduces the liquidity of those bonds due to a fear of fire sales. Moreover, we show how the role of central banks as BOLR can address fire-sale risk and permanently improve the solvency conditions of banks.

## 7. Conclusion

We document a fire-sale risk channel in the sovereign bond market following two significant interventions of the European Central Bank (ECB) during the sovereign debt crisis. Our results shed light on the contrasting effectiveness of these two types of central bank intervention—lender of last resort versus buyer of last resort—in dampening the risk of fire sales and restoring financial stability in the context of segmented sovereign bond markets in Europe.

Following the lender of last resort intervention via the ECB's LTROs, the collateral value of short-term GIIPS (Greek, Irish, Italian, Portuguese and Spanish) sovereign bonds improved. However,

[26] Also related to fire sales in the sovereign bond market, Bagattini et al. (2018) explain a mechanism that allowed German banks to mitigate fire-sale risk by transferring their sovereign bonds to the portfolios of their retail customers and affiliated mutual funds.

increasing GIIPS sovereign debt concentration in domestic banks relying on public funds led to increasing fire-sale risk for all banks exposed to GIIPS sovereign risk. In contrast, the ECB's announcement of being a potential buyer of last resort via the OMT program attracted new investors to the sovereign bond market, and reduced sovereign debt concentration and fire-sale risk.

Overall, our findings suggest that the effectiveness of unconventional central bank interventions should not only be assessed in terms of a reduction of immediate funding risk for banks. Instead, we should also carefully assess the effects of these interventions on the asset side of banks and on the concentration of illiquid assets on bank balance sheets. A lender of last resort intervention can aggravate a crisis situation and generate a fear of fire sales when banks' responses to the intervention contribute to increasing the concentration of illiquid assets in insolvent banks. In contrast, the buyer of last resort intervention provides liquidity to the market at large and can credibly address fire-sale risk, improving the solvency condition of banks and restoring their access to wholesale funding markets.

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Table 1: **LOLR vs. BOLR descriptive statistics**
This table reports the percentage change on average bank CDS spread, the percentage change on average bank equity price, and the change in banks' access to unsecured U.S. money market fund investments following LTRO 1 (12-21-2011), LTRO 2 (2-29-2012), and OMT (7-26-2012). Panel A reports the percentage change on average five-year bank CDS spread. Panel B reports the percentage change on average bank equity prices. Panel C reports the change in unsecured funding (in $ billion), and percentage change in parentheses. Note that "OMT" corresponds to the date of Mario Draghi's speech. IS stands for Italy and Spain. GIIPS excludes Greece. Banco Santander is the only GIIPS bank that recovers access to U.S. MMFs (all other GIIPS banks lose access in 2011). Sample in panels A-C: Public banks that participated in all EBA stress tests (excludes Dexia, Greek and Cypriot banks). Sample in panel D: European banks with access to U.S. MMFs.

Panel A: Change on average bank five-year CDS (%)

| | GIIPS (IS) | Euro non-GIIPS | non-Euro |
|---|---|---|---|
| LTRO 1 - LTRO 2 | -20 (-30) | -24 | -19 |
| LTRO 2 - OMT | 25 (47) | 23 | 18 |
| Post OMT | -27 (-39) | -45 | -55 |

Panel B: Change on average bank equity prices (%)

| | GIIPS (IS) | Euro non-GIIPS | non-Euro |
|---|---|---|---|
| LTRO 1 - LTRO 2 | 15 (8) | 30 | 25 |
| LTRO 2 - OMT | -60 (-62) | -36 | -11 |
| Post OMT | 36 (29) | 41 | 7 |

Panel C: Change in MMF investments in $bn (%) - unsecured

| | Banco Santander | Euro non-GIIPS | non-Euro |
|---|---|---|---|
| LTRO 1 - LTRO 2 | -0.49 (-99%) | 14 (19%) | -27 (-16%) |
| LTRO 2 - OMT | 0.10 (-) | -19 (-21%) | -28 (-19%) |
| Post OMT | 0.93 (-) | 61 (89%) | 11 (8%) |

Table 2: **Fire-sale risk channel: sovereign bond holdings of banks**
This table reports the change (in € billion) in overall sovereign bond holdings of banks in Panel A, the change in the sovereign bond holdings of banks as a percentage of country outstanding debt in Panel B, the change in the sovereign bond holdings of short maturity (between one and three years) in Panel C, and the change in the sovereign bond holdings of long maturity (above three years) in Panel D. GIIPS excludes Greece. Sample: Public banks that participated in all EBA stress tests (excludes Dexia, Greek, and Cypriot banks). Country outstanding debt is the outstanding amount in euros, of securities other than shares, excluding financial derivatives (source: ECB).

Panel A: Change in sovereign bond holdings (€ billion)

| | Change in home exposure | | | | | | Change in GIIPS exposure | |
|---|---|---|---|---|---|---|---|---|
| | GIIPS | Italy | Spain | France | Germany | UK | Euro non-GIIPS | non-Euro |
| Dec 2010–Dec 2011 | -17 | -16 | 1 | -15 | -12 | 5 | -59 | -18 |
| Dec 2011–Jun 2012 (post LTRO) | 55 | 36 | 13 | 13 | -4 | 6 | -9 | -6 |
| Jun 2012–Dec 2012 (post OMT) | 12 | 14 | -3 | 22 | -1 | -7 | 4 | -1 |
| Dec 2012–Dec 2013 | -8 | 11 | -18 | 14 | -11 | 13 | 13 | -1 |

Panel B: Change in sovereign bond holdings (% of country outstanding debt)

| | Change in home exposure | | | | | | Change in GIIPS exposure | |
|---|---|---|---|---|---|---|---|---|
| | GIIPS | Italy | Spain | France | Germany | UK | Euro non-GIIPS | non-Euro |
| Dec 2010–Dec 2011 | -1.3 | -1.4 | -2.0 | -1.4 | -1.4 | -1.9 | -3.6 | -0.8 |
| Dec 2011–Jun 2012 (post LTRO) | 1.8 | 1.9 | 1.2 | 0.6 | -0.7 | -0.3 | -0.6 | -0.3 |
| Jun 2012–Dec 2012 (post OMT) | 0.2 | 0.8 | -1.3 | 1.5 | 0.0 | -0.4 | 0.1 | -0.1 |
| Dec 2012–Dec 2013 | -1.2 | 0.1 | -3.9 | 0.6 | -1.0 | 0.8 | 0.9 | -0.1 |

Panel C: Change in sovereign bond holdings (between one and three-year maturity)

| | change in GIIPS exp | | change in Italian exp | | change in Spanish exp | |
|---|---|---|---|---|---|---|
| | GIIPS | non-GIIPS | Italian | non-Italian | Spanish | non-Spanish |
| Dec 2010–Dec 2011 | -35 | -30 | -22 | -18 | -10 | -7 |
| Dec 2011–Jun 2012 (post LTRO) | 37 | -1 | 29 | 4 | 6 | -1 |
| Jun 2012–Dec 2012 (post OMT) | 17 | 1 | 8 | -1 | -7 | 2 |
| Dec 2012–Dec 2013 | -1 | 8 | 15 | 4 | -11 | 3 |

Panel D: Change in sovereign bond holdings (above three-year maturity)

| | change in GIIPS exp | | change in Italian exp | | change in Spanish exp | |
|---|---|---|---|---|---|---|
| | GIIPS | non-GIIPS | Italian | non-Italian | Spanish | non-Spanish |
| Dec 2010–Dec 2011 | 16 | -29 | 6 | -21 | 11 | -5 |
| Dec 2011–Jun 2012 (post LTRO) | 15 | -8 | 8 | -1 | 7 | 0 |
| Jun 2012–Dec 2012 (post OMT) | 22 | 3 | 6 | 6 | 4 | -2 |
| Dec 2012–Dec 2013 | -14 | 5 | -4 | 5 | -7 | 1 |

Table 3: **Fire-sale risk channel: investor groups' exposure to sovereign bonds**
This table presents the results of the regression of several financial institutions group index returns on average five-year sovereign bond yield changes of GIIPS countries (GIIPS bond) and Germany (German bond). Non-bank indices include the macro HFRX hedge funds index (Hedge funds), and the Stoxx Europe 600 Insurance index. Crisis period: 6-01-2011–12-07-2011. Post-LTRO period: 12-08-2011–7-25-2012. Post-OMT period: 7-26-2012–6-25-2013. Estimation period: 6-01-2011–6-25-2013. All regressions include an autoregressive term, the market index return, crisis, post-LTRO, and post-OMT program intercepts. As for market return, we include the Euro Stoxx 600 for the insurance index, the MSCI World for the hedge fund index. T-statistics based on Newey-West standard errors are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. $N$ is the number of observations. $R^2$ is the adjusted $R^2$.

**Regression of stock returns on sovereign yield changes**

| | Hedge funds | Insurance |
|---|---|---|
| GIIPS bond | 0.043 | -0.007*** |
| | (0.490) | (-3.440) |
| GIIPS bond post LTRO | -0.023 | 0.001 |
| | (-0.142) | (0.181) |
| GIIPS bond post OMT | -0.756*** | 0.002 |
| | (-2.940) | (0.521) |
| German bond | -1.328*** | 0.037*** |
| | (-4.690) | (6.140) |
| $N$ | 522 | 532 |
| $R^2$ (%) | 7.82 | 89.24 |

Table 4: **Bank risk and sovereign risk contagion: Granger-causality at the country level**
This table reports in Panel A the estimated beta 1 parameters (Sovereign risk → Bank risk) of the Granger causality regressions. In Panel B, the estimated beta 2 parameters (Bank risk → Sovereign risk) of the Granger causality regressions. The regressions are split in three periods: the crisis period (06-01-2011–12-07-2011), the post LTRO period (12-09-2011–07-25-2012), and the post OMT period (07-27-2012–12-31-2012). T-statistics based on Newey-West standard errors are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. $N$ is the number of observations.

| | Panel A: Sovereign risk → Bank risk | | | Panel B: Bank risk → Sovereign risk | | |
|---|---|---|---|---|---|---|
| | **Crisis** | **post LTRO** | **post OMT** | **Crisis** | **post LTRO** | **post OMT** |
| Spain | 0.150*** | 0.145** | 0.196*** | -0.011 | 0.056 | 0.021 |
| | (2.72) | (2.24) | (2.88) | (-0.04) | (0.29) | (0.08) |
| Italy | 0.179** | -0.147 | 0.274** | -0.036 | 0.271* | -0.043 |
| | (2.37) | (-1.17) | (2.06) | (-0.19) | (1.66) | (-0.21) |
| Germany | 0.186*** | 0.032 | -0.032 | 0.106 | 0.186* | 0.287 |
| | (2.64) | (0.58) | (-0.80) | (0.45) | (1.72) | (1.36) |
| France | 0.140** | -0.067 | 0.111** | 0.250** | 0.534*** | 0.435* |
| | (2.00) | (-1.32) | (2.54) | (2.34) | (4.09) | (1.87) |
| UK | 0.095 | -0.073 | 0.107 | 0.243* | 0.241** | 0.021 |
| | (1.05) | (-0.75) | (1.22) | (1.70) | (2.57) | (0.23) |
| $N$ | 136 | 164 | 112 | 136 | 164 | 112 |

Table 5: **Fire-sale risk channel: regression analysis of determinants of Granger-causality coefficients** This table presents the results of the regressions of the influence of bank risk on sovereign risk ($\hat{\beta}_{2i}$) on banks' home sovereign bond holdings. Home holdings is the fraction of home sovereign bond holdings of a bank to the bank's total assets. T-statistics based on White heteroskedasticity-robust standard errors are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. $N$ is the number of observations. $R^2$ is the adjusted $R^2$.

| **Bank risk → Sovereign risk** | | |
|---|---|---|
| | (1) | (2) |
| Home holdings*GIIPS*crisis | | 3.25*** |
| | | (2.84) |
| Home holdings*GIIPS*LTRO | | 3.66*** |
| | | (3.38) |
| Home holdings*GIIPS*OMT | | -3.12 |
| | | (-1.66) |
| Home holdings*crisis | -2.21*** | -3.33*** |
| | (-2.87) | (-6.53) |
| Home holdings*LTRO | -0.56 | 0.61 |
| | (-0.98) | (1.11) |
| Home holdings*OMT | -0.97 | -0.09 |
| | (-1.38) | (-0.15) |
| $R^2$ (%) | 7.24 | 18.56 |
| $N$ | 84 | 84 |
| Banks | 28 | 28 |

Table 6: **Holdings channel: regression analysis of determinants of Granger-causality coefficients**
This table presents the results of the regressions of the influence of sovereign risk on bank risk ($\hat{\beta}_{1i}$) on banks' home sovereign bond holdings. Home holdings is the fraction of home sovereign bond holdings of a bank to the bank's total assets. T-statistics based on White heteroskedasticity-robust standard errors are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. $N$ is the number of observations. $R^2$ is the adjusted $R^2$.

| **Sovereign risk → Bank risk** | | |
|---|---|---|
| | (1) | (2) |
| Home holdings*GIIPS*crisis | | 1.14 |
| | | (0.92) |
| Home holdings*GIIPS*LTRO | | -0.47 |
| | | (-0.66) |
| Home holdings*GIIPS*OMT | | 0.28 |
| | | (0.38) |
| Home holdings*crisis | 0.61** | 0.27* |
| | (2.15) | (1.75) |
| Home holdings*LTRO | -0.14 | -0.29 |
| | (-0.54) | (-1.22) |
| Home holdings*OMT | 0.44 | -0.49*** |
| | (0.90) | (-3.30) |
| $R^2$ (%) | 13.80 | 34.23 |
| $N$ | 84 | 84 |
| Banks | 28 | 28 |

Table 7: **Holdings channel: regression analysis of determinants of abnormal bank performance surrounding various ECB interventions** This table presents estimates from a linear regression analysis of the determinants of two-day [-1;1] five-year CDS CARs (in Panel A) and five-year equity CARs (in Panel B) surrounding the different ECB interventions. The CARs are obtained from an event study methodology described in Appendix C. Independent variables are each bank's GIIPS and non-GIIPS eurozone sovereign bond holdings scaled by total assets. Controls include a constant, the logarithm of total assets, the Tier 1 capital ratio (Tier 1 common capital divided by total assets), risk-weighted assets divided by total assets, the bank's total GIIPS exposure divided by bank's total assets in December 2010. Bank characteristics and sovereign bond holdings are from the period prior to the intervention. T-statistics based on White heteroskedasticity-robust standard errors are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. $N$ is the number of observations. $R^2$ is the adjusted $R^2$.

**Panel A: five-year CDS CARs**

| | LTRO prelim | LTRO | LTRO 1 | LTRO 2 | Draghi's speech | OMT prelim | OMT |
|---|---|---|---|---|---|---|---|
| GIIPS 1-3year/Assets | -751.35** | 352.21 | -250.95 | 3.69 | 427.33 | -627.41 | 1249.70* |
| | (-2.35) | (1.44) | (-0.94) | (0.01) | (0.78) | (-1.47) | (1.69) |
| GIIPS long/Assets | 191.17 | -35.08 | 256.98 | -149.14 | -87.29 | -88.66 | -302.37 |
| | (1.05) | (-0.20) | (0.87) | (-1.07) | (-0.36) | (-0.53) | (-0.80) |
| Euro non-GIIPS/Assets | 59.53 | -32.17 | -130.69 | -74.95 | 3.10 | 10.75 | -47.98 |
| | (0.61) | (-0.27) | (-1.39) | (-1.16) | (0.04) | (0.24) | (-0.57) |
| Controls | Y | Y | Y | Y | Y | Y | Y |
| $N$ | 27 | 27 | 27 | 27 | 25 | 25 | 25 |
| $R^2$ (%) | 50.24 | 51.62 | 31.37 | -13.85 | 36.32 | 16.68 | 63.46 |

**Panel B: Equity CARs**

| | LTRO prelim | LTRO | LTRO 1 | LTRO 2 | Draghi's speech | OMT prelim | OMT |
|---|---|---|---|---|---|---|---|
| GIIPS 1-3year/Assets | 156.95* | -7.01 | -39.82 | 216.78*** | 24.64 | 94.04 | -99.27 |
| | (2.02) | (-0.16) | (-0.46) | (2.90) | (0.45) | (1.56) | (-1.00) |
| GIIPS long/Assets | 72.27 | -9.98 | 18.02 | -51.74 | -3.20 | 33.20 | 122.05* |
| | (0.86) | (-0.24) | (0.37) | (-1.16) | (-0.10) | (1.42) | (1.95) |
| Euro non-GIIPS/Assets | 90.91 | -52.37** | -16.08 | 24.88* | -8.60 | 5.47 | 20.40 |
| | (1.54) | (-2.49) | (-0.60) | (1.78) | (-0.68) | (0.20) | (0.75) |
| Interest rate exposure | -22.33 | 1.14 | 6.72 | -16.00** | 1.23 | -1.41 | 5.46 |
| | (-1.57) | (0.12) | (0.67) | (-2.12) | (0.25) | (-0.19) | (0.36) |
| Term spread exposure | 26.34 | 31.62* | -6.60 | 33.88 | 7.50 | -0.86 | -5.89 |
| | (0.65) | (1.72) | (-0.22) | (1.58) | (0.42) | (-0.04) | (-0.20) |
| Controls | Y | Y | Y | Y | Y | Y | Y |
| $N$ | 33 | 33 | 33 | 33 | 33 | 33 | 33 |
| $R^2$ (%) | 24.13 | 67.67 | 24.90 | 56.98 | 49.77 | 25.30 | 29.58 |

Table 8: **Summary of holdings and fire-sale risk channels effects**
This table presents the cross-sectional average effects of holdings and fire-sale risk channels on five-year bank CDS spread (in bps) changes in Panel A, and bank equity returns (in percentage) in Panel B. The channel effects are obtained by multiplying the estimated parameters of regression of Equation (D.1) to the corresponding regressor values for each bank, where parameters are set to zero if not significantly different from zero at the 10% level. In bold, we highlight the average aggregate effect of holding short-term GIIPS sovereign bonds and long-term GIIPS sovereign bonds.

**Panel A: five-year bank CDS spread changes (bps)**

| | | all | | GIIPS | | Euro non-GIIPS | | non-Euro | |
|---|---|---|---|---|---|---|---|---|---|
| | channel | LTRO | OMT | LTRO | OMT | LTRO | OMT | LTRO | OMT |
| Average raw change | | -27 | -186 | -22 | -319 | -41 | -133 | -19 | -99 |
| 1-3 year GIIPS bonds | | **-34** | **-32** | **-104** | **-68** | **19** | **-31** | **2** | **-6** |
| | holdings | -244 | 184 | -573 | 546 | -47 | 22 | -16 | 6 |
| | fire-sale risk | 210 | -233 | 469 | -614 | 70 | -53 | 18 | -12 |
| long-term GIIPS bonds | | **144** | **-48** | **297** | **-135** | **85** | **-16** | **9** | **-1** |
| | holdings | 38 | -48 | 83 | -135 | 16 | -16 | 3 | -1 |
| | fire-sale risk | 106 | - | 215 | - | 69 | - | 6 | - |

**Panel B: bank equity returns (%)**

| | | all | | GIIPS | | Euro non-GIIPS | | non-Euro | |
|---|---|---|---|---|---|---|---|---|---|
| | channel | LTRO | OMT | LTRO | OMT | LTRO | OMT | LTRO | OMT |
| Average raw return | | -10 | 35 | -38 | 37 | -5 | 50 | 14 | 21 |
| 1-3 year GIIPS bonds | holdings | **15** | **-** | **37** | **-** | **3** | **-** | **1** | **-** |
| other GIIPS bonds | holdings | **-30** | **6** | **-74** | **16** | **-8** | **2** | **-1** | **0** |

Figure 1: **Sovereign debt concentration and banks' access to funding**
This figure shows the principal amounts of unsecured funding ($ billion) invested by U.S. money market funds at eurozone banks and the concentration of eurozone sovereign bonds in domestic banks (%). Vertical bars indicate ECB interventions: LTRO 1 (12-21-2011), and the OMT program (9-06-2012). Sovereign debt concentration is the share of sovereign bonds held by resident banks. Data sources: Bruegel database of sovereign bond holdings developed in Merler and Pisani-Ferry (2012) for sovereign debt concentration, and iMoneyNet for banks' access to U.S. MMF funding.

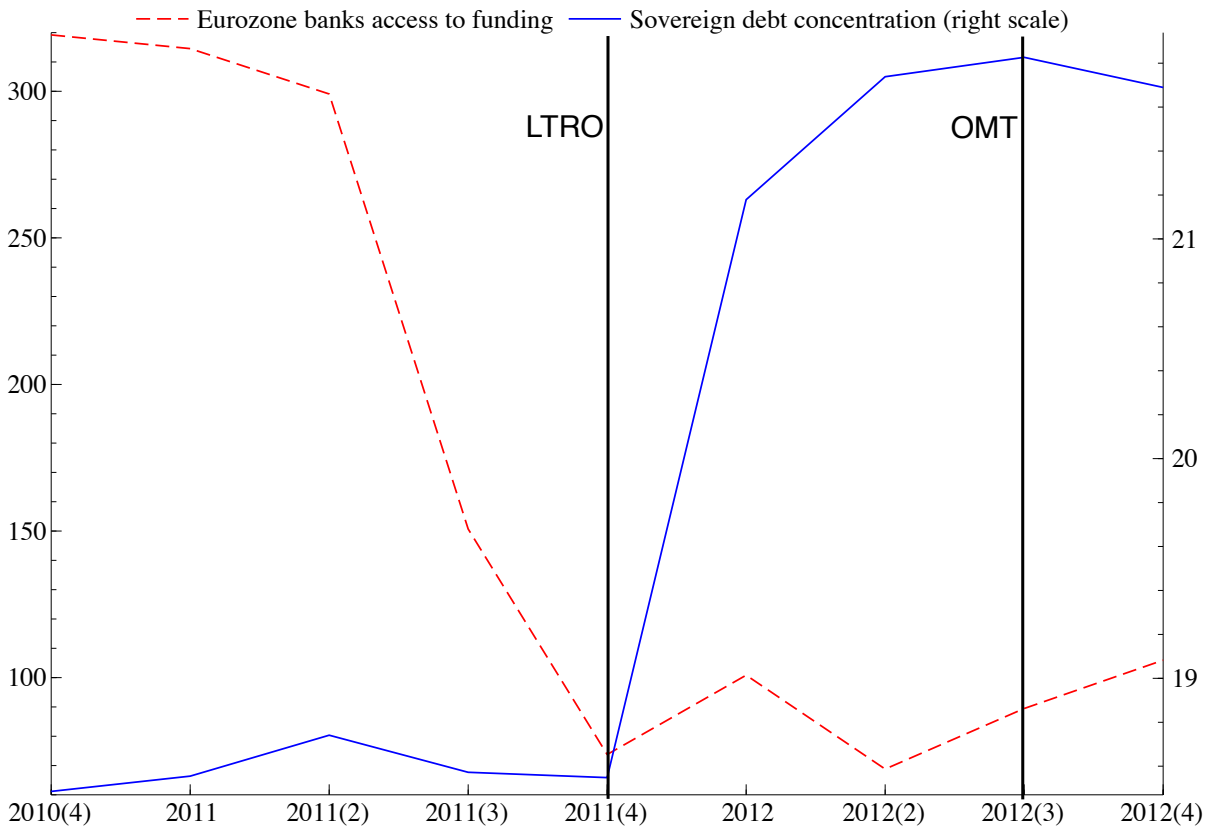
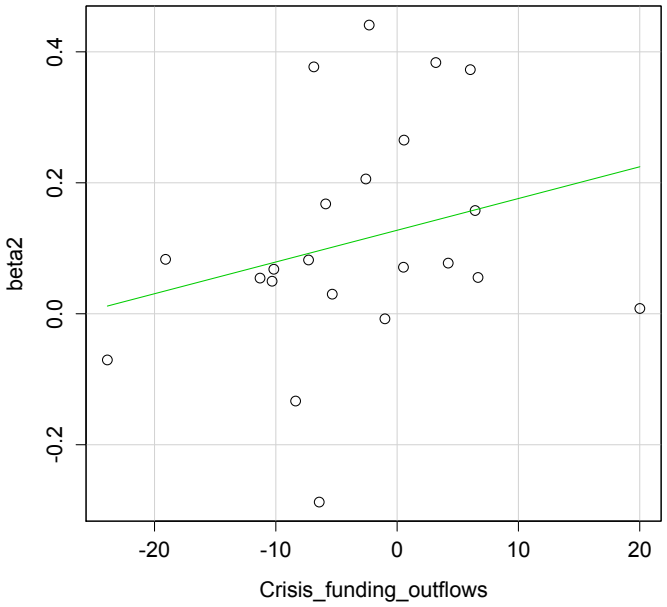


Figure 2: **Crisis funding outflows, bank risk contagion, and sovereign bond holdings**
This figure shows the correlation between the non-deposit liabilities outflows (%) of banks during 2011 and the parameters capturing the influence of bank risk on sovereign risk in the post-LTRO period (12-09-2011–7-25-2012) in Panel A, and the correlation between the unsecured non-deposit liabilities outflows (%) of banks during 2011 and the home sovereign bond holdings of banks as a share of their total assets (%) before the LTROs in Panel B. The parameters ($\hat{\beta}_{2i}$) capturing the influence of bank risk on sovereign risk are derived using the estimation procedure described in Subsection 4.4. Data sources: European Banking Authority for sovereign bond holdings, and SNL for non-deposit liabilities outflows.

(a) Bank to sovereign risk contagion and crisis funding outflows




(b) Home sovereign bond holdings of banks and crisis funding outflows

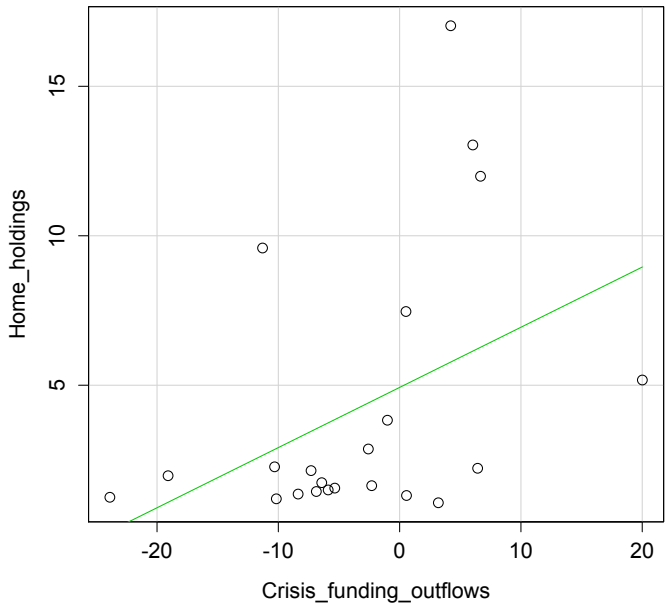
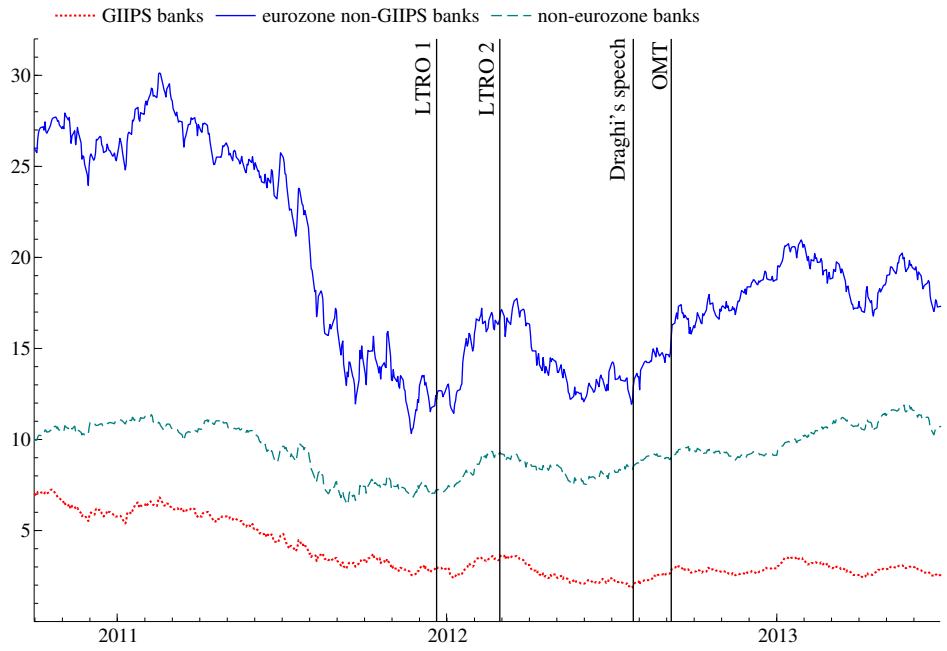


Figure 3: **Bank equity and CDS prices**
This figure shows the average equity prices (Panel A) and average five-year CDS prices (Panel B) of GIIPS banks (excluding Greek banks), non-GIIPS eurozone banks (excluding Dexia), and non-eurozone banks. Vertical bars indicate ECB interventions: LTRO 1 (12-21-2011), LTRO 2 (2-29-2012), Draghi's speech (7-26-2012), OMT program (9-06-2012).

(a) Average bank equity prices (€)




(b) Average bank CDS prices (bps)

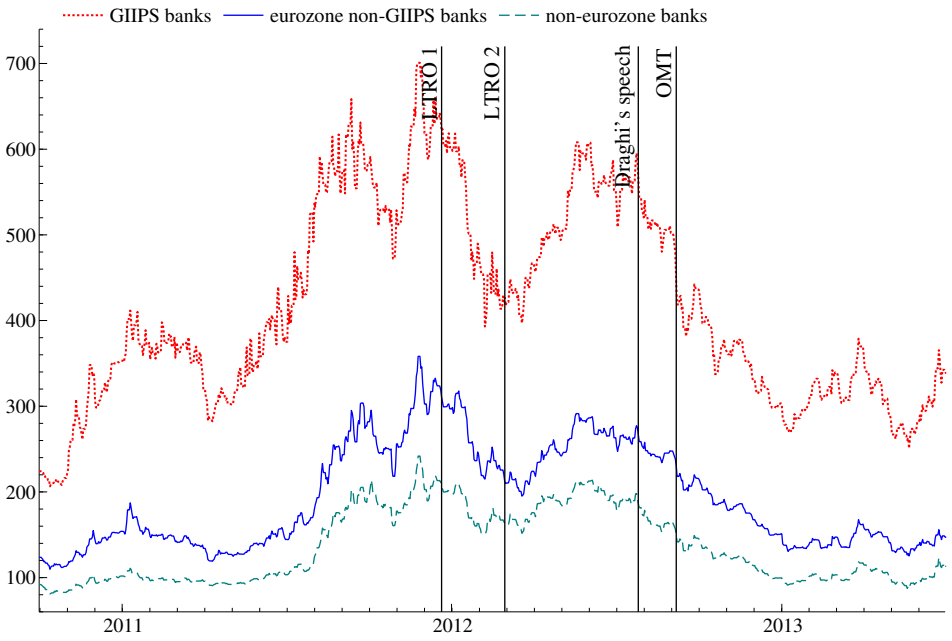


Figure 4: **Sovereign risk**
This figure shows the average five-year sovereign CDS prices of IIPS countries (Ireland, Italy, Portugal, and Spain), non-GIIPS eurozone countries, and non-eurozone countries. Vertical bars indicate ECB interventions: LTRO 1 (12-21-2011), LTRO 2 (2-29-2012), Draghi's speech (7-26-2012), OMT program (9-06-2012).

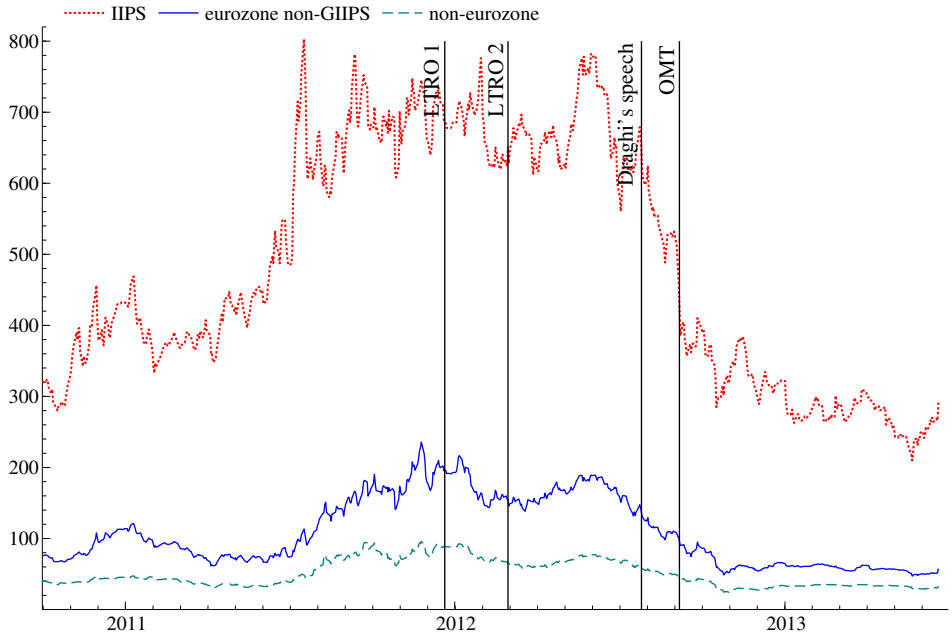


Figure 5: **Bank access to funding**
This figure shows the principal amounts of unsecured funding ($ billion) invested by U.S. money market funds at GIIPS, non-GIIPS eurozone, and non-eurozone banks. Vertical bars indicate ECB interventions: LTRO 1 (Dec 2011), LTRO 2 (Feb 2012), Draghi's speech (Jul 2012), OMT program (Sept 2012).

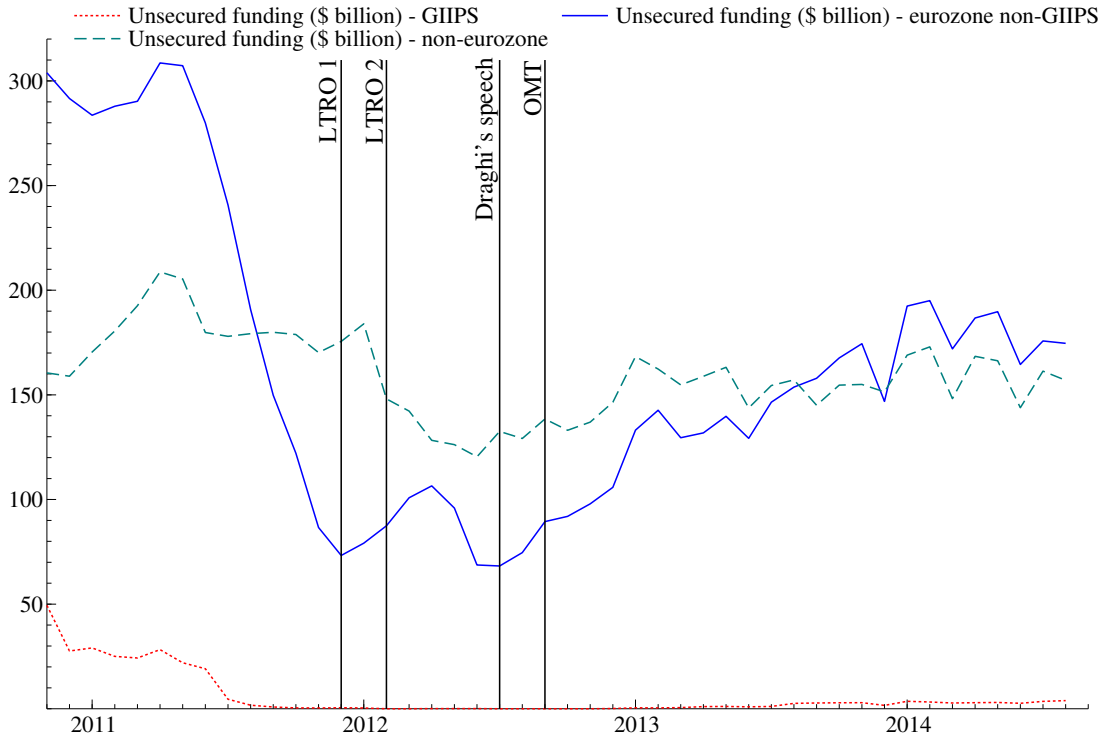
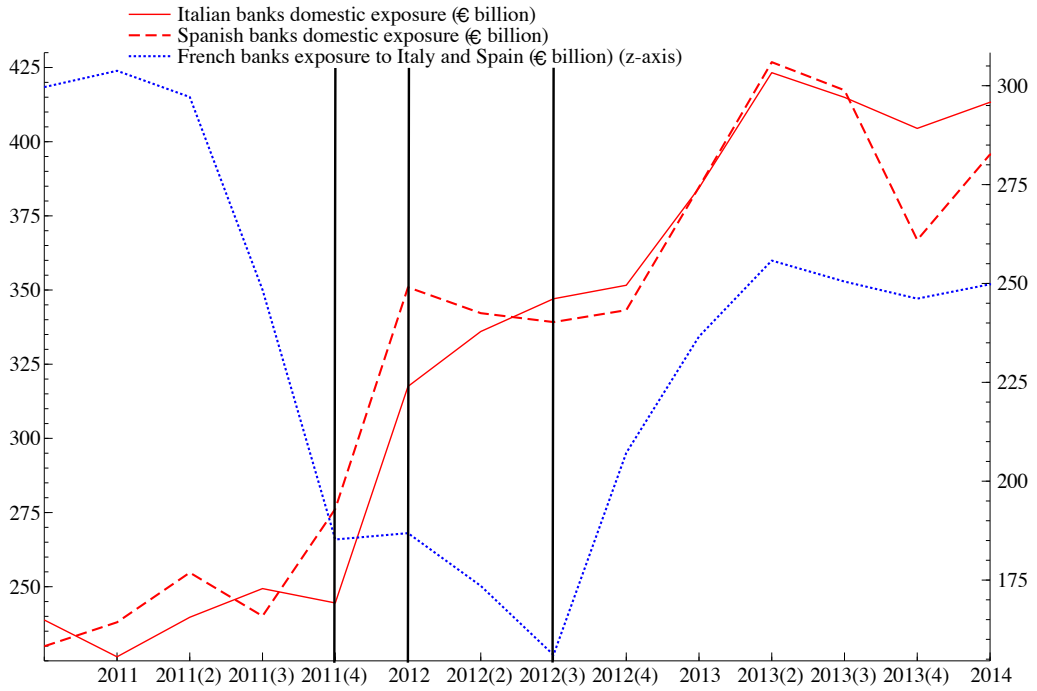


Figure 6: **Italian and Spanish sovereign debt investors**
This figure shows the national banking sectors' exposure (€ billion) to Italian and Spanish official sectors. Sources: BIS Consolidated Banking Statistics and ECB. Vertical bars indicate ECB interventions: LTRO 1 (Q4 2011), LTRO 2 (Q1 2012), Draghi's speech and OMT program (Q3 2012).



## AppendixA. Variables description, sample, and descriptive statistics

Table A.1: **Variable definitions**

| Variable | Definition |
|---|---|
| Sovereign debt concentration | Share of sovereign bonds held by domestic banks. |
| MMF investments | Principal amount of unsecured securities invested by U.S. MMFs at European banks in $ billion. |
| Crisis funding outflows | Percentage non-deposit liabilities outflows of banks during 2011. |
| beta 2 | Parameter capturing the influence of bank risk on sovereign risk, derived using the estimation procedure described in Subsection 4.4. |
| beta 1 | Parameter capturing the influence of sovereign risk on bank risk, derived using the estimation procedure described in Subsection 4.4. |
| Home holdings | Ratio of bank's holdings of home country sovereign bonds to its total assets. |
| GIIPS | Dummy variable equal to one if a bank's headquarter is located in a GIIPS country. |
| GIIPS bond | Daily changes on average five-year sovereign bond yields of GIIPS countries. |
| German bond | Daily changes in five-year sovereign bond yield of Germany. |
| Log-Assets | Natural logarithm of bank's total assets. |
| Tier 1 capital ratio | Ratio of bank Tier 1 capital to its total assets. |
| RWA/Assets | Ratio of bank's risk-weighted assets to its total assets. |
| GIIPS 1-3year/Assets | Ratio of bank's holdings of GIIPS sovereign bonds of maturity between one and three years to its total assets. |
| GIIPS long/Assets | Ratio of bank's holdings of GIIPS sovereign bonds of maturity above three years to its total assets. |
| Euro non-GIIPS/Assets | Ratio of bank's holdings of eurozone non-GIIPS sovereign bonds to its total assets. |
| Interest rate exposure | Bank-specific factor loading estimate from time series regressions of stock returns on the ECB deposit rate. |
| Term spread exposure | Bank-specific factor loading estimate from time series regressions of stock returns on the eurozone sovereign term spread. |
| Crisis MMF funding flows | Six-month percentage MMF unsecured flows from May 2011 until December 2011. |
| LTRO MMF funding flows | Six-month percentage MMF unsecured flows from December 2011 until June 2012. |

Table A.2: **Sample of banks with access to U.S. MMFs**

| Bank name (SNL) | SNL ID | Ticker | EBA ID | CDS |
|---|---|---|---|---|
| Societe Generale SA | 113818 | GLE | FR016 | yes |
| Credit Suisse Group AG | 113824 | CSGN | | yes |
| Deutsche Bank AG | 113830 | DBK | DE017 | yes |
| UBS AG | 113831 | UBSN | | yes |
| HSBC Holdings Plc | 113876 | HSBA | GB089 | yes |
| Banco Bilbao Vizcaya Argentaria, SA | 113904 | BBVA | ES060 | yes |
| Banco Santander SA | 113983 | SAN | ES059 | yes |
| Commerzbank AG | 113985 | CBK | DE018 | yes |
| Barclays Plc | 114508 | BARC | GB090 | yes |
| BNP Paribas SA | 3001689 | BNP | FR013 | yes |
| Royal Bank of Scotland Group Plc | 3001937 | RBS | GB088 | |
| ABN AMRO Group NV | 4000991 | | NL049 | yes |
| Allied Irish Banks, Plc | 4002079 | AIB | | yes |
| AXA | 4009223 | CS | | yes |
| Prudential Public Limited Company | 4023122 | PRU | | |
| Dexia SA | 4024522 | DEXB | BE004 | yes |
| Lloyds Banking Group Plc | 4041848 | LLOY | GB091 | yes |
| Bank of Ireland | 4041921 | BIR | IE038 | yes |
| Standard Chartered Plc | 4041955 | STAN | | |
| Bayerische Landesbank | 4048275 | | DE021 | yes |
| UniCredit SpA | 4055762 | UCG | IT041 | yes |
| Landesbank Baden-Wurttemberg | 4073469 | | | yes |
| Alliance & Leicester Plc | 4079602 | | | |
| Danske Bank A/S | 4080954 | DANSKE | DK008 | yes |
| Credit Agricole Group | 4085960 | ACA | FR014 | yes |
| Falcon Pvt. Bank Ltd. | 4087342 | | | |
| Erste Group Bank AG | 4089743 | EBS | AT001 | yes |
| ING Bank NV | 4092030 | INGA | NL047 | yes |
| Intesa Sanpaolo SpA | 4100801 | ISP | IT040 | yes |
| Nordea Bank AB | 4108919 | NDA | SE084 | yes |
| Landesbank Hessen-Thuringen Girozentrale | 4120106 | | DE026 | yes |
| DNB ASA | 4142645 | DNB | NO051 | yes |
| Deutsche Zentral-Genossenschaftsbank | 4142663 | | DE020 | yes |
| Svenska Handelsbanken AB | 4144846 | SHB.A | SE086 | yes |
| Skandinaviska Enskilda Banken AB | 4144847 | SEB.A | SE085 | yes |

| Bank name (SNL) | SNL ID | Ticker | EBA ID | CDS |
|---|---|---|---|---|
| Oesterreichische Kontrollbank AG | 4145033 | | | |
| KBC Group NV | 4145062 | KBC | BE005 | |
| Nationwide Building Society | 4145082 | | | |
| Rabobank Group | 4145124 | | NL048 | yes |
| NORD/LB Norddeutsche Landesbank Girozentrale | 4145342 | | DE022 | yes |
| Swedbank AB | 4153551 | SWED.A | SE087 | yes |
| Allianz Group | 4174043 | ALV | | yes |
| KfW Bankengruppe | 4182748 | | | |
| Clydesdale Bank Plc | 4183593 | | | |
| Nederlandse Waterschapsbank NV | 4186955 | | | |
| Banque Fédérative du Crédit Mutuel SA | 4216441 | | | |
| Banque et Caisse d'Epargne de l'Etat, Luxembourg | 4224076 | | LU045 | |
| Credit Industriel et Commercial | 4238541 | CC | | |
| Groupe BPCE | 4239955 | | FR015 | |
| Eksportfinans ASA | 4242177 | | | |
| Fortis Bank (Nederland) NV | 4242187 | | | |
| Kommunalbanken AS | 4242212 | | | |
| Landeskreditbank Baden-Wurttemberg Forderbank | 4242220 | | | |
| NRW.BANK | 4242234 | | | |
| Caisse des Depots et Consignations | 4251084 | | | |
| Dreyfus Sons & Co Ltd, Banquiers | 4260242 | | | |
| European Investment Bank | 4261613 | | | |
| Erste Abwicklungsanstalt | 4377953 | | | |
| SBAB Bank AB (publ) | 4397921 | | | |
| Kommuninvest i Sverige Aktiebolag | 4397927 | | | |
| Caisse d'Amortissement de la Dette Sociale | 4398177 | | | |
| NV Bank Nederlandse Gemeenten | 4400227 | | | |
| Nordic Investment Bank | 4400301 | | | |

Table A.3: **Descriptive statistics**

Panel A: bank characteristics (as of September 2011)

| **GIIPS banks** | Observations | Mean | Std. dev. | Min. | Median | Max. |
|---|---|---|---|---|---|---|
| Log-Assets | 23 | 18.71 | 1.07 | 17.15 | 18.70 | 20.95 |
| Tier 1 capital ratio (%) | 23 | 5.51 | 1.59 | 3.13 | 5.23 | 11.08 |
| RWA/Assets (%) | 23 | 57.74 | 14.66 | 21.39 | 55.69 | 88.04 |
| MMF/Assets (%) | 4 | 3.04 | 4.09 | 0.01 | 1.72 | 8.72 |
| MMF unsecured/Assets (%) | 3 | 2.67 | 3.21 | 0.07 | 1.69 | 6.26 |
| | | | | | | |
| **non-GIIPS banks** | | | | | | |
| Log-Assets | 38 | 19.40 | 1.58 | 15.58 | 19.49 | 21.55 |
| Tier 1 capital ratio (%) | 38 | 3.93 | 1.85 | 1.49 | 3.40 | 10.24 |
| RWA/Assets (%) | 38 | 36.70 | 15.65 | 14.79 | 32.03 | 80.65 |
| MMF/Assets (%) | 19 | 2.93 | 4.20 | 0.03 | 1.16 | 14.62 |
| MMF unsecured/Assets (%) | 13 | 2.52 | 4.07 | 0.22 | 1.05 | 13.35 |

Panel B: banks' sovereign bond holdings (as of September 2011)

| **GIIPS banks** | Observations | Mean | Std. dev. | Min. | Median | Max. |
|---|---|---|---|---|---|---|
| Home holdings/Assets (%) | 13 | 6.68 | 2.72 | 3.20 | 7.33 | 12.06 |
| GIIPS/Assets (%) | 13 | 7.25 | 3.03 | 3.24 | 8.08 | 12.22 |
| non-GIIPS/Assets (%) | 13 | 0.42 | 0.70 | 0.00 | 0.04 | 2.47 |
| | | | | | | |
| **non-GIIPS banks** | | | | | | |
| Home holdings/Assets (%) | 32 | 4.67 | 4.91 | 0.16 | 2.18 | 17.14 |
| GIIPS/Assets (%) | 32 | 0.67 | 0.90 | 0.00 | 0.36 | 4.39 |
| non-GIIPS/Assets (%) | 32 | 4.74 | 4.50 | 0.00 | 3.43 | 18.06 |

Panel C: Time series characteristics (January 2011 - June 2013)

| **GIIPS banks** | Observations | Mean | Std. dev. | Min. | Median | Max. |
|---|---|---|---|---|---|---|
| stock price (EUR) | 650 | 3.49 | 1.25 | 1.85 | 3.01 | 6.82 |
| stock returns (%) | 650 | -0.13 | 2.70 | -8.96 | 0.00 | 8.73 |
| CDS spread (bps) | 640 | 621.13 | 138.63 | 313.19 | 639.60 | 876.31 |
| CDS spread change (bps) | 640 | 0.37 | 12.56 | -35.18 | -0.41 | 182.60 |
| | | | | | | |
| **non-GIIPS banks** | | | | | | |
| stock price (EUR) | 650 | 14.46 | 3.20 | 9.06 | 13.82 | 21.59 |
| stock returns (%) | 650 | -0.04 | 2.25 | -9.32 | 0.01 | 11.17 |
| CDS spread (bps) | 640 | 173.03 | 49.77 | 105.35 | 159.18 | 300.83 |
| CDS spread change (bps) | 640 | -0.57 | 22.35 | -370.95 | 0.33 | 163.26 |

## AppendixB. Holdings and fire-sale risk channels

Table B.1: **Holdings versus fire-sale risk channel: Granger-causality at the country level**
This table reports in Panel A the estimated beta 1 parameters (Sovereign risk → Bank risk) of the Granger causality regressions. In Panel B, the estimated beta 2 parameters (Bank risk → Sovereign risk) of the Granger causality regressions. The regressions are split in three periods: the crisis period (06-01-2011–12-07-2011), the post LTRO period (12-09-2011–07-25-2012), and the post OMT period (07-27-2012–12-31-2012). The results in columns (1), (3), and (5) are the same results displayed in Table 2. The results in columns (2), (4), and (6) are obtained by using the Autometrics software that optimally choses the number of lags in the system of simultaneous bank–sovereign equations. The optimal number of lags and the selected lags in the regression are different for each country. The sign "-" indicates that the first lag is not selected using this procedure. T-statistics based on Newey-West standard errors are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. $N$ is the number of observations.

**Panel A: Sovereign risk → Bank risk**

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | Crisis | | post LTRO | | post OMT | |
| Spain | 0.150*** | 0.149*** | 0.145** | 0.170*** | 0.196*** | 0.103** |
| | (2.72) | (4.54) | (2.24) | (4.43) | (2.88) | (2.00) |
| Italy | 0.179** | 0.230*** | -0.147 | - | 0.274** | 0.250*** |
| | (2.37) | (4.27) | (-1.17) | | (2.06) | (2.76) |
| Germany | 0.186*** | 0.187*** | 0.032 | - | -0.032 | - |
| | (2.64) | (3.35) | (0.58) | | (-0.80) | |
| France | 0.140** | - | -0.067 | - | 0.111** | - |
| | (2.00) | | (-1.32) | | (2.54) | |
| UK | 0.095 | 0.074 | -0.073 | -0.091 | 0.107 | 0.194*** |
| | (1.05) | (0.78) | (-0.75) | (-0.94) | (1.22) | (2.55) |
| $N$ | 136 | 136 | 164 | 164 | 112 | 112 |

**Panel B: Bank risk → Sovereign risk**

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | Crisis | | post LTRO | | post OMT | |
| Spain | -0.011 | - | 0.056 | - | 0.021 | - |
| | (-0.04) | | (0.29) | | (0.08) | |
| Italy | -0.036 | - | 0.271* | 0.286*** | -0.043 | - |
| | (-0.19) | | (1.66) | (3.87) | (-0.21) | |
| Germany | 0.106 | - | 0.186* | 0.138 | 0.287 | - |
| | (0.45) | | (1.72) | (1.56) | (1.36) | |
| France | 0.250** | - | 0.534*** | 0.427*** | 0.435* | - |
| | (2.34) | | (4.09) | (4.11) | (1.87) | |
| UK | 0.243* | 0.330** | 0.241** | 0.231** | 0.021 | - |
| | (1.70) | (2.19) | (2.57) | (2.22) | (0.23) | |
| $N$ | 136 | 136 | 164 | 164 | 112 | 112 |

Table B.2: **Fire-sale risk channel versus holdings channel: robustness**
This table presents the results of the regressions of estimated Granger-causality coefficients on banks home sovereign bond holdings. In Panel A, the dependent variable is the influence of bank risk on sovereign risk ($\hat{\beta}_2$). In Panel B, the dependent variable is the influence of sovereign risk on bank risk ($\hat{\beta}_1$). Home holdings is the fraction of home sovereign bond holdings of a bank to the bank's total assets. Controls include the crisis MMF funding flows (the unsecured MMF flows from June to December 2011), the bank total home exposure divided by bank total assets in December 2010, the logarithm of bank total assets, and the fraction of bank Tier 1 capital held by the government. T-statistics based on White heteroskedasticity-robust standard errors are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. $N$ is the number of observations. $R^2$ is the adjusted $R^2$.

| | Panel A: Bank risk → Sovereign risk | | Panel B: Sovereign risk → Bank risk | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Home holdings*GIIPS*crisis | | 3.09** | | 0.60 |
| | | (2.18) | | (0.64) |
| Home holdings*GIIPS*LTRO | | 3.41*** | | -1.10 |
| | | (3.02) | | (-1.40) |
| Home holdings*GIIPS*OMT | | -3.08 | | -0.35 |
| | | (-1.48) | | (-0.44) |
| Home holdings*crisis | -2.11*** | -3.24*** | 0.46 | 0.39* |
| | (-2.68) | (-5.45) | (1.81) | (1.76) |
| Home holdings*LTRO | -0.17 | 0.83 | -0.01 | -0.27 |
| | (-0.30) | (1.25) | (-0.03) | (-1.32) |
| Home holdings*OMT | -0.81 | -0.03 | 0.24 | -0.40** |
| | (-1.11) | (-0.05) | (0.50) | (-2.58) |
| Controls | Y | Y | Y | Y |
| $R^2$ (%) | 5.65 | 15.89 | 24.29 | 43.43 |
| $N$ | 84 | 84 | 84 | 84 |
| Banks | 28 | 28 | 28 | 28 |

## AppendixC. Event studies

The reported average cummulative abnormal CDS spread changes and the abnormal cummulative equity returns (CARs) are derived from a market model adjusted for autocorrelation. The methodology we employ for deriving abnormal equity returns and CDS changes on the equally-weighted bank portfolio and their variances is described in Campbell, Lo, and MacKinlay (1997).The abnormal changes (resp. returns) in the market model adjusted for autocorrelation are derived from $AR_{iT+h} = r_{iT+h} - \left[\hat{\alpha}_i + \hat{\beta}_i r_{mT+h} + \hat{\varphi}_i r_{iT+h-1}\right]$, where $r_{it}$ is the spread change (resp. log-return) of asset $i$, and $r_{mt}$ is the spread change (resp. log-return) of the market index. This methodology accounts for cross-sectional dependence in bank abnormal returns due to overlapping events. We use the Markit iTraxx Europe Crossover Index on the most liquid sub-investment grade European corporate entities as the benchmark CDS market index, and the Euro Stoxx Index as the benchmark stock market index in computing abnormal bank CDS changes and abnormal bank equity returns, respectively.

Table C.1: **Bank event study**

This table reports in Panel A the average two-day [-1;1] cumulative abnormal changes (CARs) in five-year and three-year CDS spreads for publicly traded GIIPS, non-GIIPS eurozone, and non-eurozone banks surrounding the various ECB interventions. Panel B presents the average two-day [-1;1] cumulative abnormal returns (CARs) on equity for publicly traded GIIPS, non-GIIPS eurozone (non-GIIPS), and non-eurozone banks that participated in all EBA stress tests surrounding the various ECB interventions. These are the LTRO preliminary announcement (12-01-2011), the LTRO announcement (12-08-2011), LTRO 1 (12-21-2011), LTRO 2 (2-29-2012), Draghi's speech (7-26-2012), the preliminary OMT program announcement (8-02-2012), and the announcement of the OMT program details (9-06-2012). The evidence in Panel A is based on 12 GIIPS banks, 9 non-GIIPS eurozone banks, 9 non-eurozone banks, and a market model and autocorrelation adjusted abnormal CDS changes. We use the Markit iTraxx Europe Crossover index on the most liquid sub-investment grade European corporate entities as the benchmark CDS market index in computing the abnormal changes. The evidence in Panel B is based on 15 GIIPS banks, 9 non-GIIPS eurozone banks, 12 non-eurozone banks, and a market model and autocorrelation adjusted abnormal equity returns. We use the Euro Stoxx Index as the benchmark stock market index in computing the abnormal returns. T-statistics are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

| | Panel A: Bank CDS | | | | | | Panel B: Bank equity | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Average five-year CDS CAR** | | | **Average three-year CDS CAR** | | | **Average Equity CAR** | | |
| | GIIPS | Euro core | non-Euro | GIIPS | Euro core | non-Euro | GIIPS | Euro core | non-Euro |
| **LTRO prelim.** | -39.867* | -25.996*** | -19.030*** | -40.702*** | -20.755*** | -9.318*** | 7.459*** | 9.542*** | 4.536*** |
| 12-01-2011 | (-1.830) | (-4.209) | (-6.000) | (-2.662) | (-3.383) | (-4.157) | (3.526) | (4.191) | (2.978) |
| **LTRO** | 13.586 | 12.904** | 6.042* | 6.888 | 12.333** | 3.112 | 0.319 | -3.176 | -0.832 |
| 12-08-2011 | (0.623) | (2.028) | (1.752) | (0.447) | (1.982) | (1.325) | (0.149) | (-1.353) | (-0.541) |
| **LTRO 1** | -18.817 | -10.914* | -3.599 | -12.425 | -11.224* | -2.623 | -0.168 | 1.064 | 0.165 |
| 12-21-2011 | (-0.877) | (-1.726) | (-1.043) | (-0.816) | (-1.776) | (-1.120) | (-0.079) | (0.458) | (0.108) |
| **LTRO 2** | -3.357 | -4.109 | -1.741 | -1.999 | -3.827 | -1.492 | 2.569 | 3.483 | 0.913 |
| 2-29-2012 | (-0.158) | (-0.607) | (-0.469) | (-0.134) | (-0.584) | (-0.577) | (1.163) | (1.386) | (0.590) |
| **Draghi's speech** | -18.275 | -4.410 | -2.837 | -9.818 | -2.367 | -2.298 | 2.606 | 1.487 | 0.869 |
| 7-26-2012 | (-1.542) | (-0.584) | (-0.685) | (-0.823) | (-0.322) | (-0.778) | (1.091) | (0.569) | (0.565) |
| **OMT prelim.** | 8.166 | 5.559 | 0.950 | 9.115 | 5.111 | 1.217 | 1.861 | 2.260 | -2.114 |
| 8-02-2012 | (0.710) | (0.757) | (0.229) | (0.771) | (0.717) | (0.415) | (0.798) | (0.873) | (-1.371) |
| **OMT** | -35.656*** | -7.368 | -4.251 | -38.422*** | -5.973 | -3.110 | 2.093 | 3.062 | 0.382 |
| 9-06-2012 | (-3.362) | (-1.061) | (-1.068) | (-3.483) | (-0.895) | (-1.118) | (0.888) | (1.226) | (0.273) |

Table C.2: **Bank event study: five-year CDS CARs**
This table reports the average four-day [-2;2] and one-day [0;1] cumulative abnormal changes (CARs) in five-year CDS spreads for publicly traded GIIPS, non-GIIPS eurozone, and non-eurozone banks surrounding the various ECB interventions. These are the LTRO preliminary announcement (12-01-2011), the LTRO announcement (12-08-2011), LTRO 1 (12-21-2011), LTRO 2 (2-29-2012), Draghi's speech (7-26-2012), the preliminary OMT program announcement (8-02-2012), and the announcement of the OMT program details (9-06-2012). The evidence is based on 12 GIIPS banks, 9 non-GIIPS eurozone banks, 9 non-eurozone banks, and a market model and autocorrelation adjusted abnormal CDS changes. We use the Markit iTraxx Europe Crossover index on the most liquid sub-investment grade European corporate entities as the benchmark CDS market index in computing the abnormal changes. T-statistics are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

| | **Average five-year CDS CAR** | | | | | |
|---|---|---|---|---|---|---|
| | GIIPS | | Euro core | | non-Euro | |
| | [-2,2] | [0,1] | [-2,2] | [0,1] | [-2,2] | [0,1] |
| **LTRO prelim.** | -55.396* | -23.871 | -42.207*** | -11.170*** | -25.465*** | -15.079*** |
| 12-01-2011 | (-1.762) | (-1.561) | (-4.778) | (-2.579) | (-5.496) | (-6.892) |
| **LTRO** | 22.462 | -4.858 | 26.533*** | 5.925 | 6.638 | 0.989 |
| 12-08-2011 | (0.723) | (-0.318) | (2.936) | (1.335) | (1.353) | (0.410) |
| **LTRO 1** | -19.069 | -18.150 | -11.541 | -7.939* | -2.599 | -4.252* |
| 12-21-2011 | (-0.622) | (-1.203) | (-1.274) | (-1.787) | (-0.528) | (-1.753) |
| **LTRO 2** | -10.538 | -1.500 | -8.566 | -6.330 | -3.347 | -1.478 |
| 2-29-2012 | (-0.349) | (-0.100) | (-0.889) | (-1.328) | (-0.633) | (-0.565) |
| **Draghi's speech** | -23.983 | -10.214 | -5.497 | -3.672 | -9.012 | -4.678 |
| 7-26-2012 | (-1.418) | (-1.232) | (-0.511) | (-0.694) | (-1.529) | (-1.614) |
| **OMT prelim.** | 5.078 | 6.358 | 7.007 | 0.918 | 2.226 | 1.704 |
| 8-02-2012 | (0.311) | (0.788) | (0.671) | (0.178) | (0.378) | (0.584) |
| **OMT** | -30.946** | -16.459** | 0.661 | -3.190 | -0.118 | -2.208 |
| 9-06-2012 | (-2.031) | (-2.226) | (0.067) | (-0.656) | (-0.021) | (-0.792) |

Table C.3: **Bank event study: three-year CDS CARs**
This table reports the average four-day [-2;2] and one-day [0;1] cumulative abnormal changes (CARs) in three-year CDS spreads for publicly traded GIIPS, non-GIIPS eurozone, and non-eurozone banks surrounding the various ECB interventions. These are the LTRO preliminary announcement (12-01-2011), the LTRO announcement (12-08-2011), LTRO 1 (12-21-2011), LTRO 2 (2-29-2012), Draghi's speech (7-26-2012), the preliminary OMT program announcement (8-02-2012), and the announcement of the OMT program details (9-06-2012). The evidence is based on 12 GIIPS banks, 9 non-GIIPS eurozone banks, 9 non-eurozone banks, and a market model and autocorrelation adjusted abnormal CDS changes. We use the Markit iTraxx Europe Crossover index on the most liquid sub-investment grade European corporate entities as the benchmark CDS market index in computing the abnormal changes. T-statistics are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

| | **Average three-year CDS CAR** | | | | | |
|---|---|---|---|---|---|---|
| | GIIPS | | Euro core | | non-Euro | |
| | [-2,2] | [0,1] | [-2,2] | [0,1] | [-2,2] | [0,1] |
| **LTRO prelim.** | -50.966** | -25.587** | -17.919*** | -7.925*** | -62.515** | -23.327 |
| 12-01-2011 | (-2.306) | (-2.389) | (-3.065) | (-2.796) | (-2.001) | (-1.536) |
| **LTRO** | 15.172 | -9.011 | 13.607** | -2.224 | 14.848 | -10.807 |
| 12-08-2011 | (0.692) | (-0.834) | (2.339) | (-0.777) | (0.481) | (-0.711) |
| **LTRO 1** | -15.614 | -12.991 | -7.745 | -8.010*** | -16.451 | -10.743 |
| 12-21-2011 | (-0.717) | (-1.213) | (-1.303) | (-2.751) | (-0.539) | (-0.716) |
| **LTRO 2** | -11.955 | -5.232 | -6.516 | -2.950 | -13.125 | -4.855 |
| 2-29-2012 | (-0.565 | (-0.500) | (-1.059) | (-0.966) | (-0.449) | (-0.336) |
| **Draghi's speech** | -19.875 | -8.492 | -2.899 | -1.464 | -24.342 | -9.221 |
| 7-26-2012 | (-1.169) | (-1.016) | (-0.420) | (-0.431) | (-1.202) | (-0.925) |
| **OMT prelim.** | 7.535 | 6.464 | 3.633 | -0.496 | 13.861 | 7.253 |
| 8-02-2012 | (0.449) | (0.780) | (0.542) | (-0.150) | (0.690) | (0.730) |
| **OMT** | -32.084** | -16.431** | 1.198 | -1.539 | -37.091* | -18.925** |
| 9-06-2012 | (-2.024) | (-2.135) | (0.188) | (-0.490) | (-1.958) | (-2.054) |

Table C.4: **Bank event study: equity CARs**
This table reports the average four-day [-2;2] and one-day [0;1] cumulative abnormal returns (CARs) on equity for publicly traded GIIPS, non-GIIPS eurozone (non-GIIPS), and non-eurozone banks that participated in all EBA stress tests surrounding the various ECB interventions. These are the LTRO preliminary announcement (12-01-2011), the LTRO announcement (12-08-2011), LTRO 1 (12-21-2011), LTRO 2 (2-29-2012), Draghi's speech (7-26-2012), the preliminary OMT program announcement (8-02-2012), and the announcement of the OMT program details (9-06-2012). The evidence is based on 15 GIIPS banks, 9 non-GIIPS eurozone banks, 12 non-eurozone banks, and a market model and autocorrelation adjusted abnormal equity returns. We use the Euro Stoxx Index as the benchmark stock market index in computing the abnormal returns. T-statistics are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

| | **Average Equity CAR** | | | | | |
|---|---|---|---|---|---|---|
| | GIIPS | | Euro core | | non-Euro | |
| | [-2,2] | [0,1] | [-2,2] | [0,1] | [-2,2] | [0,1] |
| **LTRO prelim.** | 9.776 | 4.020*** | 28.955 | 6.858*** | 20.790 | 2.448** |
| 12-01-2011 | (0.543) | (2.707) | (1.494) | (4.298) | (1.607) | (2.277) |
| **LTRO** | -0.145 | 1.827 | 17.332 | -1.067 | 20.706 | 0.945 |
| 12-08-2011 | (-0.008) | (1.207) | (0.870) | (-0.645) | (1.585) | (0.866) |
| **LTRO 1** | -4.183 | 0.134 | 20.376 | 1.504 | 18.846 | 0.680 |
| 12-21-2011 | (-0.233) | (0.090) | (1.039) | (0.920) | (1.460) | (0.630) |
| **LTRO 2** | -17.230 | 1.700 | 8.622 | 1.286 | 9.828 | -0.820 |
| 2-29-2012 | (-0.926) | (1.094) | (0.408) | (0.727) | (0.755) | (-0.750) |
| **Draghi's speech** | 29.727 | -0.482 | 21.189 | -0.451 | -11.097 | -0.336 |
| 7-26-2012 | (1.490) | (-0.288) | (0.963) | (-0.246) | (-0.865) | (-0.310) |
| **OMT prelim.** | 23.025 | 1.117 | 21.244 | 1.914 | -7.059 | -1.409 |
| 8-02-2012 | (1.181) | (0.680) | (0.979) | (1.051) | (-0.548) | (-1.294) |
| **OMT** | 12.637 | 1.118 | 7.460 | 1.786 | -4.549 | 0.083 |
| 9-06-2012 | (0.645) | (0.678) | (0.358) | (1.022) | (-0.387) | (0.084) |

## AppendixD. Summary of the effects of holdings and fire-sale risk channels

We regress banks' realized performance on bank characteristics that are measured before the period used to derive banks' realized performance starts, according to the following specification:

$$\begin{aligned} Realized\,performance_i &= \alpha + \beta_1 \frac{GIIPS\,1-3yr_i}{Assets_i} + \beta_2 \frac{GIIPS\,long_i}{Assets_i} \\ &+\beta_3 \frac{GIIPS\,1-3yr_i}{Tier1_i} + \beta_4 \frac{GIIPS\,long_i}{Tier1_i} \\ &+\beta_5 \frac{Assets_i}{Tier1_i} + \beta_6 \hat{\beta}_{market,i} + \beta_7 \hat{\beta}_{interest,i} + \beta_8 \hat{\beta}_{term,i} + \epsilon_i \quad \text{(D.1)} \end{aligned}$$

where $Realized\,performance_i$ is the five-year CDS spread change (or equity stock return) of bank $i$, $GIIPS\,1-3yr_i$ is the GIIPS sovereign bond holdings of maturity between one and three years of bank $i$, $GIIPS\,long_i$ is the GIIPS sovereign bond holdings of maturity above three years of bank $i$, $Assets_i$ are the bank's total assets, $Tier1_i$ is the bank's Tier 1 common capital, and $\hat{\beta}_{market,i}$, $\hat{\beta}_{interest,i}$, $\hat{\beta}_{term,i}$ are respectively the estimates of market beta, interest rate exposure, term spread exposure of bank $i$ obtained from the procedure described in Subsection 5.1.

Note that, in Equation (D.1), the variable $\frac{GIIPS\,1-3yr_i}{Tier1_i}$ can be viewed as an interaction term between the short-term GIIPS sovereign exposure of the bank ($\frac{GIIPS\,1-3yr_i}{Assets_i}$) and its leverage ($\frac{Assets_i}{Tier1_i}$). Therefore, the marginal effect of the bank's short-term GIIPS exposure on its future performance is given by $\beta_1 + \beta_3 \frac{Assets_i}{Tier1_i}$. Similarly, the marginal effect of the bank's long-term GIIPS exposure on its future performance is given by $\beta_2 + \beta_4 \frac{Assets_i}{Tier1_i}$. These exposure marginal effects are linear functions of bank leverage (defined by the ratio of bank's total assets to their Tier 1 common capital).

The effect on bank realized performance of holding short-term GIIPS sovereign bonds is given by $\hat{\beta}_1 \frac{GIIPS\,1-3yr_i}{Assets_i} + \hat{\beta}_3 \frac{GIIPS\,1-3yr_i}{Tier1_i}$. This effect can be further decomposed into a holdings effect ($\hat{\beta}_1 \frac{GIIPS\,1-3yr_i}{Assets_i}$) and a fire-sale risk effect ($\hat{\beta}_3 \frac{GIIPS\,1-3yr_i}{Tier1_i}$). The decomposition relies on the observation that forced sales of sovereign bonds are more likely for banks that do not hold sufficient buffers of capital to absorb asset losses. Those undercapitalized banks would become insolvent conditional on a liquidity shock. The effect of holding short-term GIIPS sovereign bonds is given by $\hat{\beta}_2 \frac{GIIPS\,long_i}{Assets_i} + \hat{\beta}_4 \frac{GIIPS\,long_i}{Tier1_i}$, and can be similarly decomposed into holdings and fire-sale risk effects. To derive the effects, we set to zero the parameters of Equation (D.1) that are not significantly different from zero at the 10% level.

We illustrate the marginal effects of banks' GIIPS sovereign exposures on their five-year CDS spreads for different values of the Tier 1 common capital ratio in the post-LTRO 1 period (between LTRO 1 and LTRO 2), the post-LTRO 2 period (between LTRO 2 and Draghi's speech), and the post-OMT period (after Draghi's speech until the end of 2012) in Figure D.1. The effect of a one percentage point increase of the bank's short-term GIIPS exposure on its CDS spread ($\hat{\beta}_1 + \hat{\beta}_3 \frac{Assets_i}{Tier1_i}$) is presented in Panel A of Figure D.1. We find that the risk of banks holding GIIPS sovereign bonds of maturity between one and three years decreases between LTRO 1 and LTRO 2. After LTRO 2, the effect of short-term GIIPS sovereign bond holdings on bank risk depends on the bank's capitalization. For example, one additional percentage point of short-term GIIPS sovereign bond holdings in the bank portfolio leads to an increase of 165 bps of the five-year CDS spread of the bank when the bank's capitalization ratio is 3%, while the increase is only 80 bps for a bank with a capitalization ratio of 4%. When the bank's capitalization ratio is above 6%, we actually find that bank risk decreases with short-term GIIPS sovereign bond holdings.

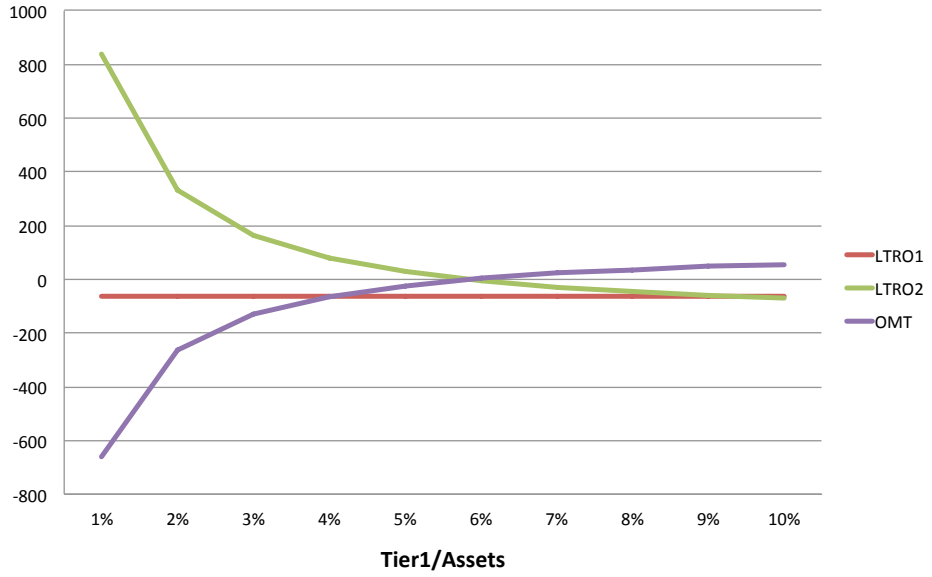
While the post-LTRO 1 sovereign bond holdings effect on bank risk indicates less funding pressure for the banks holding short-term GIIPS sovereign bonds, the post-LTRO 2 effect is simultaneous to a reallocation of GIIPS sovereign bonds in the portfolios of GIIPS banks. Figure D.1 (Panel A) shows that the effect of short-term GIIPS holdings on bank risk is greater for banks that do not hold sufficient capital to absorb asset losses. This is consistent with a fire-sale risk effect since the increase in bank risk due to its GIIPS bond holdings is greater for weak banks, i.e., banks that are poorly capitalized and thus more likely to be subject to funding liquidity risk.

In the post-OMT period, we find a reversal of this fire-sale risk effect for short-term GIIPS sovereign bonds; the CDS spreads of weakly capitalized banks subject to fire-sale risk during the post-LTRO 2 period decrease after the OMT program announcement. Weak banks benefit from an implicit government guarantee in the post-OMT period through the put option on short-term sovereign bonds that will be provided in bad times by the ECB acting as a BOLR. The intervention affects primarily the risk of banks that would default precisely in the states where the put option could be exercised.

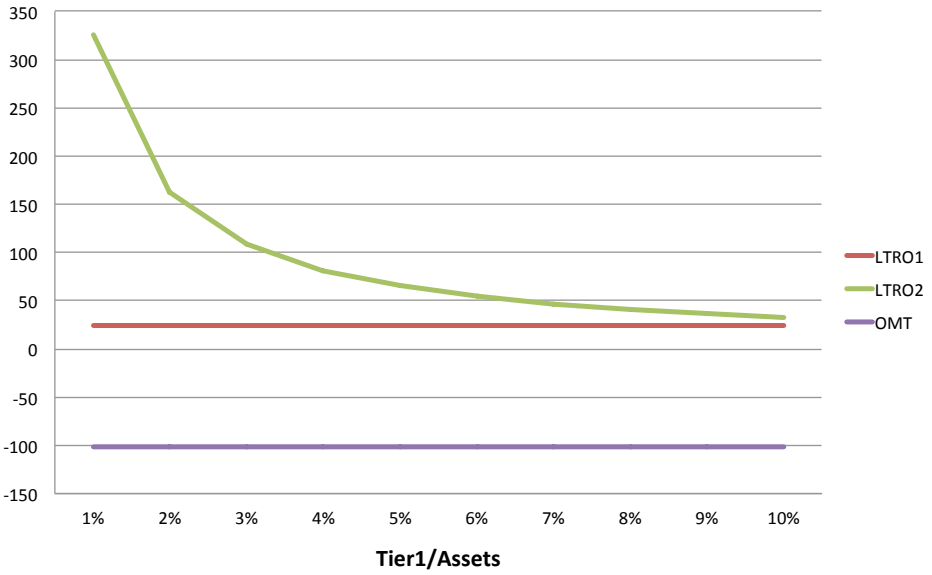
Turning to long-term bonds, we show in Panel B of Figure D.1 the effect of a one percentage point increase of the bank's long-term GIIPS sovereign exposure on its five-year CDS spread ($\hat{\beta}_2 + \hat{\beta}_4 \frac{Assets_i}{Tier1_i}$). This figure highlights a preference for short-term GIIPS sovereign bonds in the post-LTRO 1 period; bank risk decreases with short-term GIIPS bond holdings and increases with long-term GIIPS bond holdings. In the post-LTRO 2 period, we find a similar fire-sale risk effect for long-term GIIPS sovereign bonds as we find for short-term bonds; the increase in bank risk due to long-term GIIPS bond holdings is more important at weakly capitalized banks. Finally, we observe a reduction of bank risk for banks holding long-term GIIPS sovereign bonds in the post-OMT period.

Figure D.1: **Effect of GIIPS sovereign bond holdings on five-year bank CDS spreads**
This figure shows the estimated increase in bps of the five-year CDS spread of a bank following an increase of one percentage point of the fraction of GIIPS sovereign bond holdings of the bank to the bank's total assets as a function of bank's capitalization (measured by the ratio of bank's Tier 1 common capital to its total assets). Panel A shows the effect of short-term GIIPS sovereign bond holdings with maturity between one and three years. Panel B shows the effect of long-term GIIPS sovereign bond holdings with maturity above three years.

(a) Effect of short-term GIIPS sovereign bond holdings on five-year bank CDS spread (bps)




(b) Effect of long-term GIIPS sovereign bond holdings on five-year bank CDS spread (bps)



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